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# L'activité physique aux âges extrêmes de la vie

Camille Chambonniere

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# THÈSE DE SCIENCES

École Doctorale des Sciences de la Vie, Santé, Agronomie, Environnement

*En vue de l'obtention du grade de*

**DOCTEUR DE L'UNIVERSITÉ CLERMONT AUVERGNE**

**Discipline** : Sciences et Techniques des Activités Physiques et Sportives

**Spécialité** : Activité Physique Adaptée et Santé

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## L'activité physique aux âges extrêmes de la vie

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Présentée et soutenue publiquement par

**Camille CHAMBONNIERE**

*Le 18 janvier 2024*

Devant le Jury composé de

Pr DUTHEIL Frederic

Pr VANHELST Jeremy

Dr PERROT Alexandra

Pr BOIS Julien

Dr MOLINA DARGENT Patricia

Pr DUCLOS Martine

Dr METZ Lore

CHU Gabriel Montpied

Université Sorbonne Paris Nord

Université Paris-Saclay

Université de Pau et des Pays de l'Adour

INSERM

CHU Gabriel Montpied

Université Clermont Auvergne

Président

Rapporteur

Rapporteuse

Examinateur

Examinatrice

Directrice

Co-encadrante



*« Seul l'arbre qui a subi les assauts du vent est vraiment rigoureux,  
car c'est dans cette lutte que ses racines, mises à l'épreuve, se fortifient ».*

Sénèque



## REMERCIEMENTS

---

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## LISTE DES ABBREVIATIONS

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**ANSES** : Agence Nationale de Sécurité Sanitaire de l'alimentation, de l'Environnement, et du travail

**AP** : Activité Physique

**APAS** : Activité Physique Adaptée et Santé

**APMV** : Activité Physique d'Intensité Modérée à Vigoureuse

**AVQ** : Activités de la Vie Quotidienne

**AIVQ** : Activités Instrumentales de la Vie Quotidienne

**APS** : Activité Physique et Sportive

**CCAS** : Centre Communal d'Action Sociale

**CPTS** : Communauté Professionnelles de Santé Territoriales

**DE** : Dépense Energétique

**EPS** : Education Physique et Sportive

**FC** : Fréquence Cardiaque

**GPAQ** : Global Physical Activity Questionnaire (questionnaire global sur l'activité physique)

**HAS** : Haute Autorité de Santé

**HELENA** : étude Healthy Lifestyle in Europe by Nutrition in Adolescence (mode de vie sain en Europe par la nutrition à l'adolescence)

**ICOPE** : Integrated Care of Older People (soins intégrés des personnes âgées)

**IMC** : Indice de Masse Corporelle

**INCA** : étude Individuelle Nationale des Consommations Alimentaires

**IPAQ** : International Physical Activity Questionnaire (questionnaire international sur l'activité physique)

**MCV** : Maladies CardioVasculaires

**MET** : Metabolic Equivalent Task (équivalent métabolique)

**MNT** : Maladies Non Transmissibles

**NAP** : Niveau d'Activité Physique

**ODD** : Objectif de Développement Durable

**OMS/WHO** : Organisation Mondiale de la Santé / World Health Organization

**ONAPS** : Observatoire National de l'Activité Physique et de la Sédentarité

**SBRN** : Sedentary Behaviour Research Network (réseau de recherche sur le comportement sédentaire)

**UNICEF** : United Nations International Children's Emergency Fund (fonds international d'urgence pour l'enfance des Nations Unies)

## PUBLICATIONS

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**ARTICLE | Chambonnière, C.**, Blanquet, M., Delorme, C., Flory, L., Pereira, B., Metz, L., Duclos, M. Screening for frailty according to rural and suburban health areas in the context of adapted integrated care for older people (ICOPE) approach: the FRAGING study. *Soumis dans Public Health Nursing*. **(SOU MIS)**.

**ARTICLE | Chambonnière, C.**, Metz, L., Fillon, A., Demonteix, P., Fearnbach, N., Bailly, M., Boscaro, A., Pereira, B., Thivel, D., Duclos, M. (2023). The effects of using a cycling desk at school on executive function, physical fitness, and body composition in primary school children: impact of socioeconomic status. *Pediatric Exercise Science*. **(PUBLIE)**.

**ARTICLE | Chambonnière, C.**, Lambert, C., Fearnbach, N., Tardieu, M., Fillon, A., Genin, P., Larras, B., Melsens, P., Bois, J., Pereira, B., Tremblay, A., Thivel, D., Duclos, M. (2021). Effect of the COVID-19 lockdown on physical activity and sedentary behaviors in French children and adolescents: New results from the ONAPS national survey. *European Journal of Integrative Medicine*, 43, 101308. **(PUBLIE)**.

**ARTICLE | Chambonnière, C.**, Lambert, C., Tardieu, M., Fillon, A., Genin, P., Larras, B., Melsens, P., Baker, J., Pereira, B., Tremblay, A., Thivel, D., Duclos, M. (2021). Physical Activity and Sedentary Behavior of Elderly Populations during Confinement: Results from the FRENCH COVID-19 ONAPS Survey. *Experimental Aging Research*, 47(5), 401–413. **(PUBLIE)**.

**ARTICLE | Chambonnière, C.**, Fearnbach, N., Pelissier, L., Genin, P., Fillon, A., Boscaro, A., Bonjean, L., Bailly, M., Siroux, J., Guirado, T., Pereira, B., Thivel, D., Duclos, M. (2021). Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children. *International Journal of Environmental Research and Public Health*, 18(21), 11099. **(PUBLIE)**.

**ARTICLE | Guirado, T., Chambonnière, C.**, Chaput, J.-P., Metz, L., Thivel, D., & Duclos, M. (2021). Effects of Classroom Active Desks on Children and Adolescents' Physical Activity, Sedentary Behavior, Academic Achievements and Overall Health: A Systematic Review. *International Journal of Environmental Research and Public Health*, 18(6), 2828. **(PUBLIE) -Annexe**.



## COMMUNICATIONS

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**COMMUNICATION ORALE | Chambonnière, C., Lambert, C., Tardieu, M., Fillon, A., Genin, P., Larras, B., Melsens, P., Baker, J., Pereira, B., Tremblay, A., Thivel, D., Duclos, M. (2021).** Physical Activity and Sedentary Behavior of Elderly Populations during Confinement: Results from the FRENCH COVID-19 ONAPS Survey. JEFAPA. **(PRESENTEE).**

**COMMUNICATION ORALE | Chambonnière, C., Blanquet, M., Metz, L., Duclos, M. (2022).** Détection, évaluation et suivi des fragilités des séniors. Symposium de l'ILVV, Paris. **(PRESENTEE).**

**COMMUNICATION ORALE | Chambonnière, C., Metz, L., Fillon, A., Demonteix, P., Fearnbach, N., Bailly, B., Boscaro, A., Pereira, B., Thivel, D., Duclos, M.** Effets de l'utilisation de vélo-bureaux à l'école sur les fonctions exécutives, les capacités physiques et la composition corporelle chez les enfants de primaire : Une étude pilote intra-sujet (BICLASS) (2022). Congrès 2PASS-4HEALTH, Tarbes. **(PRÉSENTÉE).**

**COMMUNICATION ORALE | Chambonnière, C., Blanquet, M., Metz, L., Duclos, M.** FRAGING Project : Detection, evaluation and monitoring of frailties in the elderly (2023). Congrès AgeingFit, Lille. **(PRESENTEE).**

**POSTER | Chambonnière, C., Fearnbach, N., Pelissier, L., Genin, P., Fillon, A., Boscaro, A., Bonjean, L., Bailly, M., Siroux, J., Guirado, T., Pereira, B., Thivel, D., Duclos, M. (2021).** Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children (2022). JED de l'Ecole Doctorale SVSAE, Clermont-Ferrand. **(PRESENTEE) - Annexe.**

**POSTER | Chambonnière, C., Metz, L., Fillon, A., Demonteix, P., Fearnbach, N., Bailly, B., Boscaro, A., Pereira, B., Thivel, D., Duclos, M.** The effects of using a cycling desk at school on executive functions, physical fitness and body composition in primary school children: a pilot within-subject study (BICLASS) (2022). CIR3, Clermont-Ferrand. **(PRESENTEE) - Annexe.**

# PARTIE I – REVUE DE LA LITTÉRATURE

## 1. L'inactivité physique et la sédentarité : des concepts au cœur des préoccupations de santé publique

D'ici à 2050, la population française verra approximativement un tiers de ses membres atteindre l'âge de 60 ans et plus, marquant ainsi un phénomène démographique significatif de vieillissement. Cette réalité pressante exige des mesures concertées pour influencer les déterminants de la santé, dans le but de retarder la diminution de l'autonomie et de favoriser la prévention et la promotion de la santé publique. En conséquence, il devient impératif de consacrer une attention particulière à l'état de santé des générations qui avancent en âge, notamment celle des adultes à mi-vie. En effet, cela s'explique d'une part par l'existence d'une relation étroite entre la santé au milieu de la vie et un vieillissement sain, et d'autre part, parce que c'est à cette période que les facteurs de risque et les maladies chroniques commencent à s'accumuler. Le présent paragraphe s'emploiera tout d'abord à établir les définitions des concepts fondamentaux qui seront mobilisés tout au long du présent manuscrit de thèse, avant de porter une attention particulière aux facteurs déterminants qui influencent ces phénomènes, afin de dégager des tendances significatives. Parmi ces facteurs, l'importance de l'activité physique (AP), de l'inactivité physique et de la sédentarité se démarquent. Par la suite, nous procéderons à une analyse des outils de mesure de l'AP et de la sédentarité disponibles avant d'analyser les niveaux de pratiques de deux groupes de populations particulièrement vulnérables : les enfants et adolescents d'une part, et les personnes âgées d'autre part. Une analyse des impacts des comportements de mouvements en termes de santé, de coûts financiers et humains ainsi que les adaptations politiques en découlant sera réalisée. Enfin, un gros plan sera réalisé sur la pandémie mondiale de COVID-19 et notamment son premier confinement, du fait de ses répercussions en termes de possibilités de mobilité.

### 1.1. Définition des concepts

#### 1.1.1. *La santé*

A l'image des attitudes sociales et culturelles de la population, la définition de la santé a évolué. Dans un premier temps, la santé était traditionnellement définie comme l'absence de maladie manifeste, mais cette approche binaire « *malade-non malade* » ne permettait pas d'envisager la prévention, en particulier en ce qui concerne le dépistage des maladies. Par la suite, l'Organisation Mondiale de la Santé (OMS) a défini la santé comme « *un état de complet bien-être physique, mental et social, et ne consiste pas seulement en une absence*

*de maladie ou d'infirmité* » (OMS, 1946). Cette définition, bien que globale avec une prise en compte de la dimension psychologique et sociale, reste utopique et statique.

Dans les années 1970, de plus en plus de voix se sont élevées pour critiquer cette définition de la santé, qui était jugée trop axée sur l'individu et ne tenant pas suffisamment compte des facteurs socioenvironnementaux qui influencent la santé. Afin de répondre à cette problématique, l'OMS a intégré dans la Charte d'Ottawa la notion de promotion de la santé comme processus visant à habiliter les populations à exercer un contrôle accru sur leur propre bien-être, tout en cherchant à l'améliorer. Cette approche repose sur un concept qui définit la santé comme « *la mesure dans laquelle un groupe ou un individu peut, d'une part, réaliser ses ambitions et satisfaire ses besoins et, d'autre part, évoluer avec le milieu ou s'adapter à celui-ci* » (OMS, 1986). La santé est ainsi considérée comme une ressource essentielle à la vie quotidienne plutôt que comme une finalité en soi. Ce concept positif met en avant les ressources sociales et individuelles ainsi que les capacités physiques. Il convient donc de souligner que la promotion de la santé ne se limite pas au domaine de la santé médicale, mais dépasse les modes de vie sains pour favoriser le bien-être global. Par conséquent, pour mieux appréhender les multiples dimensions de la santé, il est nécessaire de considérer les différents domaines d'intervention de la santé publique, tels que les aspects curatifs, éducatifs, sociaux et préventifs. De plus, il convient de reconnaître que la santé est profondément influencée par une gamme de facteurs personnels, sociaux, économiques et environnementaux, communément appelés déterminants de la santé.

### 1.1.2. *Les déterminants de la santé et la prévention*

Les déterminants de la santé jouent un rôle essentiel dans la compréhension de la santé d'une population en regroupant l'ensemble des facteurs qui influencent, positivement ou négativement, l'état de santé des individus et des populations (Raimondeau et al., 2020). Ils sont interconnectés entre eux et leur impact sur la santé est à la fois complexe et dynamique. Classiquement, les déterminants de la santé se divisent en quatre catégories : biologiques (âge, sexe, génétique), comportementaux (habitudes de vies), environnementaux et ceux liés au système de santé (Whitehead & Dahlgren, 1991). Parmi ces déterminants, l'AP joue un rôle essentiel en tant que déterminant de santé comportemental (Marmot et al., 2012).

L'activité physique est maintenant largement reconnue comme un facteur majeur contribuant à la santé globale des individus, en favorisant le maintien ou l'amélioration des indicateurs

biologiques de santé (Janssen & Leblanc, 2010; Warburton & Bredin, 2017) tels que la diminution de l'adiposité (Mintjens et al., 2018), la santé cardio-métabolique (Aadland et al., 2018; Koskinen et al., 2017; J. Li & Siegrist, 2012; Telama et al., 2005), la santé osseuse (Rizzoli et al., 2010) et la réduction de la survenue des maladies chroniques (ANSES, 2016). De plus, des effets bénéfiques ont été montrés sur le plan psychologique et cognitif (Dionigi, 2007; Janssen & Leblanc, 2010; Kandola et al., 2020; Landi et al., 2010; Schuch et al., 2018).

De la même manière que les études étiologiques des maladies améliorent les traitements des patients, il s'avère pertinent de comprendre les facteurs étiologiques liés aux environnements d'AP afin d'appréhender leur variabilité selon le pays, l'âge, le sexe, l'origine ethnique et le statut socio-économique. Une revue de littérature a mis en évidence les multiples déterminants qui influencent la pratique d'une AP, pour toutes les catégories d'âges (Bauman et al., 2012) (Figure 1). En raison de leur sensibilité à l'AP, tant sur le plan du développement physique et cognitif que sur celui de la vulnérabilité aux problèmes de santé associés, les enfants et les personnes âgées se trouvent particulièrement exposés aux risques liés à l'insuffisance d'AP. Ainsi, tout au long de ce manuscrit de thèse, ils seront considérés comme des publics cibles.



Figure 1 : Modèle écologique adapté des déterminants de l'activité physique.

Source : Figure adaptée de Bauman *et al.* (2012)

Afin de minimiser la vulnérabilité des enfants et des personnes âgées face à l'insuffisance d'AP pour leur santé, il est crucial d'adopter une approche préventive. Définie comme « *l'ensemble des mesures visant à éviter ou réduire le nombre et la gravité des maladies, des accidents et des handicaps* » (OMS, 1948), la prévention se déploie en trois types distincts. Tout d'abord, la prévention primaire vise à réduire l'incidence d'une maladie dans une population et à réduire les risques d'apparition. Ensuite, la prévention secondaire, s'attache à diminuer la prévalence d'une maladie dans une population. Enfin, la prévention tertiaire se concentre sur la diminution de la prévalence des incapacités chroniques ou récidives. Cependant, il est essentiel de distinguer la sédentarité de l'inactivité physique afin d'adapter les approches préventives de manière plus ciblée et efficace, en prenant en compte les comportements sédentaires et les différents niveaux d'AP (Tremblay et al., 2017).

### 1.1.3. *Activité physique et inactivité physique*

Dans le langage courant, l'AP est souvent réduite à la pratique d'un sport, négligeant ainsi son champ d'application plus large. En 1985, l'AP est définie comme « *tout mouvement corporel produit par la contraction des muscles squelettiques entraînant une dépense énergétique supérieure à celle de repos* » (Caspersen et al., 1985), dont le sport ne représente qu'une faible partie. Plus récemment, une approche holistique de l'AP a fait émerger une nouvelle définition, la considérant comme englobant les personnes qui se déplacent, jouent et réalisent des performances dans des contextes culturels et des lieux spécifiques, et qui sont influencées par leurs propres intérêts, émotions, idées, relations ainsi que par des consignes (Piggin, 2020). Il est possible qu'un consensus se forme dans la future littérature scientifique.

Communément, l'AP est subdivisée en trois domaines distincts : les AP de la vie quotidienne (transports actifs, activités réalisées dans un contexte domestique, professionnel ou scolaire), les exercices physiques qui sont planifiés, structurés et répétitifs et les activités sportives à des fins de performances. Ainsi, l'AP est caractérisée par sa fréquence, son intensité, sa durée, et sa modalité de pratique et peut être effectuée dans le cadre des loisirs, sur le lieu de travail, pour se déplacer ou lors des activités de la vie domestique (Ferguson, 2014). L'intensité de l'exercice peut être mesurée de manière absolue en évaluant la dépense énergétique réelle. Dans les sections suivantes, nous ferons régulièrement référence au MET (Metabolic Equivalent Task) qui est une unité d'intensité de l'AP. Un MET équivaut à une consommation

d'oxygène (VO<sub>2</sub>) de 3,5 ml/kg/min<sup>1</sup> (dépense énergétique de repos), ce qui permet de classer l'AP en quatre catégories (Ferguson, 2014; HAS, 2023) (Tableau 1):

Intensité	METs	Valence affective
Légère	< 3	Respiration presque normale, pas d'essoufflement Conversation possible Battements cardiaques peu perceptibles
Modérée	3 -< 6	Respiration légèrement accélérée, essoufflement modéré Conversation possible Augmentation modérée de la fréquence cardiaque perçue
Élevée	6 - < 9	Respiration accélérée, essoufflement Conversation difficile, phrases courtes Augmentation importante de la fréquence cardiaque perçue
Très élevée	> 9	Respiration rapide, essoufflement important Conversation impossible, phrases très courtes Sensation de palpitations cardiaques au niveau du cou

Tableau 1 : Intensité de l'activité physique selon la valence affective.

MET : Metabolic Equivalent Task/équivalent métabolique

Source : HAS. (2023)

L'inactivité physique peut quant à elle être définie comme un niveau inadéquat d'activité physique d'intensité modérée à vigoureuse (APMV), qui est inférieure à un niveau recommandé par l'OMS (Tremblay et al., 2017). Ces recommandations, actualisées en 2020, sont adaptées par catégories d'âge. Les sections à venir mettront en évidence la sensibilité à l'AP des enfants et des personnes âgées, ce qui les rendra particulièrement vulnérables. Cette sensibilité nécessite une adaptation des recommandations spécifiques à ces deux populations. Ainsi, pour les enfants et les adolescents (5-17 ans), les recommandations sont de pratiquer **« au moins une moyenne de 60 minutes par jour d'APMV, principalement aérobique, tout au long de la semaine. De manière plus détaillée, les activités aérobiques d'intensité vigoureuse, ainsi que celles qui renforcent les muscles et les os, devraient être intégrées au moins 3 jours par semaine »** (WHO, 2010, 2020a). Les recommandations à destination des personnes âgées sont similaires à celles préconisées chez les adultes soit **« pratiquer au moins 150 à 300 minutes d'activité physique aérobique d'intensité modérée ou au moins 75 à 150 minutes d'activité physique aérobique d'intensité soutenue, ou une**

<sup>1</sup> Ml: millilitre; kg: kilogramme; min : minute

*combinaison équivalente tout au long de la semaine pour en retirer des bénéfices substantiels sur le plan de la santé » (WHO, 2010, 2020a).*

#### 1.1.4. *La sédentarité*

Au cours des dernières décennies, la sédentarité a suscité un intérêt croissant au sein de la communauté scientifique, se traduisant par une augmentation significative du nombre d'études examinant ce phénomène (Owen et al., 2010; Tremblay et al., 2017). Pour autant, dans la majorité des études, la sédentarité était encore trop souvent confondue avec la notion d'inactivité physique. C'est pourquoi en 2012, le *Sedentary Behaviour Research Network (SBRN)* a publié une lettre proposant une première définition de la sédentarité afin de la dissocier de l'inactivité physique (Sedentary Behaviour Research Network, 2012). En 2017, un consensus a été établi afin de définir les termes liés aux comportements de mouvements, ce qui a permis d'élaborer une définition précise des comportements sédentaires. Selon ce consensus, les comportements sédentaires ont été définis comme « *tout comportement d'éveil caractérisé par une dépense énergétique  $\leq 1,5$  MET, en position assise, allongée ou couchée* » (Tremblay et al., 2017).

Dans la littérature scientifique, le temps passé assis et/ou devant un écran est couramment utilisé comme indicateur de la sédentarité via des questionnaires (Tremblay et al., 2010; WHO, 2010). En se référant aux définitions de la sédentarité et de l'inactivité physique une personne peut, d'une part respecter ou même dépasser les recommandations en termes d'AP, mais d'autre part passer la plupart de son temps d'éveil assis (Figure 2). Ainsi, il est possible qu'une personne soit active tout en étant sédentaire, ou inversement, inactive et non sédentaire (Figure 3).



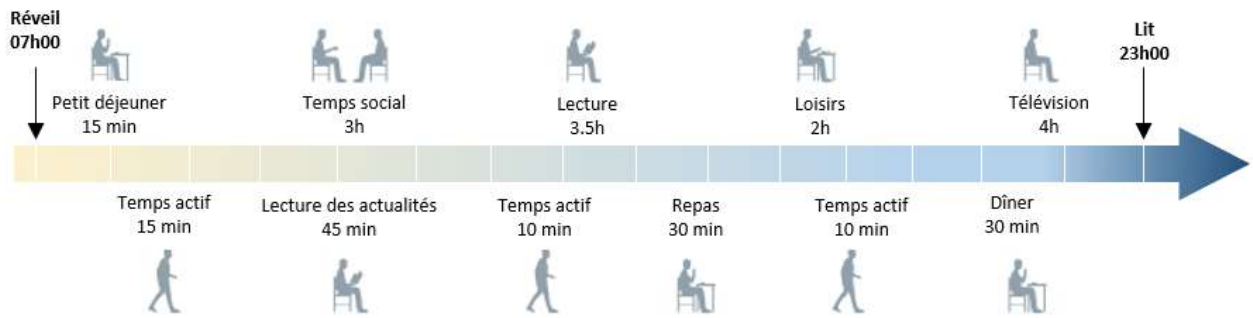


Figure 2 : Les activités quotidiennes qui impliquent d'être assis.

Pour les adultes qui ne travaillent pas et qui dorment 8 heures par cycle de 24 heures, les heures de veille restantes (16 heures) peuvent être consacrées à diverses activités récréatives et aux activités de la vie quotidienne. Dans cet exemple hypothétique, ces adultes peuvent être considérés comme physiquement actifs selon les recommandations actuelles en matière d'activité physique, car ils accumulent jusqu'à 30 minutes d'activité physique au cours de la journée. Cependant, ces personnes peuvent également passer plusieurs heures (14,5 heures) assises à l'heure des repas, moments d'échanges sociaux et à profiter d'activités récréatives. Par conséquent, même s'ils respectent les recommandations actuelles en matière d'activité physique, les adultes qui ne travaillent pas peuvent passer jusqu'à 90 % de leurs heures d'éveil restantes en position assise. Ce temps passé assis n'est pas un schéma atypique pour de nombreuses personnes âgées et pourrait être qualifié d'« actif mais aussi de très sédentaire ». Cet exemple souligne l'importance de cibler non seulement le temps passé à être actif, mais aussi de réduire le temps passé assis pendant les heures d'éveil (ou « s'asseoir moins et bouger plus »).

Source : Figure traduite de Dunstan *et al.* (2021)



Figure 3 : Profils liés à l'activité physique et la sédentarité.

Source : Figure adaptée de l'ONAPS

Par conséquent, il est crucial de reconnaître tout au long de ce manuscrit de thèse que l'inactivité physique et la sédentarité sont deux dimensions distinctes qui peuvent coexister chez un même individu. Afin de mieux appréhender ces phénomènes et d'évaluer leur impact sur la santé, il est nécessaire d'effectuer des analyses épidémiologiques de pratique en utilisant des outils de mesure adaptés et validés, permettant d'explorer les comportements de mouvements au sein des populations spécifiques.

## 1.2. Outils et techniques de mesure de l'activité physique et de la sédentarité

L'évaluation du niveau d'activité physique (NAP) et de sédentarité est primordiale dans le domaine de la prévention pour diverses raisons : i) documenter le niveau habituel d'AP et de sédentarité chez les sujets sains ou malades et ses variations ; ii) comprendre les liens entre le niveau habituel d'AP et de sédentarité et le développement de pathologies en général ; iii) analyser les déterminants des comportements de mouvements habituels ; iv) évaluer les effets d'interventions visant à augmenter le niveau habituel d'AP et limiter la sédentarité chez les sujets sains et les patients (Wareham & Rennie, 1998). Lorsque l'AP et la sédentarité sont évaluées, l'objectif est d'identifier la fréquence, la durée, l'intensité et le type de comportement adopté pendant un temps donné. Plusieurs instruments de routine sont disponibles pour mesurer l'AP en condition de vie libre, répartis en deux catégories d'évaluation (Kemper et al., 1996; Oppert, 2001; Terrier & Schutz, 2004) (Tableau 2):

- ***Les méthodes de mesures objectives*** qui quantifient l'AP et la sédentarité indépendamment du contexte de la pratique. Elles sont appropriées pour déterminer les niveaux et les variations des comportements de mouvement, établir des liens entre l'AP, la sédentarité et les pathologies, ainsi que pour évaluer l'efficacité des interventions. Parmi les mesures objectives, il existe le principe de la mesure de fréquence cardiaque et les capteurs de mouvements (podomètre, accéléromètre).
- ***Les méthodes de mesures subjectives*** qui offrent une quantification moins précise de l'AP et de la sédentarité, mais qui permettent de renseigner sur les contextes de chaque activité. Elles sont appropriées pour comprendre les pratiques d'AP et leurs variations, ainsi que pour établir les relations entre ces pratiques et les pathologies, mais surtout pour identifier les liens avec leurs déterminants. Parmi les mesures

subjectives, il existe les observations directes et les données autodéclarées (journal, entretien, questionnaires).

Il est important de questionner les caractéristiques des outils de mesures utilisés puisqu'ils offrent des données fiables pour la mise en place de recommandations adaptées. Ainsi, dans la section qui suit nous dresserons une liste des outils de mesure de l'AP et de la sédentarité le plus couramment utilisés en condition libre, tout en questionnant de leur fiabilité et faisabilité.

	Méthodes subjectives			Mesures objectives		
	Observations directes	Journal	Questionnaire	Podomètre	Accéléromètre	Cardiofréquencemètre
<b>Comportement de mouvement évalué :</b>						
<i>AP</i>	Oui	Oui	Oui	Oui	Oui	Oui
<i>SED</i>	Oui	Oui	Oui	Non	Oui	Non
<b>Paramètres :</b>						
<i>Mesurés</i>	AP + SED, comportement	AP + SED	AP + SED	Nb de pas	Coups/min, variation d'accélération moyenne	FC
<i>Estimés</i>	DE (intensité d'activité * durée)	DE (intensité d'activité * durée)	DE (intensité d'activité * durée)	Distance (nb de pas * longueur moyenne du pas)	DE (amplitude de l'accélération proportionnelle à la DE)	DE (FC proportionnelle à la DE)
<i>Période mesurée</i>	Actuelle	3 jours	1-7 jours, 12 mois précédent	Plusieurs jours	Quelques heures à quelques semaines	Quelques heures à quelques jours
<b>Evaluation de l'intensité :</b>	Oui	Oui	±, très subjectif	Non	Oui	Oui
<b>Profil journalier de l'AP :</b>	Oui	Oui	Non	Non (techniquement possible, peu exploité)	Oui (certains appareils)	Oui
<b>Identification d'activités spécifiques :</b>	Oui	Oui	Oui, mais limité aux activités structurées et volontaires	± Détection de la marche, mais manque de spécificité	Non. Détection de la marche ou de la posture possible	Oui
<b>Groupe d'âge :</b>						
<i>Enfants</i>	Oui	Non	Non	Oui	Oui	Oui
<i>Adolescents</i>	Oui	±	Oui	Oui	Oui	Oui
<i>Adultes</i>	?	Oui	Oui	Oui	Oui	Oui
<i>Sujets âgés</i>	?	±	Oui	Oui	Oui	Oui
<b>Coût :</b>	Elevé	Modéré	Faible	Faible	Modéré	Modéré à élevé
<b>Acceptabilité par le sujet :</b>	Bonne	Variable	Excellente	Très bonne	Très bonne	Variable
<b>Faisabilité technique :</b>	Médiocre	Moyenne	Excellente	Très bonne	Très bonne	Bonne

Tableau 2 : Comparaisons de quelques méthodes (objectives et subjectives) d'évaluation de l'activité physique et de la sédentarité journalière.

AP: Activité Physique; SED : Sédentarité ; FC : Fréquence Cardiaque ; DE: Dépense Energétique.

Source : Tableau adapté de Oppert *et al.* (2003) ; Terrier et Schutz. (2004)

### 1.2.1. *Les mesures subjectives*

- *Les observations directes*

Réalisées en temps réel ou en vidéo, le NAP peut être interprété via des échelles d'évaluation de l'activité comme la Children Activity Rating Scale (CARS) pour les enfants (Puhl et al., 1990) ou le Quick Physical Activity Rating (QPAR) pour les personnes âgées (Galvin et al., 2020). Pour autant, le traitement des données est long.

- *L'entretien*

L'entretien peut se réaliser avec les proches et offre l'opportunité d'inclure les personnes qui ne savent pas lire et/ou écrire. Pour autant, le délai de rappel doit être court et sa faisabilité est moindre pour de grandes cohortes.

- *Le journal*

Les journaux contiennent des informations à remplir concernant le type d'activité ou la durée, mais aussi sur le moment de la journée ou l'état émotionnel pendant la pratique. Le journal peut être utilisé sur des périodes qui ne sont pas trop prolongées, avec des personnes qui savent écrire et nécessite une coopération. Sa faisabilité est moindre pour de grandes cohortes. L'avantage principal est d'être plus précis qu'un questionnaire faisant appel à la mémoire, tout en étant moins onéreux qu'un dispositif de mesure objectif. En revanche, beaucoup de ressources sont nécessaires pour traiter les données si le journal est en format papier, et cela demande une attention tout au long de la journée pour le participant.

- *Les questionnaires*

Dans la littérature scientifique, les questionnaires sont couramment utilisés en raison de leur facilité d'envoi, de réalisation, de faible coût et de simplicité d'administration (Sallis & Saelens, 2000), particulièrement pour les études de large envergure (Bauman et al., 2011; Guthold et al., 2018). Génériques ou spécifiques, différents questionnaires sont présents pour évaluer le NAP et le niveau de sédentarité dont la forme (papier, assisté par ordinateur, à remplir sur internet) et la période de rappel peuvent varier. Une récente revue de la littérature a identifié 25 questionnaires mesurant l'AP chez les enfants et adolescents et 12 la combinaison de l'AP et des comportements sédentaires (Rodrigues et al., 2023). Concernant les adultes et

personnes âgées, parmi les 60 questionnaires évaluant les comportements de mouvement, 68,3 % présentaient une validité de contenu adéquate (Rodrigues et al., 2022).

Communément, deux questionnaires sont utilisés pour mesurer les comportements de mouvements : le Global Physical Activity Questionnaire (GPAQ) développé par l'OMS (Cleland et al., 2014) et le International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). La différence principale réside dans la période de rappel : alors que le GPAQ interroge sur une « *semaine typique* », l'IPAQ questionne les sept jours précédents l'enquête. Pour autant, l'évaluation du niveau de sédentarité à l'aide du GPAQ et de l'IPAQ montrent une faible validité de critère (Meh et al., 2021). Ainsi, en France, l'ONAPS-Q a récemment été développé par l'Observatoire National de l'Activité Physique et de la Sédentarité (ONAPS) (Charles et al., 2021). Inspiré du GPAQ pour les parties relatives à l'AP, ce questionnaire comprend des parties détaillées concernant les comportements sédentaires, en incluant également les activités domestiques, ce qui n'est pas le cas du GPAQ. En complément de l'évaluation du niveau d'AP et de sédentarité, le CAPAS-Q<sup>2</sup> a été développé en France afin d'identifier les problématiques majeurs et les leviers d'actions possibles de ces comportements de mouvement. Ainsi, ce questionnaire mesure la durée et l'intensité de l'AP, la durée des comportements sédentaires (écran ou non) et les périodes consécutives de sédentarité et l'utilisation des transports motorisés (Fillon et al., 2022).

Par la diversité des questionnaires, des domaines évalués, des scores utilisés, des périodes de rappel, des mesures de comparaison, des unités de déclaration et des approches statistiques employées, l'évaluation comparative des questionnaires est complexe, et ce quel que soit le public cible (Prince et al., 2020). Bien que les questionnaires utilisant une période de rappel montrent des résultats avec une bonne précision, il existe une grande variabilité (sur- et sous-estimations) entre les études portant sur la sédentarité. Ainsi, l'interprétation des données doit être réalisée avec prudence lorsque les résultats issus de différents outils d'évaluation sont mis en perspective avec les effets sur la santé.

### 1.2.2. *Les mesures objectives*

Il existe deux types d'approches pour la mesure de l'AP et de la sédentarité de manière objective : la mesure de paramètres physiologiques (la fréquence cardiaque) et la détection des mouvements et de la posture d'un individu (nombre de pas ou accélérométrie).

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<sup>2</sup> CAPAS-Q : Children and Adolescents Physical Activity and Sedentary-Questionnaire

- Mesure de la fréquence cardiaque

Dans les années 80, l'évaluation de l'intensité de l'AP a été marquée par l'apparition du cardiofréquence-mètre sans fil, évaluant la fréquence cardiaque (FC). Ce dispositif détecte les ondes électrocardiographiques et calcule le nombre de battements cardiaques par minute (bpm). Cependant, pour certaines AP de faible intensité, des facteurs tels que le stress ou l'excitation peuvent entraîner une augmentation de la FC qui ne peut être entièrement expliquée par la dépense énergétique (Åstrand, 2003). De plus, d'autres éléments comme l'hydratation, l'altitude, la température et l'humidité peuvent également influencer la FC. En outre, certaines AP peuvent augmenter la FC de manière plus significative que d'autres, et la position du corps peut également influencer les valeurs de FC enregistrées. Enfin, cet outil ne permet pas de mesurer le niveau de sédentarité.

- Le podomètre

Il est de notoriété publique que « réaliser 10 000 pas par jour » (soit environ 1 heure 30 minutes de marche) est un objectif de marche quotidien pour maintenir une bonne santé. Tudor-Locke *et al.* proposent un index d'AP quotidienne estimé par podométrie :  $\leq 5\ 000$  pas : sédentaire,  $5\ 000 < \text{pas} \leq 7\ 500$  : faible activité,  $7\ 500 < \text{pas} \leq 10\ 000$  : activité modérée,  $10\ 000 < \text{pas} \leq 12\ 500$  : activité élevée,  $\text{pas} > 12\ 500$  : activité très élevée (Tudor-Locke & Bassett, 2004). Cela peut servir de référence pour évaluer son NAP et pour se motiver à bouger plus régulièrement. Cependant, cet objectif ne convient pas à tous les individus qui peuvent avoir des besoins et des capacités différentes en matière d'AP, et ne prend pas en compte de l'intensité de l'exercice. De plus, Le podomètre sous-estime l'AP lors d'activités statiques (comme faire du vélo) et ne peut être utilisé pour des activités aquatiques. De plus, cet outil n'est pas précis pour les personnes obèses ou les personnes avec une vitesse de marche faible ( $< 3,5$  km/h) comme les séniors. Les mouvements verticaux (comme se lever d'une chaise) peuvent éventuellement être détectés et comptés comme des pas, selon le seuil de réglage ou le modèle du podomètre (Schneider *et al.*, 2004; Schönhofer *et al.*, 1997). Aussi, la sédentarité ne peut pas être évaluée avec cette méthode.

- L'accéléromètre

Les capteurs de mouvement, ou accéléromètres, sont des petits capteurs légers pouvant se positionner à la taille, au poignet ou à la cheville permettant d'évaluer les comportements de mouvement à partir des mesures mécaniques des mouvements (Chen & Bassett, 2005) exprimés initialement en données brutes appelées « counts ». La quantité et l'intensité de l'AP

et de la sédentarité peuvent être obtenues en classant les comptes d'activité accumulés dans un intervalle de temps spécifique (durée de l'époque) avec des seuils d'intensité pour la classification de l'intensité de l'AP (Bassett et al., 2012; Migueles et al., 2017; Warren et al., 2010). Les premiers accéléromètres développés, dont le plus commercialisé « ActiGraph », étaient uniaxiaux, permettant d'évaluer les comportements de mouvement à partir des accélérations de l'axe vertical (Cole et al., 1992; Freedson et al., 1998; Trost et al., 1998). Par la suite, l'ActiGraph GT3X a permis de détecter les accélérations dans les 3 axes (verticale, médio-latérale et antéro-postérieure), dont les processus de calibrations ont été classifiés par âge dans une revue (Migueles et al., 2017). Il a été montré que les différences entre les estimations de l'activité totale attribuable au traitement des données sont au moins aussi importantes que celles qui sont uniquement attribuables à la différence entre un signal uni et triaxial (Hislop et al., 2012).

L'utilisation d'accéléromètre est valide et fiable pour mesurer les comportements de mouvements chez les enfants et adolescents (Trost, 2007; Trost et al., 2005) et chez les adultes (Aguilar-Farías et al., 2014). De plus, il est léger, objectif et réutilisable. L'utilisation d'un accéléromètre permet également une analyse plus précise et complète que les mesures autodéclarées, en identifiant le temps sédentaire mais également l'AP de faible intensité (toutes deux mal caractérisées par les mesures autodéclarées), ainsi que l'APMV (Dunstan et al., 2021).

Les conclusions des enquêtes à large échelles reposent principalement sur des données subjectives, alors que des données objectives pourraient améliorer la précision des résultats (Prince et al., 2020). Cela s'explique par la faible disponibilité de ces outils dans les pays à faible revenu, leur incapacité à être utilisés dans des activités aquatiques et leur manque de précision pour les activités portées telles que le vélo (Chow et al., 2012). De plus, le manque de consensus sur les méthodes d'harmonisation des données entre les différents dispositifs est une réalité à prendre en compte. (Ekelund et al., 2011; Migueles et al., 2017). Malgré la difficulté que cela représente, il est recommandé de combiner l'utilisation des questionnaires et des accéléromètres pour obtenir des informations exhaustives concernant les NAP et les niveaux de sédentarité (Colley et al., 2019; Skender et al., 2016) (Figure 4).



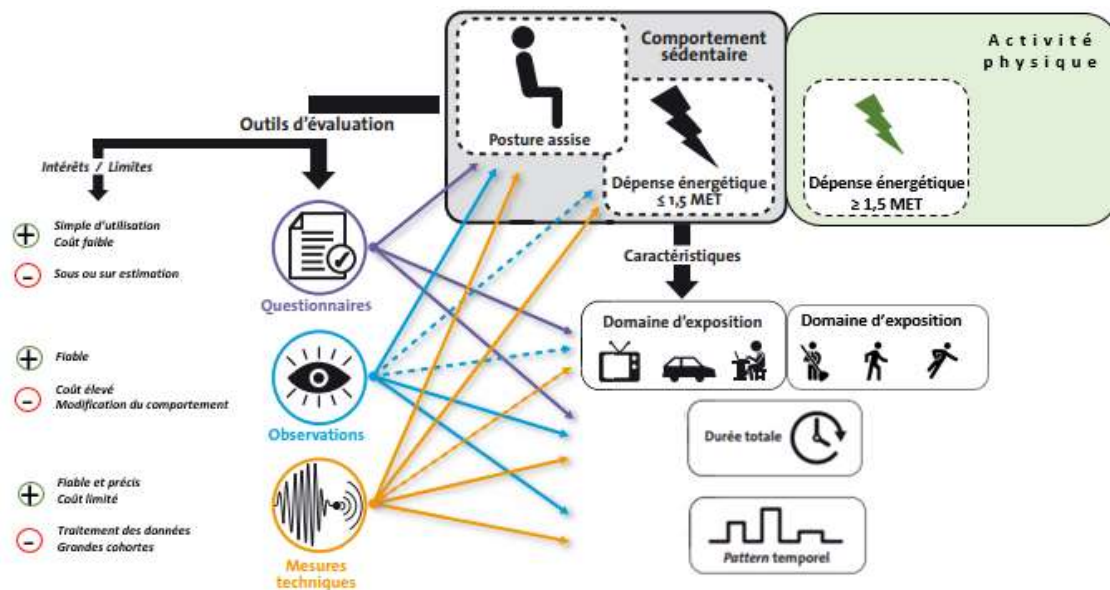


Figure 4 : Intérêts et limites et outils d'évaluation de l'activité physique et de la sédentarité.

Flèche pleine : bonne capacité ; flèche pointillée : capacité moyenne (nécessitant un complément d'information).

MET : Metabolic Equivalent Task/équivalent métabolique

Source : Figure adaptée de Desbrosses *et al.* (2020)

En intégrant ces outils de mesure dans la pratique clinique, les professionnels de la santé peuvent concevoir des interventions ciblées et personnalisées visant à encourager une augmentation de l'AP et la réduction de la sédentarité, contribuant ainsi à l'amélioration de la santé individuelle et collective.

### 1.3. Épidémiologie des comportements de mouvements

La surveillance épidémiologique revêt une importance cruciale pour appréhender l'ampleur des comportements de mouvements aux différents âges de la vie, ainsi que développer des stratégies efficaces pour améliorer la santé et le bien-être des personnes de tous les âges. Les données provenant de 168 pays, englobant 1,9 millions de participants, indiquent qu'en 2016 la prévalence de l'inactivité physique chez l'adulte était de 27,5 %, avec une stabilité observée depuis 2001 (Guthold *et al.*, 2018). Cependant, une étude antérieure avait estimé la prévalence de l'inactivité physique à 23,3 % en 2010, ce qui s'explique par l'augmentation du nombre d'études et de pays inclus dans l'analyse (Sallis *et al.*, 2016). L'accroissement des données disponible est encourageant, mais le Global Observatory for Physical Activity (GoPA!) estime que près de 49,6 millions de personnes ne font pas l'objet

d'une surveillance globale en AP (Ramírez Varela et al., 2023), soulignant la nécessité d'accroître la surveillance accrue des comportements de mouvements. Dans cette section, nous procéderons donc à une synthèse exhaustive des niveaux de pratique mesurés de manière objective et subjective au sein de ces populations les plus vulnérables, à savoir les enfants, les adolescents et les personnes âgées.

### 1.3.1. *Epidémiologie des comportements de mouvements chez les enfants et les adolescents*

- *L'inactivité physique*

Les dernières données internationales de grande ampleur mesurant le niveau d'inactivité physique publiées dans *The Lancet Children & Adolescents Health* sont issues de plus de 146 pays soit plus d'1,6 millions d'enfants de 11-17 ans (Guthold et al., 2020). Selon cette revue basée sur des données d'accélérométrie, en 2016 plus de huit enfants et adolescents sur dix sont inactifs (81 %), des chiffres stables mais alarmants depuis 2008 (Hallal et al., 2012; Sallis et al., 2016), qui concordent avec des données européennes basées sur des mesures objectives (Steene-Johannessen et al., 2020). En France, les chiffres sont préoccupants : les trois quarts des enfants de 3 à 17 ans n'atteignent pas les recommandations de l'OMS mais les chiffres atteignent le plus souvent 90 % si on utilise des accéléromètres (Farooq et al., 2018; INCA 3, 2017). Des résultats alarmants qui positionnent la France à la 119ème place sur un classement de 146 pays (le 1<sup>er</sup> pays étant le pays avec les adolescents les plus actifs) au sein de la cohorte HELENA<sup>3</sup> (Guthold et al., 2020).

Globalement, la prévalence de l'inactivité physique chez les enfants et adolescents était plus élevée chez les filles que chez les garçons entre 2001 et 2016, ce qui se retrouve dans d'autres enquêtes internationales (Inchley et al., 2020) et nationales (Esen, 2017; Verdot et al., 2020). Cette prévalence a diminué de manière significative pour les garçons entre 2001 et 2016, mais pas pour les filles ce qui creuse les différences de niveaux d'inactivité physique entre les sexes au fil du temps (Guthold et al., 2020).

Il semble y avoir plusieurs facteurs qui influencent la pratique d'AP chez les enfants et les adolescents, tels que le sexe, l'âge et le milieu socio-économique, sans tendance claire selon le revenu du pays en 2016 (Guthold et al., 2020). Ainsi, un faible milieu socio-économique des

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<sup>3</sup> Cohorte HELENA: *Healthy Lifestyle in Europe by Nutrition in Adolescence*

parents peut prédire un niveau d'inactivité physique élevé plus tard dans la vie (Cheval et al., 2018; Elhakeem et al., 2015; Johnson et al., 2011).

Une revue systématique a identifié une forte diminution du niveau d'APMV à 9 ans chez les garçons (-7,8 %) et les filles (-10,2 %), ce qui équivaut à 6 minutes par jour de perte annuelle d'APMV (Figure 5) (Farooq et al., 2020). Ainsi, le décrochage de l'AP chez les enfants semblent apparaître de manière précoce dès la petite et moyenne enfance, dans les deux sexes et n'est pas forcément marquée à l'adolescence (Cooper et al., 2015; Dumith et al., 2011; Harrington et al., 2016). Ce décrochage dès l'âge de 9 ans est lié avec l'entrée à l'école secondaire (Janssen et al., 2016). Très récemment, van Sluijs *et al.* ont conclu que malgré une littérature scientifique très riche en termes de recherche sur l'enfant, il existe encore d'importantes lacunes dans les connaissances, et des efforts doivent être réalisés pour améliorer la surveillance de l'AP de l'enfant (van Sluijs et al., 2021).

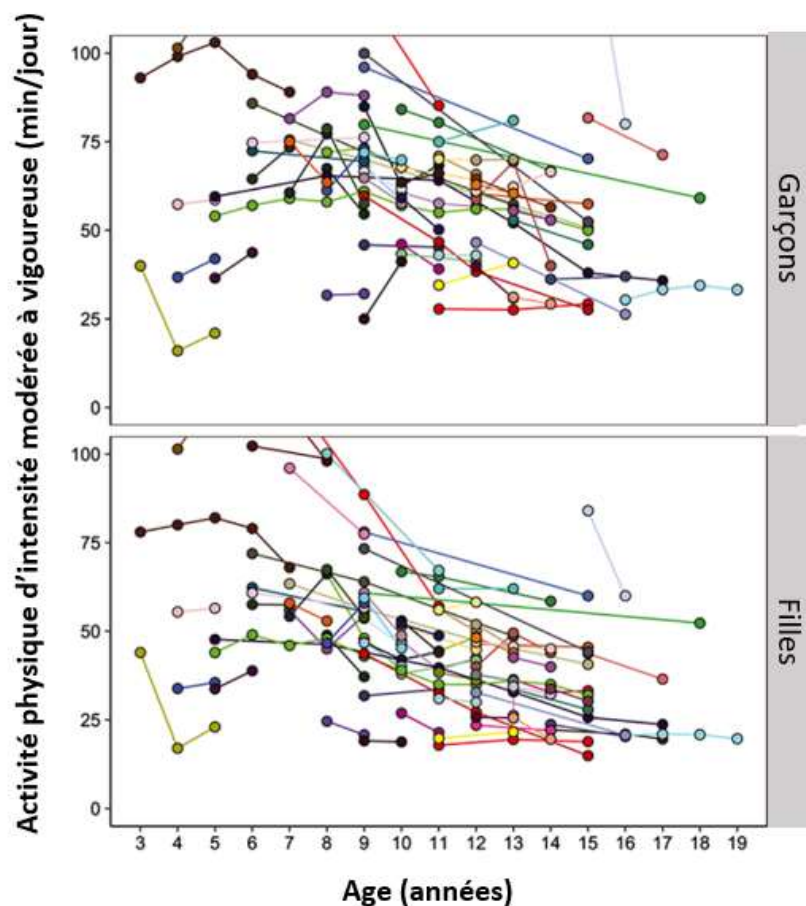


Figure 5 : Trajectoires de l'activité physique d'intensité modérée à vigoureuse chez les garçons (au-dessus) et les filles (en dessous) mesurées par accélérométrie de 3 à 18 ans.

Les couleurs correspondent aux différentes études analysées ; Min : minutes.

Source : Figure traduite de Farooq *et al.* (2020)

- La sédentarité

Concernant les données relatives à la sédentarité, elles sont moins abondantes que celles portant sur l'AP et l'inactivité physique. En effet, comme nous l'avons montré dans un paragraphe précédent, la définition de la sédentarité est relativement récente. Une étude menée au Royaume-Uni, basée sur les données d'accélérométrie de la cohorte *Gateshead Millennium Study*, a examiné les variations des comportements sédentaires chez les enfants et adolescents âgés de 7 à 15 ans (Janssen et al., 2016) (Figure 6).

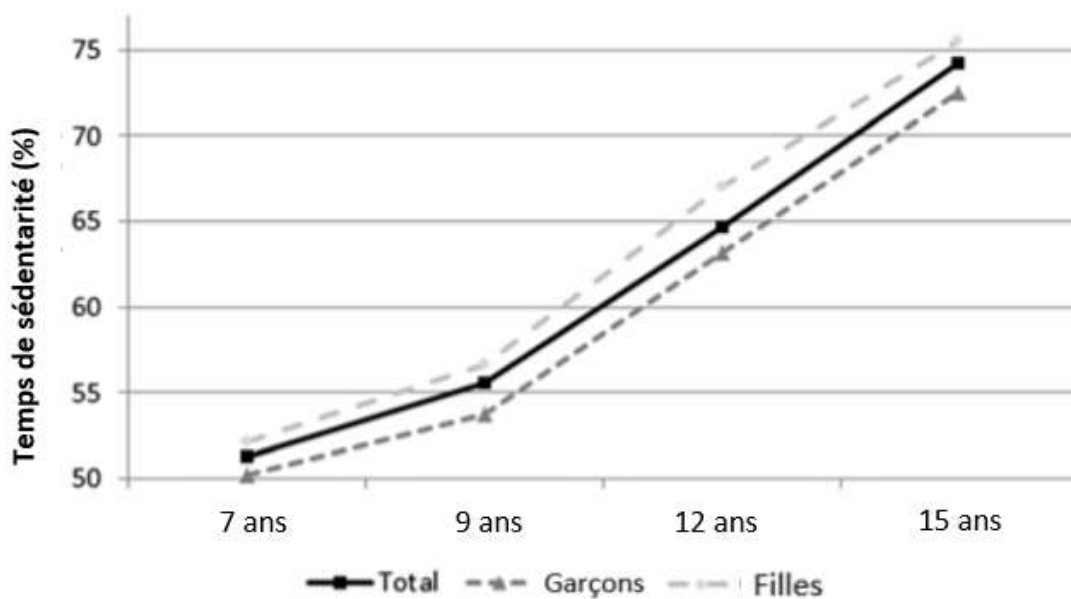


Figure 6 : Changements dans le comportement sédentaire entre l'âge de 7 et 15 ans, en pourcentage du temps sédentaire par jour.

Source : Janssen *et al.* (2016)

Janssen *et al.* montrent que le temps passé à des activités sédentaires croît considérablement chaque année, représentant 51,3 % du temps éveillé à 7 ans pour atteindre 74,2 % du temps éveillé à 15 ans (Janssen et al., 2016). Cela représente une augmentation globale de 22 % de temps passé sédentaire entre 7 et 15 ans, soit 24 min/jour par année (Janssen et al., 2016). Ces résultats concordent avec l'étude ICAD<sup>4</sup> basée sur une méthodologie similaire (Cooper et al., 2015). Ainsi, il a été montré que le temps sédentaire mesuré objectivement augmentait avec l'âge, au détriment de l'AP de faible intensité et de l'APMV (Farooq et al., 2018), toujours en lien avec l'entrée à l'école, l'augmentation de l'utilisation des technologies et la diminution des mobilités actives (ONAPS, 2022).

<sup>4</sup> ICAD : International Children's Accelerometry Database

En France, la plupart des enquêtes sur la sédentarité se concentrent majoritairement sur le temps passé devant un écran d'ordinateur ou de télévision, évalué de manière subjective. Selon l'étude nationale INCA<sup>5</sup> 3 menée entre 2014 et 2016, il a été constaté que 39 % enfants de 3 à 17 ans passent plus de trois heures par jour devant un écran (ANSES, 2017a). Selon les études nationales Esteban et INCA 3 (ANSES, 2017a; Esen, 2017), il existe une corrélation positive entre le temps passé devant un écran et l'âge de l'enfant, 45,5 % des filles et garçons de 6-10 ans passent plus de trois heures par jour devant un écran pour atteindre 70 % des 11-14 ans (ANSES, 2017a). Aussi, les données nationales (ANSES, 2017a; Esen, 2017) et internationales (Cooper et al., 2015; Janssen et al., 2016) s'accordent à dire que les filles sont plus sédentaires que les garçons.

Analysées conjointement, la prévalence de l'inactivité physique et de la sédentarité peut être influencée par le niveau socio-économique des parents. Une étude de l'Anses<sup>6</sup> a montré que la prévalence des profils les plus actifs (> 60 min/j) est la plus élevée chez les enfants dont le représentant légal a un plus haut niveau d'étude, indépendamment du temps de sédentarité (Anses, 2020). A l'inverse, les enfants les plus sédentaires (> 4h30) sont ceux dont les parents ont les plus faibles niveaux d'étude.

### 1.3.2. *Epidémiologie des comportements de mouvement chez les personnes âgées*

- *L'inactivité physique*

Les données portant sur la prévalence conjointe de l'inactivité physique et de la sédentarité sont plus rares (Sims et al., 2010). Les résultats de l'étude américaine NHANES<sup>7</sup> de 2017-2018 ont montré que seulement la moitié (52,6 %) des personnes âgées déclarent respecter les recommandations de 150 minutes d'APMV par semaine (voir section 1.1.3.) (Whitfield et al., 2021). Une revue a conclu que les personnes âgées sont la catégorie d'âge adulte la moins active (47,4 %) comparée aux jeunes adultes (21,5 %) et aux adultes en milieu de vie (32,7 %) (Elhakeem et al., 2015), faisant des seniors une population vulnérable. Les études s'accordent à dire que le NAP décroît avec l'avancée en âge (Caspersen et al., 2000; Harris et al., 2009; Takagi et al., 2015; Troiano et al., 2008), dans les deux sexes (Cheval et al., 2018). Aussi, l'âge

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<sup>5</sup> INCA: étude individuelle nationale des consommations alimentaires

<sup>6</sup> Anses : Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail

<sup>7</sup> NHANES : National Health and Nutrition Examination Survey

d'entrée à la retraite semble être une période cruciale de changement des niveaux d'AP et de sédentarité (Barnett et al., 2012).

Les variations de comportements de mouvements semblent être influencées par le niveau socio-économique. Il a été observé que les personnes défavorisées en début de vie ont un plus faible NAP à un âge avancé (Elhakeem et al., 2017; Manz et al., 2018). Par conséquent, les circonstances socio-économiques précoces peuvent prédire un risque accru d'inactivité physique à un âge plus avancé, bien que cet effet soit modéré par les indicateurs socio-économiques à l'âge adulte (Cheval et al., 2018). Les études portant sur l'influence du milieu de vie sur les comportements de mobilité à un âge avancé sont peu fréquentes, disparates et difficilement comparables à notre propre territoire en raison des disparités démographiques entre les pays où ces études sont menées. Les études s'accordent à dire que les personnes vivant en milieu urbain ont un plus haut NAP qu'en milieu rural (Omelan et al., 2017; Parks et al., 2003)

- La sédentarité

Concernant les données de sédentarité, une revue a estimé qu'en moyenne les personnes âgées passent 9,4 heures par jour sédentaire, soit de 65 à 80 % de leur temps éveillé, selon des mesures objectives (Harvey et al., 2015). La sédentarité autorapportée est moins élevée avec en moyenne 5,3 heures par jour sédentaire, et spécifiquement 3,3 heures par jour passées devant la télévision et 3,3 heures par jour passées assis (Harvey et al., 2015). Globalement, l'AP et la sédentarité semble évoluer au cours des jours de la semaine chez les personnes âgées, les activités étant privilégiées le matin, et minimales le week-end (Barnett et al., 2012). Aussi, les personnes vivant en milieu rural semblent également plus sédentaires que celles vivant en milieu urbain (Wilcox et al., 2000).

#### **1.4. Inactivité physique et sédentarité : impacts sanitaires en population générale**

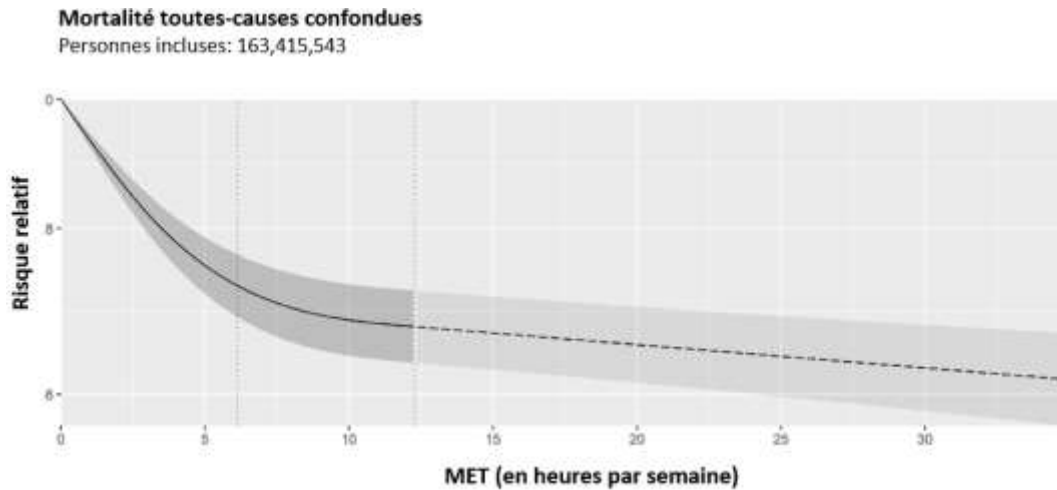
Il est désormais largement reconnu que l'inactivité physique joue un rôle majeur dans l'apparition des maladies chroniques non transmissibles (MNT) et de leurs facteurs de risques (Booth et al., 2012), à travers le monde. Les preuves formelles confirment les effets délétères de l'inactivité physique sur la santé de la population. Bien que les données sur la sédentarité soient plus récentes et souvent confondues avec celles de l'inactivité physique, nous

analyserons d'abord séparément puis conjointement les effets de l'inactivité physique et de la sédentarité sur la santé. Dresser une liste exhaustive des effets néfastes de ces comportements de mouvements est impossible, néanmoins nous nous efforcerons de présenter les preuves les plus pertinentes et spécifiques aux populations vulnérables que sont les enfants et adolescents ainsi que les séniors. Nous nous pencherons également sur impacts financiers de ces comportements de mouvements. Enfin, nous ferons une liste non exhaustive des mesures politiques mises en place afin de limiter ces comportements de mouvements.

#### 1.4.1. *Inactivité physique et effets sur la santé en population générale*

L'inactivité physique est considérée comme le quatrième facteur de risque de mortalité à l'échelle mondiale, et responsable de 15,7 % de la mortalité prématurée (Garcia et al., 2023). Au niveau européen de l'OMS, l'inactivité physique représente 10 % de la mortalité totale, soit un million de décès par an (Katzmarzyk et al., 2021; WHO, 2009, 2016a).

Une récente méta-analyse regroupant les données de plus de 30 millions de participants a révélé une association dose-réponse curviligne entre l'AP et la mortalité toutes causes confondues, la mortalité cardiovasculaire et la mortalité liée au cancer, ainsi que leur incidence (Garcia et al., 2023). Cette méta-analyse se focalise pour la première fois sur l'AP non professionnelle, étant donné que l'évaluation de l'AP professionnelle s'avère complexe et souvent surestimée (Golubic et al., 2014). Ainsi, les personnes actives (respectant les recommandations d'AP) présentent un risque inférieur de mortalité toutes causes confondues de 31 % par rapport aux personnes inactives (Garcia et al., 2023) (Figure 7). Des bénéfices appréciables de l'AP pour la santé peuvent être obtenus à partir de 75 minutes par semaine ou moins d'APMV (c'est-à-dire la moitié du niveau minimum recommandé). Ces résultats sont importants en termes de santé publique, montrant qu'« *il est préférable de faire un peu d'AP que de ne pas en faire du tout* ».



**Figure 7 : Association dose-réponse entre l'activité physique non professionnelle et les résultats en matière de mortalité.**

MET : équivalent métabolique.

Source: Figure traduite de Garcia *et al.* (2023)

Quel que soit l'âge cible, la pratique d'une AP agit sur les mêmes tissus de façon bénéfique, mais des sections spécifiques aux différentes classes d'âges ciblées dans ce manuscrit de thèse sont proposées dans les parties 2 et 3. Globalement, l'inactivité physique est associée à des effets néfastes sur de nombreuses pathologies, contribuant à 29 % des cas de maladies cardiovasculaires (MCV), 7 % des diabètes de type 2, 2 % de la mortalité liée aux cancers et 8,1 % des démences (Aune et al., 2015; Garcia et al., 2023; Katzmarzyk et al., 2021). Les associations dose-réponse montrent que si tous les individus atteignaient les recommandations, une proportion significative des décès liés aux maladies cardiovasculaires (12,3 %) et au cancer (7,1 %) aurait potentiellement été évitée. Aussi, des bénéfices appréciables pour la santé peuvent être obtenus à partir de 75 minutes par semaine ou moins d'activité d'intensité modérée (soit l'atteinte de la moitié des recommandations) (Garcia et al., 2023).

Il existe des risques liés à la pratique excessive d'AP, notamment des pathologies articulaires de surutilisation (arthrose), des troubles du rythme de type fibrillation auriculaire par hypertrophie de l'oreillette. Pour autant, les effets négatifs de l'inactivité physique et de la sédentarité sont bien établis et dépassent largement les risques associés à une pratique régulière d'AP. Il ne faut pas exagérer les risques liés à l'AP.



#### 1.4.2. Sédentarité et effets sur la santé en population générale

Les directives en matière de santé publique évoluent en raison des preuves tangibles démontrant les effets néfastes de la sédentarité sur la santé à tous les âges (Carson et al., 2016; Gibbs et al., 2015; Katzmarzyk et al., 2019; LeBlanc et al., 2017). Ces effets incluent l'augmentation de la mortalité toutes causes confondues et de la morbidité, indépendamment du NAP (Diaz et al., 2017; Dohrn et al., 2018; Ekelund et al., 2020; Katzmarzyk, 2010; Lee et al., 2018; Matthews et al., 2016; Thorp et al., 2011). Quel que soit l'âge cible, la sédentarité agit sur les mêmes tissus de façon délétère, mais des sections spécifiques aux différentes classes d'âges ciblées dans ce manuscrit de thèse sont proposées dans les parties 2 et 3.

Des niveaux de preuve élevés ont mis en évidence une relation inverse entre le niveau de sédentarité et la mortalité générale (Department of Health and Human Services, 2018). De nombreuses études se sont ainsi intéressées au temps total passé assis et aux risques de décès prématuré associés. Ainsi, des seuils de sédentarité au-delà desquels le risque de décès prématuré est augmenté ont été estimés à hauteur de 4 heures par jour (Ekelund et al., 2016), 6 à 8 heures par jour (Patterson et al., 2018), 7 heures par jour (Chau et al., 2013) ou plus récemment 9,5 heures par jour de sédentarité (Ekelund et al., 2019) (Figure 8). Ces différences s'expliquent par l'hétérogénéité des méthodes de mesure utilisées.

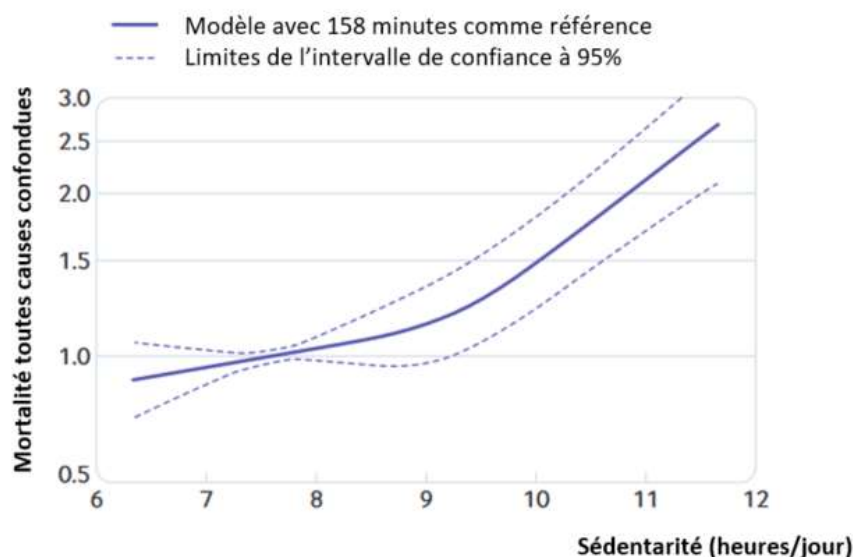


Figure 8 : Association dose-réponse entre le temps passé sédentaire en heures par jour et le risque de mortalité toutes causes confondues.

La référence d'exposition (ici 158 minutes) est fixée à la médiane des médianes dans le groupe de référence (le moins actif)

Source: Figure traduite de Ekelund *et al.* (2019)

En plus du temps total passé assis, il faut tenir compte de la durée de chaque épisode de sédentarité. Chez les adultes, le risque de mortalité augmente de manière très nette pour des durées moyennes de périodes de sédentarité supérieures à 10 minutes chacune, en comparaison à des périodes inférieures à 10 minutes (Diaz et al., 2017) (Figure 9). Aussi, des périodes de sédentarité plus courtes, entrecoupées de pauses (breaks) plus fréquentes pourraient favoriser des profils cardiométaboliques plus favorables chez les enfants (Bailey et al., 2017; Santos et al., 2019), et les seniors (Bellettiere et al., 2019), soulignant l'importance de réduire le temps consacré à la sédentarité, mais également de limiter les longues périodes sédentaires. Cependant, se lever toutes les 10 minutes est impossible au quotidien. Aussi, il reste à déterminer la fréquence des ruptures des temps de sédentarité, leur durée et l'intensité de l'AP à pratiquer pendant ces ruptures (Ding et al., 2020; Duran et al., 2023), les études proposant des résultats hétérogènes.

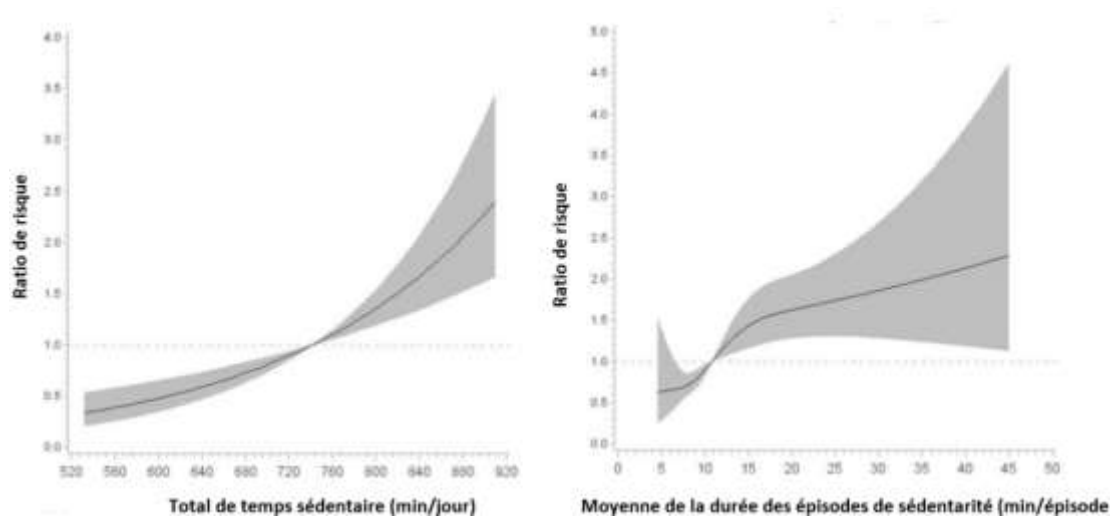


Figure 9 : Ratio de risque de mortalité toutes causes confondues en fonction du temps total de sédentarité (à gauche) et de la durée moyenne des épisodes de sédentarité (à droite).

Source: Figure traduite de Diaz *et al.* (2017)

Outre la mortalité et la morbidité, la sédentarité est associée à un éventail de conséquences néfastes sur la santé tels que la mortalité liée au cancer (Gilchrist et al., 2020), la morbidité (Biswas et al., 2015), les MCV (Bellettiere et al., 2019), une mauvaise condition cardiorespiratoire (D. A. Santos et al., 2012), la diminution des capacités physiques, des troubles psychosociaux (McPhee et al., 2016), ainsi que la détérioration des capacités cognitives (Buchman et al., 2012). De plus, des études ont également établi un lien entre la sédentarité et des indicateurs tels que les triglycérides, la pression artérielle diastolique,

l'obésité et la santé métabolique (Bankoski et al., 2011; Júdice et al., 2020; Katzmarzyk et al., 2009; Stamatakis et al., 2011).

De récentes études ont évalué plus précisément le risque relatif de différentes pathologies associées à la sédentarité, révélant des augmentations de risques allant de 13 % (diabète de type 2) à 30 % (cancer colorectal et démence) chez les adultes ayant un comportement sédentaire excessif par rapport à ceux dont le niveau de sédentarité est plus faible (Chaput et al., 2023) (Tableau 3).

Paramètres de santé	Risque relatif (95% IC)
Maladies cardiovasculaires <sup>1</sup>	1.29 (1.13-1.47)
Diabète de type 2	1.13 (1.04-1.22)
Cancer colorectal	1.30 (1.12-1.49)
Cancer de l'endomètre	1.28 (1.08-1.53)
Cancer des poumons	1.27 (1.06-1.52)
Cancer du sein	1.17 (1.03-1.33)
Démence	1.30 (1.12-1.51)
Dépression	1.14 (1.06-1.21)

**Tableau 3 : Estimations regroupées des risques relatifs pour les huit effets sur la santé associés à un comportement sédentaire excessif, tels que rapportés dans des méta-analyses récentes d'études de cohortes prospectives.**

<sup>1</sup>Infarctus du myocarde, maladies coronariennes et accident vasculaire cérébral ; IC: Intervalle de Confiance.

Source: Tableau traduit de Chaput *et al.* (2023)

Il est donc essentiel non seulement de limiter le temps passé en position sédentaire, mais également de trouver le juste équilibre avec le NAP afin de réduire les néfastes des mauvais comportements de mouvements sur la santé. Des études suggèrent que remplacer une heure de temps sédentaire par de l'AP de faible intensité peut réduire le risque de mortalité (Fishman et al., 2016; Loprinzi et al., 2016), en particulier chez les adultes inactifs, avec des effets encore plus bénéfiques pour la pratique d'APMV (Matthews et al., 2016) (Figure 10).

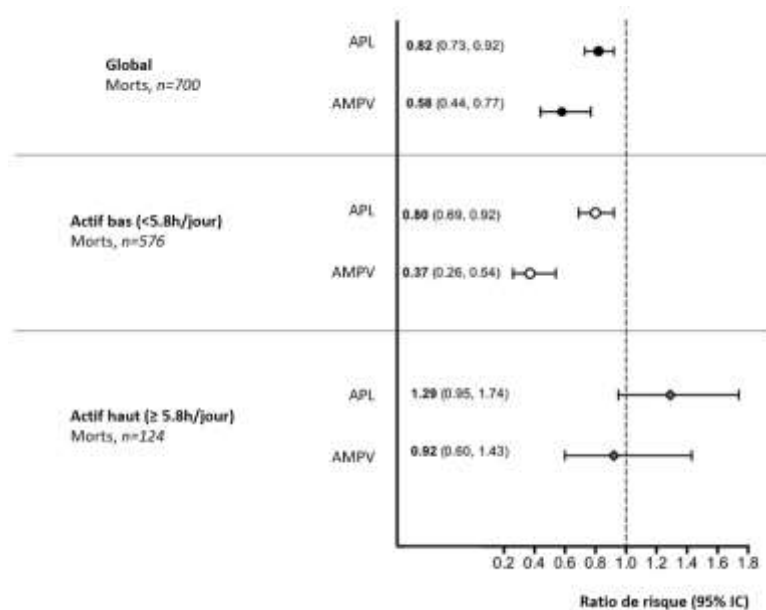


Figure 10 : Mortalité associée au remplacement d'une heure de sédentarité par une heure d'activité physique de faible intensité et modérée à vigoureuse (AMPV), chez les participants faiblement actifs et hautement actifs (n=1400).

Les associations ont été ajustées par âge, origine ethnique, éducation, sexe, tabac, consommation d'alcool, indice de masse corporelle ; CI : Intervalle de Confiance.

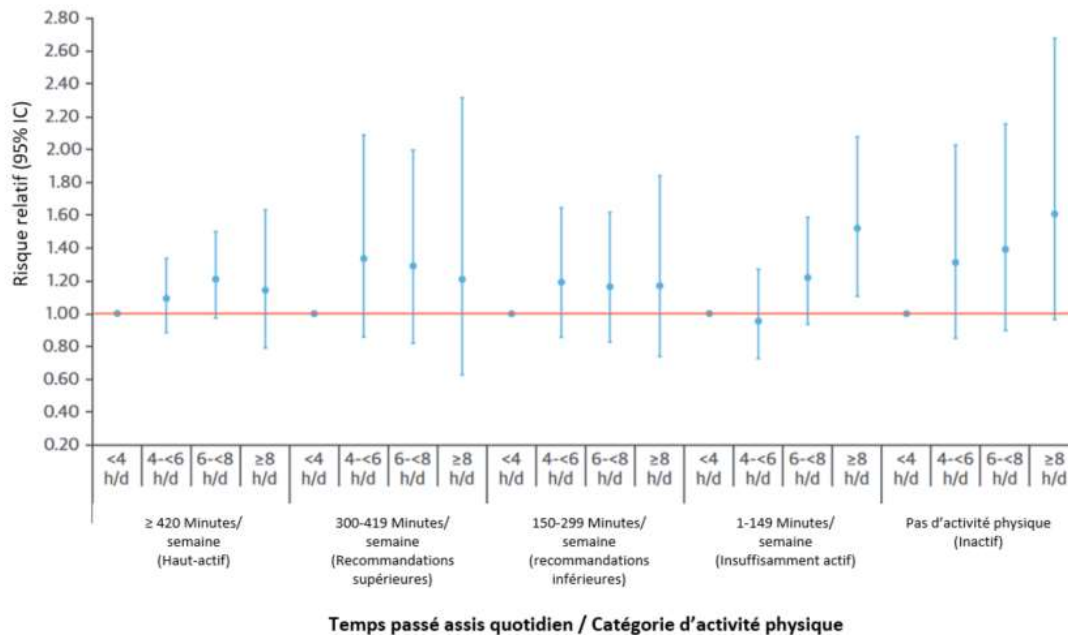
Source : Figure traduite de Matthew *et al.* (2016)

#### 1.4.3. L'accumulation de l'inactivité physique et de la sédentarité

Les effets conjoints de l'inactivité physique et de la sédentarité sur la santé suscitent donc un intérêt croissant dans la communauté scientifique. En effet, comme l'avaient mis en avant Ekelund *et al.* chez l'adulte, un bon NAP ne suffit pas à protéger des méfaits de la sédentarité (Ekelund, Tarp, et al., 2019). Dans ce contexte, il est devenu essentiel de mieux appréhender la façon dont ces deux comportements peuvent interagir.

Les premières études basées sur des données objectives ont révélé que chez les personnes les plus actives, la sédentarité n'était pas significativement associée avec la mortalité (Loprinzi et al., 2016; Schmid et al., 2015), avec une réduction de risque plus grande pour la pratique d'AMPV, sans l'éliminer complètement (Biswas et al., 2015; Chau et al., 2013; Loprinzi et al., 2016; Schmid et al., 2015). Il semble pourtant qu'au-delà de 5.8 heures par jour de pratique d'AP, le temps passé sédentaire n'a plus d'impact sur la santé (Matthews et al., 2016), bien que cette quantité d'AP soit difficilement atteignable en condition réelle. Diverses études ont examiné les associations conjointes et stratifiées de la position assise et de la pratique d'AMPV avec la

mortalité toutes causes confondues et les MCV (Ekelund et al., 2019; Ekelund et al., 2016; Stamatakis et al., 2019), montrant une relation dose-réponse dans les groupes d'AP inférieurs. Cependant, chez les individus les plus actifs, des preuves solides suggèrent une atténuation des effets néfastes de la position assise (Ekelund et al., 2019; Stamatakis et al., 2019) notamment sur la mortalité toutes causes confondues (Figure 11).



**Figure 11 : Associations stratifiées entre la position assise et les événements de mortalité toutes causes confondues dans chaque catégorie d'activité physique (n=149 0077).**

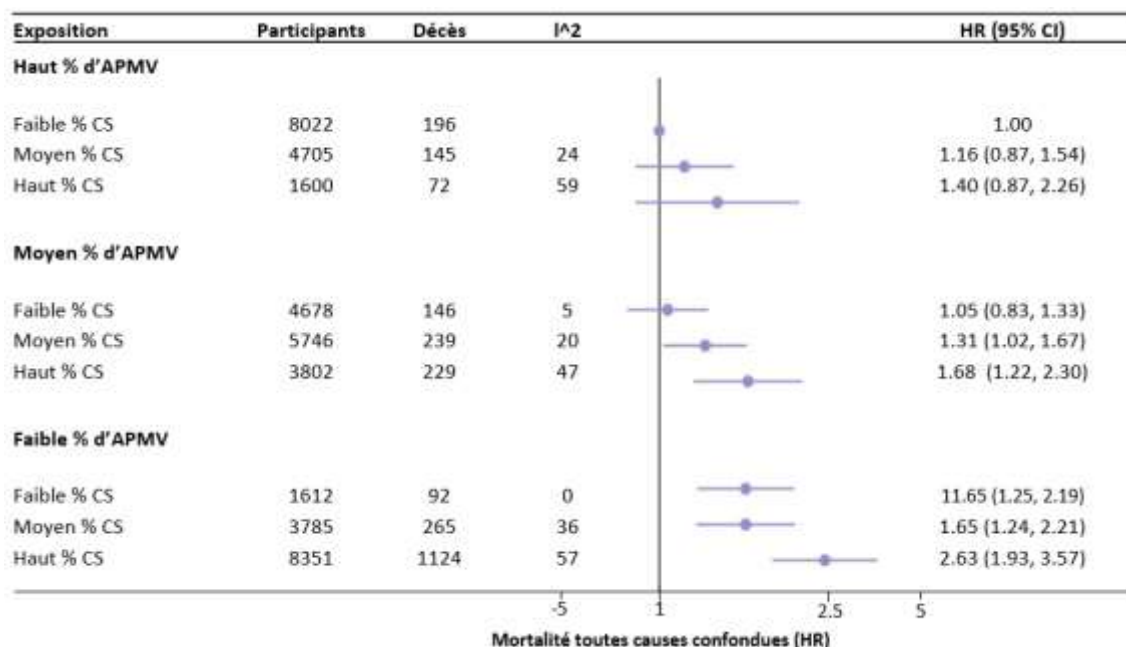
Les analyses sont ajustées pour l'âge, le sexe, l'éducation, le statut marital, l'éloignement, l'indice de masse corporelle, le tabagisme, la santé autoévaluée, l'aide au handicap, la détresse psychologique, la consommation de fruits et légumes et le diabète.

IC= intervalle de confiance ; h/d : heure par jour.

Source: Figure traduite de Stamatakis *et al.* (2019)

Pour autant, même pour les personnes actives, rester assis plus de 8 heures par jour est associé à un risque élevé de mortalité (Stamatakis et al., 2019), il semble nécessaire de consacrer entre 60 et 75 minutes de pratique d'APMV par jour pour éliminer le risque de mortalité lié au temps passé en position assise (Ekelund et al., 2016). Une nouvelle méta-analyse de Ekelund *et al.* basée sur des données objectives, a réévalué la dose de pratique d'APMV quotidienne nécessaire pour annuler les effets de la sédentarité sur la mortalité (Ekelund et al., 2020) (Tableau 4). Un temps de sédentarité élevé (>10,7 heures par jour) est associé à un risque de mortalité accru, en particulier chez les personnes ayant un faible NAP

(Ekelund et al., 2020) qui pourrait être atténué par 30 à 40 minutes d'APMV par jour, ce qui est inférieur aux estimations antérieures de 60 à 75 minutes de données autorapportées (Ekelund et al., 2016).



**Tableau 4 : L'association entre l'activité physique d'intensité modérée à vigoureuse (APMV) et le temps sédentaire et la mortalité toutes causes confondues.**

Les analyses sont ajustées en fonction de l'âge, du sexe, de la situation socio-économique, de l'indice de masse corporel, du tabagisme, de la présence de maladies ou d'un mauvais état de santé autodéclaré. Le temps médian (minutes/jour) passé en sédentarité et en APMV (minutes/jour) selon les tertiles était de 8,5, 9,5 et 10,7 heures/jour ; et de 2,3, 11,2 et 34,3 minutes/jour, respectivement. CS : Comportements Sédentaires ; APMV : Activité Physique d'intensité Modérée à vigoureuse ; CI = Intervalle de Confiance ; HR : Ratio de risque.

Source: Tableau adapté de Ekelund *et al.* (2020)

L'association entre le temps passé assis et le risque d'événements cardiovasculaires dépend également du NAP (Bjørk Petersen et al., 2014; Chomistek et al., 2013; Herber-Gast et al., 2013), le risque étant majoré dans les groupes d'AP inférieurs et assis plus de 8 heures par jour par rapport au groupe le moins assis (<4h/jour) (Ekelund et al., 2019). Respecter la limite supérieure d'AP élimine ces associations, tandis que respecter la limite inférieure compense largement le risque accru lié à la position assise, sauf chez les personnes qui passent beaucoup de temps assis.

Etant donné que le temps passé en position assise est souvent influencé par la profession, l'environnement ou les limitations fonctionnelles, la question se pose de savoir si les recommandations en matière d'AP pourraient être adaptées à différents contextes et situations. Une approche plus équilibrée pourrait consister à intégrer les recommandations relatives à différents comportements, plutôt que de se fier à des recommandations isolées pour chaque comportement individuel. À cet égard, Chastin *et al.* proposent une carte personnalisée permettant d'identifier les possibilités de compenser les périodes sédentaires par la pratique d'APMV (Chastin et al., 2021) (Figure 12).

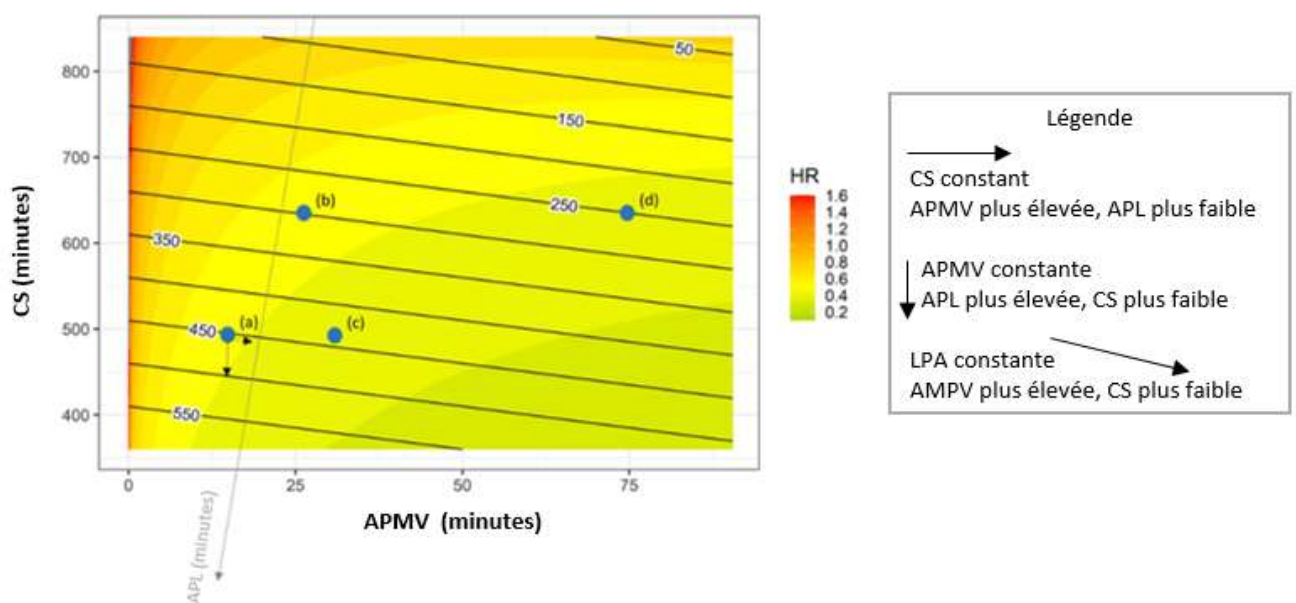


Figure 12 : Relation entre le risque de mortalité toutes causes confondues (couleur) et la composition quotidienne du temps consacré à l'APMV (axe des abscisses), aux CS (axe des ordonnées) et à l'activité physique de faible intensité (courbes de niveau axe gris).

HR indique les rapports de risque ; APMV : activité physique d'intensité modérée à vigoureuse ; CS : comportement sédentaire.

Source: Figure traduite de Chastin *et al.* (2021)

Ainsi, à titre d'exemple, un équilibre de plus de 2,5 minutes d'APMV par heure de sédentarité quotidienne est associé à la même réduction du risque de mortalité toutes causes confondues que celle obtenue en étant physiquement actif selon les recommandations actuelles. Ces données pourraient conduire à l'élaboration de recommandations plus intégrées, telles que « *visez x minutes d'activité physique pour x heures de la journée où vous êtes habituellement assis* », ou encore présentées sous forme visuelle, comme la carte de la figure 12 (Chastin et al., 2021).

Avec l'augmentation de l'inactivité physique et de la sédentarité, de nombreuses études se focalisent sur des stratégies visant à rompre la position assise en pratiquant des exercices physiques. Cette stratégie, nommée « active breaks » ou traduite par « pauses actives » couple une interruption de la sédentarité par une pratique d'AP de courte durée d'intensité variable. Chez les enfants, les *active breaks* ont permis une augmentation de l'AP quotidienne et de l'APMV (Carrasco-Uribarren et al., 2023). Aussi, des revues et méta-analyses s'accordent à dire que l'utilisation des pauses d'intensité modérée à vigoureuse permettent une amélioration de la glycémie post-prandiale (Buffey et al., 2022; Chastin et al., 2015; Loh et al., 2020; Saunders et al., 2018) et de l'insuline (Loh et al., 2020; Saunders et al., 2018). avec une atténuation de la glycémie plus importante pour les personnes ayant un IMC<sup>8</sup> élevé (Loh et al., 2020). Les *active breaks* ont également montré des effets préventifs inflammatoires associés au temps prolongé sédentaire, notamment le niveau d'adiponectine, et donc sur l'augmentation de la sensibilité à l'insuline (Sahabudhee et al., 2023), bien que ces résultats n'en soient qu'à leur prémisse.

Les effets néfastes de l'inactivité physique et de la sédentarité sur la santé des enfants et des personnes âgées sont incontestables. Aussi, il est important de questionner des coûts financiers et évitables de ces comportements de mouvements malsains.

## 1.5. Coûts financiers et coûts évitables de l'inactivité physique et de la sédentarité

### 1.5.1. *Inactivité physique*

- *Coûts financiers*

Nous avons précédemment montré que l'inactivité physique est associée à une augmentation du risque de mortalité et à la survenue des MNT, mais cela engendre également des coûts financiers. En 2013, le coût global de l'inactivité physique pour les systèmes de santé a été estimé à 53,8 milliards de dollars internationaux, dont 58 % ont été supportés par le secteur public (Ding et al., 2016). Cependant, ces chiffres considérables sous-estiment le coût global réel de l'inactivité physique, car ils se concentrent uniquement sur cinq pathologies spécifiques : maladies coronariennes, accidents vasculaires cérébraux,

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<sup>8</sup> IMC : Indice de Masse Corporel. Il est calculé en divisant le poids (kg) par le carré de la taille (m).



diabète de type 2, cancers du sein et du côlon (Santos et al., 2023). En effet, en ajoutant aux maladies précédemment analysées les cancers de la vessie, de l'endomètre, de l'estomac, de l'œsophage et du rein, ainsi que la dépression et la démence, les résultats sont encore plus préoccupants. Ainsi, si aucun changement de comportement de mouvement n'est noté entre 2020 et 2030, les coûts de l'inactivité physique s'élèveront à 523,9 milliards de dollars internationaux dans le monde (Santos et al., 2023).

Les études s'accordent à dire que l'inactivité physique a des répercussions négatives sur la production (Cadilhac et al., 2011, 2009, 2009) et la main d'œuvre (Crosland et al., 2019; Ding et al., 2016), sans pour autant s'accorder sur l'impact réel. Une récente revue a estimé que les groupes de personnes actives engendrent des coûts de soins de santé inférieurs de 9 % à 26,6 % que pour les groupes inactifs (Duijvestijn et al., 2023). Concernant l'impact de l'inactivité physique sur les coûts de traitement et de prise en charge des MNT et des affections mentales, son estimation dépend de la prévalence mais également des coûts directs des soins de santé. Par exemple, bien que la démence ne représente que 3 % des nouveaux cas évitables, elle représente 22 % du total des coûts directs des soins de santé (Figure 13). En 2013 en France, les coûts directs totaux de l'inactivité physique représentaient 1 390 540 € dont 1 040 124 € de coûts directs et 350 416 € de coûts indirects (Ding et al., 2016). Toujours en France, le coût social de l'inactivité physique a été estimé à 140 milliards d'euros par an, correspondant à plus de 38 000 décès et 62 000 pathologies causées chaque année (France stratégie & Ministre de la transition écologique, 2022).

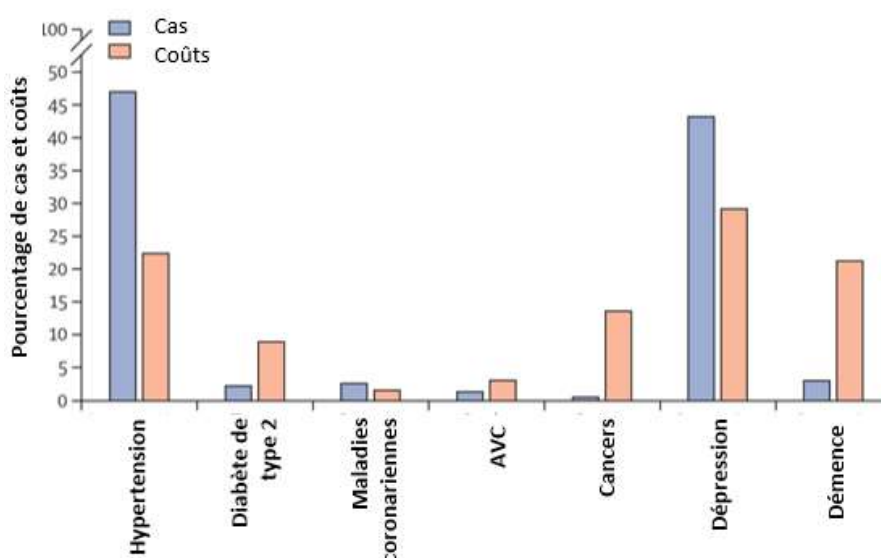


Figure 13 : Proportion mondiale totale des nouveaux cas et des coûts directs des soins de santé liés aux maladies non transmissibles et aux troubles de la santé mentale attribués à l'inactivité physique, 2020–2030.

Source : Figure traduite de Santos *et al.* (2023)

- Coûts évitables

Jusqu'à présent, la majeure partie des études évaluent les coûts financiers de l'inactivité physique mais peu d'études se sont penchées sur les économies potentielles réalisables en réduisant cette inactivité physique. Les études de Ding *et al.* et de Santos *et al.* examinent les économies potentielles découlant de la réduction de l'inactivité physique dans le monde (Ding et al., 2016; Santos et al., 2023). Cependant, les divergences méthodologiques rendent la comparaison entre ces deux études complexe.

Les études menées aux Etats-Unis s'accordent à dire que les coûts annuels des soins de santé sont significativement moins élevés pour les participants ayant une bonne condition physique à mi-vie que pour ceux ayant une faible condition physique à mi-vie (Bachmann et al., 2015; Myers et al., 2019; Weiss et al., 2004). Aussi, une augmentation de 1 MET de condition physique était associée à une réduction des coûts de santé entre 5 et 7 % en moyenne (Bachmann et al., 2015; Myers & Kokkinos, 2019; Weiss et al., 2004). Cette réduction des coûts a été majorée chez les personnes en surpoids et obèses (Weiss et al., 2004). En plus des bénéfices pour la santé de la population, l'AP permet également de limiter les coûts de santé.

De récentes estimations indiquent qu'une augmentation du NAP de la population mondiale jusqu'au seuil recommandé par l'OMS pourrait engendrer une économie mondiale cumulée de 8,6 milliards de dollars d'ici à 2050 (WHO, 2020a), en particulier dans les pays à revenu élevé où le niveau d'inactivité physique est élevé (Santos et al., 2023). Aussi, une réduction de l'inactivité physique de 5 à 10 % permettrait de réaliser des économies financières annuelles comprises entre 228,1 et 453,9 milliards de dollars, associées à une « économie humaine » de 12 000 à 25 000 années de vies corrigées en fonction de l'incapacité et entre 1 000 et 2 000 décès (Beavis et al., 2014; Cadilhac et al., 2009). Ces données soulignent l'importance des interventions visant à promouvoir l'AP tant en termes d'économies potentielles financières qu'humaines.

### 1.5.2. *La sédentarité*

- Coûts financiers

Les études sur les coûts de la sédentarité sont rares dans la littérature scientifique. Une revue systématique (Nguyen et al., 2022) a identifié seulement trois études évaluant les coûts liés à l'excès de sédentarité (Heron et al., 2019; Peeters et al., 2014; Yu & Schwingel, 2019) avec

une prise en compte des coûts directs et indirects ainsi que la perte de productivité (Larg & Moss, 2011). Ainsi, au Canada, en utilisant le seuil de 8 heures par jour, la charge économique annuelle d'un comportement sédentaire excessif est estimé à 2,2 milliards de dollars, ce qui représente 1,6 % du coût total de la charge de morbidité à l'échelle nationale en 2021 (Chaput et al., 2023), contre 1,8 milliards de dollars soit 1,3 % des coûts de morbidité si le seuil utilisé est de 9 heures par jour. Tout comme pour l'inactivité physique, les maladies les plus coûteuses en lien avec la sédentarité sont les maladies cardiovasculaires, et le diabète de type 2, auxquels s'ajoutent les cancers, la démence et la dépression (Tableau 5).

	Coût attribuable à l'excès de sédentarité (>8h/jour)			
	Direct	Indirect	Total	% du coût total
Maladie cardiovasculaire <sup>9</sup>	725,4	22,5	747,9	34,1
Diabète de type 2	607,4	2	609,4	27,8
Cancer colorectal	141,2	6,3	147,5	6,7
Cancer de l'endomètre	22,6	1,3	23,9	1,1
Cancer du poumon	115,5	14,9	130,4	5,9
Cancer du sein	48,1	3,3	51,4	2,3
Démence	161,6	0,2	161,8	7,4
Dépression	322,3	0,02	322,3	14,7

**Tableau 5 : Coûts directs, indirects et totaux d'un comportement sédentaire excessif (> 8 h/jour) pour des résultats de santé spécifiques chez les adultes canadiens en 2021.**

Les coûts directs incluent la perte de productivité due à la mortalité prématurée.

Source: Chaput *et al.* (2023)

En France, 51 193 décès prématurés par an semblent liés à une sédentarité quotidienne prolongée. Chaque année, la sédentarité prolongée coûte 494 millions d'euros à l'assurance maladie. La perte de productivité annuelle due à la mortalité prématurée imputable à la sédentarité prolongée coûte 507 millions d'euros et la perte de productivité annuelle due à la morbidité coûte entre 43 et 147 millions d'euros (Racine et al., 2022).

- Coûts évitables

Des études ont estimé qu'une réduction du niveau de sédentarité de 10 % permettrait de réaliser des économies mondiales annuelles de 219 millions de dollars (Chaput et al., 2023). Aussi, une étude Australienne menée dans des écoles primaires a montré que la combinaison

<sup>9</sup> Inclus l'infarctus du myocarde, la maladie coronarienne, les Accidents Vasculaires Cérébraux

de l'AP et de la réduction la sédentarité permettrait de gagner 60 780 années de vie en bonne santé et d'économiser 641 millions de dollars sur le coût total des soins de santé (Nguyen et al., 2022). Plusieurs analyses coûts-efficacité ont conclu que les interventions ciblant les comportements sédentaires étaient rentables, avec une probabilité de rentabilité se situant entre 66 % et 100 %, avec des interventions plus prometteuses en incluant l'environnement physique sur le lieu de travail, notamment l'utilisation de bureaux actifs (Nguyen et al., 2022).

Les résultats de ces études devraient être mobilisés par les décideurs politiques en vue de promouvoir la santé et accélérer la mise en œuvre de politiques. Il est important que la communauté scientifique continue de développer des méthodes et des preuves concernant les impacts de l'inactivité physique et de la sédentarité sur la santé et les aspects économiques, en accordant une attention particulière aux populations à risque.

## **1.6. L'orientation des politiques publiques vers la promotion d'une population active à tous les âges de la vie**

Suite à la recrudescence de l'inactivité physique à l'échelle mondiale (Hallal et al., 2012; Kohl et al., 2012) l'AP est au cœur des plans et programmes de prévention des pathologies chroniques mais également des limitations fonctionnelles et cognitives associées au vieillissement.

### *1.6.1. Echelle mondiale et européenne*

Le *Global Observatory for Physical Activity* (GoPA!) Working group a conclu qu'au total, 6,3 milliards de personnes, soit 88,2 % de la population mondiale vivent dans des pays où la promotion de l'AP devrait être considérablement améliorée (Ramírez Varela et al., 2023). En effet, bien que la Stratégie mondiale de l'OMS pour la prévention et le contrôle des MNT 2013-2020 encourage la pratique de l'AP pour prévenir les MNT chez les personnes de tous âges (OMS, 2013), l'AP n'est qu'une composante de cette politique, et non l'objet central. Aussi, en 2018 l'OMS a lancé le Plan d'action mondial sur l'AP pour 2018-2030, dont l'objectif est de réduire de 15 % l'inactivité physique dans le monde d'ici à 2030 (WHO, 2019a), encouragé par l'actualisation des recommandations mondiales d'AP (OMS, 2022).

Parmi ces mesures préconisées, certaines ciblent directement les enfants et adolescents ainsi que les personnes âgées, qui sont particulièrement sensibles à l'inactivité physique et à la sédentarité. Chez les enfants, la pratique d'AP peut avoir un effet direct sur l'atteinte de certains Objectifs de Développement Durable (ODD) (WHO, 2019a). Elle peut contribuer à favoriser une bonne santé et bien-être (ODD 3) en participant à la réduction des MNT et au maintien du bien-être ; favoriser une éducation de qualité (ODD 4) en améliorant les capacités cognitives, de concentration et les résultats scolaires (Barbosa et al., 2020), tout en permettant d'identifier les obstacles à la pratique chez les filles et donc contribuer à l'équité des genres (ODD 5) (Roper & Polasek, 2019). C'est pourquoi, le Plan d'action mondial sur l'AP pour 2018-2030 préconise notamment des politiques visant à améliorer l'AP à l'école et en dehors.

Concernant les personnes âgées, les initiatives communautaires pour promouvoir l'AP ainsi que les politiques de transport actif sont favorisées. Ce plan n'est pas la première tentative de lutte contre une « *démographie apocalyptique* » et ses conséquences économiques et sociales sur la santé (Gee & Gutman, 2000) par la promotion de l'AP à travers le monde. En 1998, l'AP est pour la première fois apparue dans les politiques, associée à la prévention des chutes (OMS, 1998). Depuis, une « *faible priorité est accordée à la transition démographique* » (United Nations Population Fund & HelpAge International, 2011), s'expliquant par la diversité des personnes âgées qui rend complexe la mise en place de politiques adaptées. L'OMS a récemment lancé la décennie pour le vieillissement en bonne santé 2020-2030 (WHO, 2020b) afin de promouvoir un vieillissement actif et en bonne santé en mettant l'accent sur la promotion de modes de vie sains, dont l'AP est un levier majeur.

### 1.6.2. *Echelle nationale*

En France, différents programmes et plans se succèdent, adaptés aux tranches d'âges : la Stratégie Nationale de Santé 2018-2022, dont découle le Plan national de santé publique (Priorité Prévention) 2018-2022 (Ministère des Solidarités et de la Santé, 2017), le Programme National de Nutrition Santé 2019-2024 (Ministère des Solidarités et de la Santé, 2018), et la Stratégie Nationale Sport Santé 2019-2024 (Ministère de la santé & Ministère des sports, 2017).

Des politiques de santé spécifiques à des populations ont également été développées. Concernant les enfants et adolescents, plusieurs d'entre elles sont menées à l'école comme le projet « *savoir rouler à l'école* » (article D312-43 du Code de l'éducation) ou le « *savoir-nager* » qui ont pour objectif d'apprendre aux enfants à devenir autonomes dans l'eau et ainsi

favoriser les mobilités actives, respectivement (Ministère de l'Éducation Nationale de la Jeunesse, 2007, 2022b) (l'article D. 312-47-2 du code de l'éducation). Aussi, dans un département par académie pour l'année scolaire 2022-2023, une expérimentation a été menée afin de promouvoir la pratique sportive et l'AP. Ainsi, en complément de l'éducation physique et sportive (EPS) et de l'offre des associations sportives, deux heures d'activité physique et sportive (APS) supplémentaires hebdomadaires ont été proposées au collège à titre gratuit durant le temps périscolaire. Pour encore plus faciliter l'accès aux structures sportives, depuis le 19 mai 2021 le ministère des sports et des Jeux Olympiques et Paralympiques ont instauré le Pass'Sport, aide à la pratique sportive de 50 euros par enfant pour financer tout ou une partie de l'inscription dans une structure sportive. En collaboration avec les jeux olympiques de Paris 2024, depuis la rentrée 2020 le ministère chargé de l'éducation nationale s'engage à ce que chaque élève puisse bénéficier de 30 minutes d'AP quotidienne dans les écoles primaires (Ministère de l'Éducation Nationale de la Jeunesse, 2022a). Néanmoins, pour l'instant il s'agit d'une préconisation et seulement 36 des 250 écoles primaires du pays l'avaient adopté en septembre 2022.

La transition démographique, caractérisée par une augmentation de la longévité des Français a induit la conduite de plans nationaux spécifiques de lutte contre la dépendance dont le plan national Bien Vieillir 2007-2009 où « *au moins trente minutes de marche rapide chaque jour* » sont recommandées (Ministère de la Santé et des Solidarités, 2007). Pour renforcer l'AP et sportive des seniors, le soutien vers les fédérations sportives et la formation des professionnels a été renforcé. Par la suite, le plan national d'action de prévention de la perte d'autonomie de 2015 a été publié (Ministère des affaires sociales, de la Santé et des droits de la femme, 2015), identifiant dans la mesure 16 « *un des enjeux de santé publique prépondérant dans la prévention de la perte d'autonomie est la prévention des chutes qui s'avère étroitement liée à la prévention de la sédentarité et la promotion de la mobilité* » (Ministère des affaires sociales, de la Santé et des droits de la femme, 2015). Ce plan préconise la mise en place d'un dépistage de la fragilité, incluant des signes indiquant une perte d'autonomie progressive réversible liée à une diminution de la mobilité. Il vise également à lutter contre la sédentarité, préserver la mobilité en améliorant l'accessibilité des informations sur les bienfaits de l'AP, et prendre des mesures préventives pour réduire les risques de chute. L'intégration de l'AP dans la vie quotidienne, la promotion des activités physiques adaptées au sein de la communauté et l'harmonisation des programmes de prévention des chutes sont essentielles. Pour atteindre ces objectifs, la collaboration de divers professionnels de santé est préconisée et des outils sont mis à disposition en ligne.

Bien que les politiques de promotion de l'AP se développent, les données de la littérature ne montrent aucun consensus sur des possibles changements de comportements en faveur d'un mode vie physiquement plus actif (Sallis, Cerin, et al., 2016). Les politiques publiques sont insuffisantes, elles ne s'accompagnent généralement pas de financements suffisants et même si elles donnent une impulsion importante, le modèle écologique de l'AP montre qu'il faut impliquer d'autres acteurs. Aussi, la pandémie mondiale de COVID-19 a bouleversé nos habitudes de vie et impacté nos politiques de promotion de l'AP.

### **1.7. La survenue de la pandémie mondiale de COVID-19: un bouleversement pour les habitudes de vie**

En 2019, le COVID-19 a émergé en tant que virus d'ampleur mondiale, conduisant à une pandémie mondiale officiellement déclarée par l'OMS le 11 mars 2020. Par conséquent, pour faire face à la situation, près de la moitié de la population mondiale a été confinée soit près de 80 pays ou territoires. Pour autant, selon les pays, les modalités de confinement (partiel ou total) et la durée des confinements ont différé.

En France, un premier confinement d'une durée de 55 jours a été mis en œuvre à partir du 17 mars 2020. Pendant cette période, les écoles ont fermé et l'enseignement a été assuré à distance via des modalités en ligne. De plus, des mesures restrictives ont été mises en place lors de la première phase de confinement, avec des interdictions de déplacement qui ont été progressivement assouplies. Le déconfinement qui a suivi a été accompagné par des mesures sanitaires visant à limiter la propagation du virus, particulièrement à destination des personnes qualifiées « à risques » telles que les personnes atteintes de maladies chroniques et les personnes âgées.

Ce confinement imposé a engendré diverses conséquences, parmi lesquelles l'isolement social, (Chawla et al., 2021; Lazzari & Rabottini, 2022), des transformations dans les modalités de déplacement et l'incapacité d'entreprendre des activités de loisir en dehors du domicile. En réponse à ces contraintes, de nombreuses personnes ont eu recours à des applications afin de préserver un style de vie actif (Calderón Peralvo et al., 2022). La pandémie de COVID-19 a engendré des répercussions significatives sur les habitudes de vie, notamment en ce qui concerne les comportements de mobilité de la population. Afin de préserver un mode de vie actif, les individus ont été contraints de s'adapter à cette nouvelle réalité. Ainsi, il apparaît

important de mesurer l'impact du confinement et des restrictions sanitaires, mais également d'identifier les facteurs qui ont influencé la modification des comportements de mouvements.

### A retenir

Il a été constaté une augmentation de la prévalence l'inactivité physique et de la sédentarité avec l'avancée en âge. Cette prévalence semble se renforcer aux deux âges extrêmes de la vie, c'est-à-dire chez l'enfant pendant la période de croissance et à un âge avancé, avec des taux encore plus élevés chez les personnes ayant un niveau socio-économique bas.

Parallèlement, en 2019, l'apparition du COVID-19 a entraîné des mesures de confinement et sanitaires qui ont perturbé les habitudes de vies de la population. Les enfants ont été affectés par la fermeture des écoles et la transition vers un enseignement à distance, restreignant les mouvements. Les personnes âgées ont également été particulièrement touchées par les mesures sanitaires (confinement strict) en raison de leur vulnérabilité aux maladies.

*À la lumière de ces données, il est légitime de questionner des effets du COVID-19 sur les comportements de mouvements aux âges extrêmes de la vie et tout particulièrement sur les effets sur les capacités physiques et cognitives des enfants.*



## 2. Les effets de l'inactivité physique et de la sédentarité sur la croissance et la maturation

Les enfants et adolescents âgés de 10 à 24 ans représentent 24 % de la population mondiale (United Nations Population Fund, 2019). Aussi, en 2016, la *Commission du Lancet* et le *Global Accelerated Action for the Health of Adolescents (AA-HA!)* ont conjointement établi que le fait d'investir dans la santé des adolescents apportait trois avantages : immédiat, à l'âge adulte et pour la génération future (Patton et al., 2016; WHO, 2017a). Le Lancet a ainsi lancé la Campagne 2020 sur la santé des enfants et des adolescents dans le but de mobiliser et de motiver entre autres les dirigeants politiques, les décideurs, la société civile, les chercheurs, les cliniciens ainsi que les jeunes eux-mêmes (Lancet, 2020).

Nous avons précédemment montré que les enfants et adolescents étaient particulièrement touchés par des comportements de mouvements délétères pour leur santé. Nous allons ainsi identifier dans ce paragraphe les effets délétères spécifiques de ces comportements sur cette population vulnérable, et ainsi identifier des stratégies innovantes et prometteuses pour limiter l'inactivité physique et la sédentarité chez les enfants.

### 2.1. Effets délétères de l'inactivité physique et de la sédentarité

#### 2.1.1. *Inactivité physique, sédentarité, composition corporelle et capacités physiques*

Encourager une pratique régulière d'AP dès l'enfance favorise une bonne croissance, tout en réduisant les risques de développer des maladies chroniques à l'âge adulte. En effet, les enfants les plus actifs qui deviennent moins actifs en grandissant sont plus susceptibles de développer une obésité précoce (Kwon et al., 2015).

Des recherches ont montré que les connaissances et les comportements acquis pendant l'enfance peuvent influencer les comportements à l'âge adulte (Lynch & Smith, 2005). Les AP et les comportements sédentaires des enfants ont été particulièrement identifiés comme des facteurs déterminants non seulement de leur santé actuelle, mais aussi de leur santé et de leurs comportements à l'adolescence et à l'âge adulte (Thivel et al., 2018). Une nouvelle analyse des données issues de l'étude Européenne BetaJudo a révélé, à partir de données d'accélérométrie, que le niveau de sédentarité a un effet prédominant sur la santé cardio-

métabolique et hépatique des adolescents suivis pour un surpoids, quel que soit leur NAP (Julian et al., 2022; 2021; 2022). Des temps de sédentarité plus longs sont inversement associés à la masse grasse des enfants et adolescents (Santos et al., 2019). Une étude a cependant nuancé ces propos en identifiant une corrélation uniquement entre un temps passé devant la télévision plus élevé et un niveau d'adiposité plus élevé, mais pas pour la sédentarité globale (Kwon et al., 2022). Ces résultats confortent encore plus l'idée que « *chaque mouvement compte* » et que la pratique d'AP doit se faire tout au long de la croissance pour la prévention de certaines maladies chroniques.

Les capacités physiques sont un important marqueur de la santé (Ortega et al., 2008), alors que l'inactivité physique chez les enfants et les adolescents est associée à de faibles capacités physiques (force musculaire, endurance cardiorespiratoire, flexibilité, capacités motrices) et à une augmentation de la morbidité et de la mortalité à l'âge adulte (García Cruz et al., 2014; Katzmarzyk & Lee, 2012). Le terme de capacité physique est complexe, de nombreux termes sont employés pour définir le même concept : aptitude physique, capacité physique, qualité physique, valeur physique, condition physique ou même « physical fitness » (Ratel & Martin, 2014). La capacité physique est définie comme « *la capacité à accomplir les tâches quotidiennes avec vigueur et promptitude, sans fatigue excessive et avec suffisamment d'énergie en réserve pour jouir pleinement du temps consacré aux loisirs et pallier aux situations d'urgence rencontrées* » (President's Council on Physical Fitness and Sport, 2000). Selon Ortega *et al.* les politiques de promotion de la santé et les programmes d'AP devraient être conçus pour améliorer la forme cardiorespiratoire, la forme musculaire et la vitesse/agilité (Ortega, Ruiz, et al., 2008).

L'association « *inactivité et sédentarité* » chez les enfants induit des risques cardio-métaboliques qui s'installent à bas bruit mais très tôt dans la vie (Chastin et al., 2015; Dunstan et al., 2012; Gutin & Owens, 2011; Saunders et al., 2014; Väistö et al., 2014). De façon préoccupante, la capacité physique en endurance (ou capacité cardiorespiratoire) des collégiens a diminué de 20 % depuis les années 1980 et cette diminution persiste en France contrairement aux autres pays européens (-5,4 % entre 1980 et 2000 et -7,9 % entre 2000 et 2014) (Catley & Tomkinson, 2013; Olds et al., 2006; Tomkinson et al., 2019) (Figure 14).

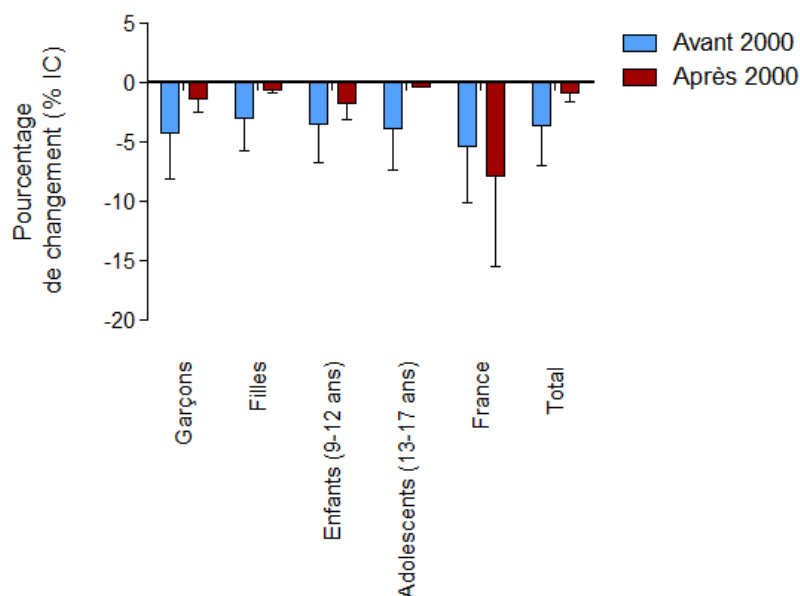


Figure 14 : Tendances temporelles nationales et internationales du pourcentage de changement de la capacité cardiorespiratoire moyenne chez les enfants âgés de 9 à 17 ans entre 1981 et 2014 (n=965 264).

Source : Figure adaptée de l'étude de Tomkinson *et al.* (2019)

La diminution de la capacité cardiorespiratoire chez les enfants et adolescents est un puissant prédicteur de risques cardiovasculaires chez les enfants indépendamment des facteurs qui peuvent influencer ces performances (niveau socio-économique des parents, âge de la mère à la naissance, niveau d'éducation des parents...). Une étude a suggéré que la pratique de 20 minutes d'AP intenses quotidiennes pourrait être le meilleur moyen de maximiser la capacité cardiorespiratoire pendant l'adolescence (Burden et al., 2022). Par ailleurs, les enfants qui ont les meilleures capacités cardio-respiratoires ont de meilleurs résultats sur les tests cognitifs, les tests de mémoire et les résultats scolaires que leurs pairs moins « *fit* » (capacités cardiorespiratoires les plus basses) (Chaddock et al., 2010; Syväoja et al., 2018; Voss et al., 2011).

### 2.1.2. Capacités cognitives, résultats scolaires et impacts de l'inactivité physique et de la sédentarité

Les résultats scolaires ne doivent pas être utilisés comme la seule mesure de la valeur ou du potentiel d'un enfant. Pour autant, ils ont un impact significatif sur la vie future des

enfants, et notamment la réussite scolaire, le statut socio-économique et l'espérance de vie (Blair & Razza, 2007; Moffitt et al., 2011; Ritchie & Bates, 2013). L'évolution des résultats scolaires est toutefois sous-tendue par le développement cognitif et général de l'élève au cours de l'enfance.

Les capacités cognitives peuvent se définir ainsi comme un « *ensemble de processus permettant à un individu de réguler de façon intentionnelle sa pensée et ses actions afin d'atteindre des buts, ceci lorsque la tâche est nouvelle ou complexe* » (Chevalier, 2010), et émergent et se développent rapidement dans la petite enfance (Anderson & Reidy, 2012). Ces capacités cognitives sont liées à l'évolution des fonctions exécutives telles que la mémoire de travail, la planification et la résolution de problèmes (Best & Miller, 2010; Diamond, 2013; Jacob & Parkinson, 2015) qui se développent avec la croissance et la maturation de l'enfant (Bolton & Hattie, 2017; Diamond, 2013), en lien avec l'évolution structurelle du cerveau et notamment du cortex préfrontal (Figure 15).

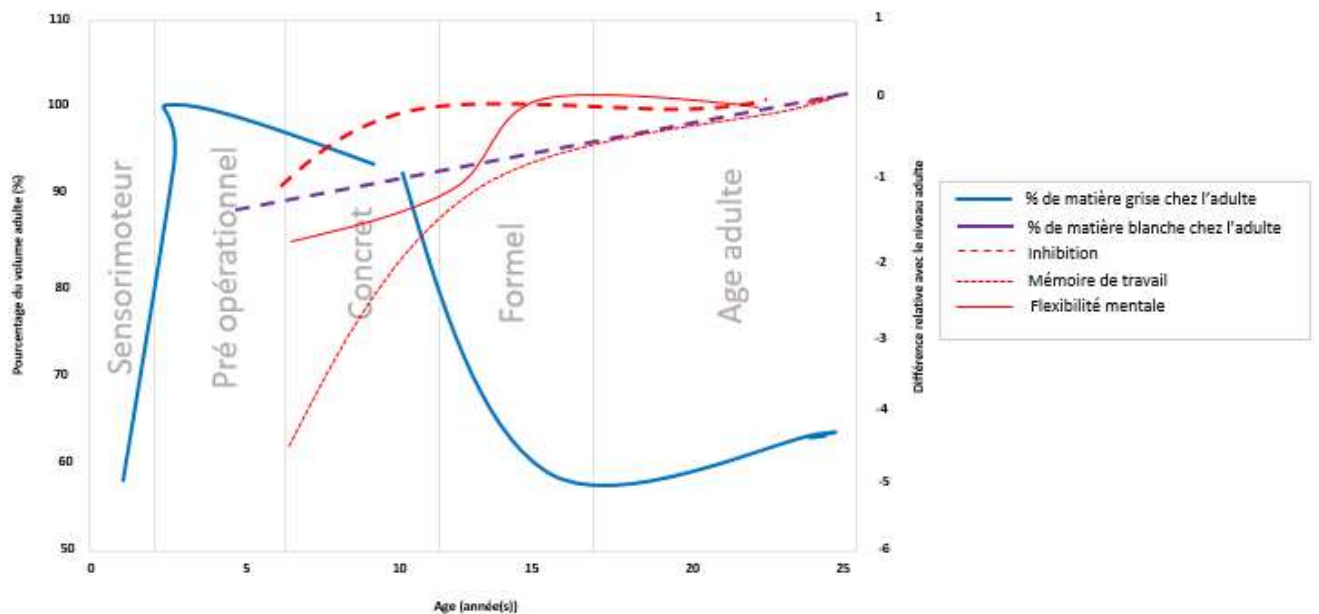


Figure 15 : Changements liés à l'âge dans les composantes de la fonction exécutive, de la matière grise du cortex préfrontal et de la matière blanche du cortex préfrontal correspondant aux stades de développement cognitif de Piaget.

Source : Figure traduite de Bolton *et al.* (2017)

Plus récemment plusieurs études ont documenté les effets bénéfiques de l'AP régulière chez l'enfant et l'adolescent sur les performances académiques et cognitives reliant fonctions cognitives, mesures objectives de l'AP et/ou capacité cardiorespiratoire et imagerie cérébrale (volume et structures cérébrales) (Chaddock-Heyman et al., 2014). L'évolution de la condition physique aérobie et musculaire est positivement associée à l'évolution des résultats scolaires au cours de l'adolescence (Sylväoja et al., 2019), modérée par les fonctions exécutives (Yanguéz et al., 2021).

A l'inverse, les études retrouvent une association entre le temps de sédentarité chez l'enfant et la diminution des performances cognitives (Sylväoja et al., 2018). L'ensemble de ces résultats confirme l'idée que les enfants en bonne santé apprennent mieux (IUHPE, 2010). Une large revue systématique incluant quarante-et-une revues systématiques et méta-analyses suggère que dans l'ensemble l'AP ne semble pas nuire aux résultats scolaires des enfants et des adolescents en âge scolaire et pourrait même leur être bénéfique (Barbosa et al., 2020), malgré des méthodologies et des qualités des études hétérogènes. Cette revue recommande notamment d'agir au niveau de l'école en soutenant les enseignants dans l'adoption d'approches et de stratégies novatrices visant à promouvoir l'AP chez les élèves.

## 2.2. Agir pour limiter l'inactivité physique et la sédentarité

### 2.2.1. *Le rôle de l'école pour favoriser l'AP et limiter la sédentarité des jeunes*

Selon l'UNICEF<sup>10</sup>, les jours de classes environ 1 milliard d'enfants dans le monde sont à l'école (Organisation mondiale de la Santé, 2022). Les enfants passent la majeure partie de leur temps éveillé à l'école (57 %) (Guinhouya et al., 2009) qui est un cadre idéal pour promouvoir la santé et induire des changements de comportements (Pinel-Jacquemin, 2016), en s'adressant à un public large comprenant les parents, les élèves et les aidants (WHO & UNESCO, 2021). De plus, le temps passé à des comportements sédentaires augmente significativement à l'entrée dans le primaire avec un effondrement parallèle de l'AP, et ceci est dû au temps contraint assis au cours de l'enseignement primaire (Janssen et al., 2016) qui représente 223 minutes par jour en moyenne (Tassitano et al., 2020) (Figure 16).

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<sup>10</sup> United Nations International Children's Emergency Fund (fonds international d'urgence pour l'enfance des Nations Unies)

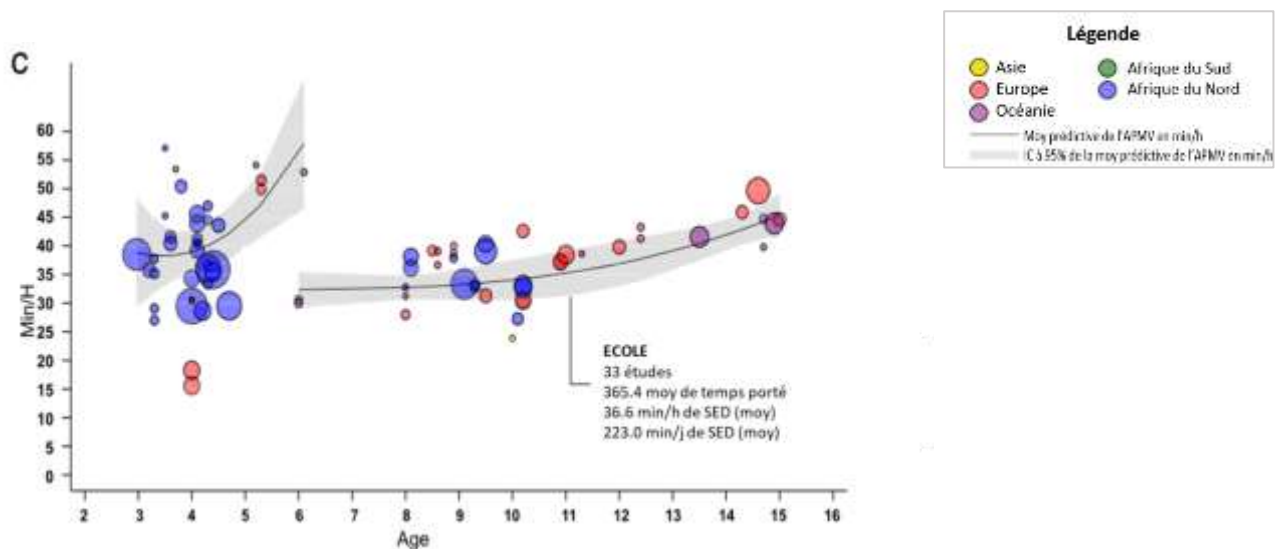


Figure 16 : Diagramme de dispersion et estimation du temps sédentaire moyen (min/heure) par âge pendant l'école chez les filles et les garçons.

SED: sédentarité; moy: moyenne; min: minutes; h: heures; j: jour.

Source : Figure traduite de Tassitano *et al.* (2020)

C'est à l'école que les enfants peuvent acquérir les connaissances, les compétences et les attitudes nécessaires pour adopter des habitudes d'AP tout au long de leur vie (WHO & UNESCO, 2021). L'OMS soutient que « *tous les enfants et les jeunes devraient être physiquement actifs avec le soutien des écoles ou des institutions publiques par le biais de jeux, de sports, de loisirs, d'éducation physique et d'activités physiques planifiées* » et souligne la mission des écoles en ce qui concerne l'AP (WHO, 2010). De plus, un enfant sur deux n'aurait pas d'autre pratique physique et sportive que celle proposée par l'école (ONAPS, 2020). Ainsi, la littérature rapporte une augmentation du nombre d'expériences visant à mettre en œuvre des interventions pour briser et réduire le temps sédentaire en classe (Ayala et al., 2018; Fedewa et al., 2017).

La promotion de l'AP à l'école fait partie intégrante du programme scolaire, l'UNESCO<sup>11</sup> estime que 97 % des pays ont une loi qui impose l'éducation physique et sportive (EPS) (WHO, 2020a), mais que seulement 23 % d'entre elles sont respectées (Deguilhem & Juanico, 2016). En France, l'AP compte d'ailleurs parmi les sept priorités des programmes d'éducation à la santé en milieu scolaire (MEN, 2016), est évaluée tout au long de l'année et compte dans l'obtention du brevet et du baccalauréat (EDUSCOL, 2017; Bulletin officiel hors-série n° 3 du 19 juin 2008, 2008). Pourtant, seulement 83,8 % des enfants de 6-10 ans et 76,6 % des 15-17 ans déclarent avoir eu un cours d'EPS la semaine précédente de l'enquête (Verdot et al., 2020).

<sup>11</sup> UNESCO : L'Organisation des Nations unies pour l'éducation, la science et la culture

En effet, trois heures hebdomadaires d'EPS sont obligatoires en primaires et deux heures au lycée. Pour autant, deux heures et quinze minutes d'EPS seraient effectivement dispensées à l'école primaire au lieu des trois heures hebdomadaires obligatoires (Deguilhem & Juanico, 2016). Malgré le renforcement de l'EPS en France via la Loi d'orientation et de programmation pour la refondation de l'École de la République en 2013, la discipline semble mise de côté par rapport aux autres enseignements, bien que les preuves légitiment la place de l'AP dans la santé des enfants (Deguilhem & Juanico, 2016).

### 2.2.2. Les différentes stratégies mises en place à l'école pour favoriser les comportements de mouvements sains

Promouvoir des programmes favorisant l'AP à l'école peut permettre de dépasser les 60 minutes d'AP quotidiennes recommandées (Tassitano et al., 2020) et impacter les habitudes des enfants avec une augmentation de la pratique d'APMV quotidienne de 12,57 minutes par jour (Amor-Barbosa et al., 2022), permettant à tous les enfants de se rapprocher des recommandations de l'OMS (WHO, 2020a). Ainsi, l'OMS identifie six domaines comme ayant des preuves fiables de l'efficacité de la promotion de l'AP à travers une approche globale dans les écoles (OMS, 2022) (Figure 17).



Figure 17 : Les six domaines concernés par l'approche englobant l'ensemble des écoles pour promouvoir l'activité physique dans les écoles.

Source : OMS. (2022)

Les recommandations internationales du Réseau de recherche sur le comportement sédentaire (SBRN) sont qu'une journée saine devrait interrompre régulièrement les périodes prolongées de comportement sédentaire et incorporer l'AP chez les jeunes (Saunders et al., 2014). Ainsi, diverses stratégies sont réalisables en milieu scolaire afin de favoriser l'AP: les *active breaks* (ou pauses actives), l'intégration d'une AP pendant les cours théoriques, la restructuration de l'environnement (comme les bureaux actifs, le design actif dans les cours de récréation) ou les cours en dehors de la classe (Amor-Barbosa et al., 2022). La réduction de la sédentarité en milieu scolaire peut être promue en réduisant le temps total quotidien passé en position assise en classe et en interrompant de manière régulière les périodes passées en position assise (Bedard et al., 2019). L'ANSES recommande ainsi de rompre régulièrement les temps de sédentarité par la promotion d'AP, même de faible intensité et de courte durée pendant le temps scolaire ou lors de période de sédentarité prolongée (Anses, 2020).

Trois méta-analyses ont montré que l'interruption du temps passé assis à l'école a des effets bénéfiques sur l'augmentation du niveau d'AP, d'APMV et sur la réduction de la sédentarité (Carrasco-Uribarren et al., 2023). Bien que les effets bénéfiques des pauses actives dans l'augmentation du temps d'AP quotidienne aient été mis en avant dans la littérature (Barr-Anderson et al., 2011; Kibbe et al., 2011), les contraintes spatiales (Dinkel et al., 2016; Goh et al., 2017) et temporelles (Howie et al., 2015; Watson et al., 2017) viennent ternir ces résultats. Dans le contexte actuel de plus en plus préoccupant de la sédentarité chez les enfants, il est primordial de trouver des solutions favorisant leur mouvement au sein de la classe, tout en préservant le bon déroulement de l'enseignement. C'est pourquoi, il nous semble essentiel d'identifier des outils qui répondraient à ces exigences spécifiques. Les bureaux actifs nous semblent répondre à ces critères en agissant à la fois sur la sédentarité et l'AP.

### 2.2.3. *Les différents bureaux actifs et leur efficacité*

Il est intéressant de noter que ces dernières années ont vu une augmentation significative du nombre d'études consacrées aux bureaux actifs dans la littérature scientifique et notamment les effets des bureaux debout chez les enfants et adolescents (Minges et al., 2016; Sherry et al., 2016), ou chez les populations spécifiques (Josaphat et al., 2019). Les effets des bureaux actifs sur la composante cognitive ont également été étudiés (Rollo et al., 2019), bien que les bureaux actifs les plus représentés soient les bureaux actifs debout.



Les bureaux actifs offrent en effet les avantages que n'ont pas les *active breaks* : ne pas interrompre la classe, pas ou peu d'aménagement de la salle de classe, et aucune préparation des enseignants. En 2016, une première revue fait état des bénéfices de l'utilisation de bureaux debout spécifiquement chez les enfants de moins de 12 ans sur la réduction du temps passé assis, une augmentation du temps passé debout et de la dépense énergétique (Minges et al., 2016). Par la suite, la revue de Hegarty *et al.* a également intégré les bureaux assis debout à son analyse et conclu que la plus grande réduction de la sédentarité a été remarquée pour les études remplaçant des bureaux traditionnels par des bureaux assis debout chez les enfants (Hegarty et al., 2016). Les études ayant utilisé des bureaux debout montrent qu'ils constituent une alternative intéressante aux bureaux assis traditionnels, car ils limitent les possibilités de s'asseoir (Clemes et al., 2016a; Koeppe et al., 2012) avec une bonne acceptabilité des enfants et enseignants (Aminian et al., 2015).

Pour autant, ces études ne s'intéressant qu'aux enfants ne prennent pas en considération leurs effets sur les performances académiques, les capacités cognitives ou les capacités physiques. De plus, les bureaux assis debout et les bureaux debout ne sont qu'une catégorie des bureaux actifs existants. Aussi, la récente revue de Guirado *et al.* a complété ces analyses en identifiant trois types de bureaux actifs: les bureaux actifs verticaux, les vélo-bureaux et les swissball (Guirado et al., 2021) (Tableau 6). Ainsi, il apparaît accessible d'obtenir des bureaux actifs en classe avec un coût allant d'une dizaine d'euros à 900 euros, et des bureaux qui peuvent être partagés par les élèves.




Type de bureau actif	Description	Tranche de prix (USD)	Image
Bureau actif debout	Correspond à un bureau debout, un bureau assis-debout ou un bureau debout incliné	150-900	
Vélo-bureaux	Vélo stationnaire avec un bureau individuel qui permet de travailler en pédalant	200-900	
Ballon de stabilité	Ballon de stabilité qui remplace une chaise traditionnelle, accompagné d'un bureau individuel	10-100	

Tableau 6 : Différentes caractéristiques des bureaux actifs et tranches de prix.

Source: Tableau adapté de Guirado *et al.* (2021)

Cette revue a mis en évidence des effets minimes voir nuls de l'utilisation de bureaux actifs chez les enfants et les adolescents sur la composition corporelle, attribuable à la faible dépense énergétique associée aux bureaux actifs. La dépense énergétique varie selon le type de bureau actif (Benden et al., 2014; Blake et al., 2012; Mehta et al., 2015; Swartz et al., 2019), le vélo-bureau étant le plus prometteur avec une augmentation de la dépense énergétique estimée à 36 % (Torbeyns et al., 2017). Concernant les capacités physiques, aucune étude n'a évalué les effets des bureaux actifs sur l'ensemble de ces composantes, se limitant aux capacités cardiorespiratoires.

En ce qui concerne les performances cognitives et académiques, les études ont montré une amélioration (Ruiter et al., 2019; Wick et al., 2018) ou l'absence de changement (Mehta et al., 2015; Sudholz et al., 2016; Torbeyns et al., 2017; Wendel et al., 2016), n'indiquant aucun effet délétère des bureaux actifs. Aucune modification n'apparaît quant à la concentration des enfants (Clemes et al., 2020; Erwin et al., 2016; Verloigne et al., 2018). Les résultats scolaires ont quant à eux été améliorés en utilisant les bureaux assis debout (Blake et al., 2012; Dornhecker et al., 2015). Aussi, les bureaux actifs ont été bien accueillis par les élèves et les enseignants, ce qui renforce leur pertinence et souligne la possibilité de les mettre en place de manière appropriée auprès des acteurs académiques et des parents.

Cette revue a également montré de nombreuses limites. En effet, parmi les 19 études incluses, seulement trois portent sur les vélo-bureaux (Fedewa et al., 2017; Ruiter et al., 2019; Torbeyns et al., 2017) et aucune nouvelle étude n'a été publiée depuis à notre connaissance, bien que cette stratégie soit prometteuse en termes d'augmentation de la dépense énergétique. De plus, ces études portaient majoritairement sur des élèves du secondaire, la seule étude portant sur les élèves de primaire n'a duré que deux semaines, limitant la généralisation de ces données. Des études complémentaires sont donc essentielles afin d'identifier les effets des vélo-bureaux sur les paramètres de santé des enfants, notamment ceux d'école primaire.

## A retenir

La prévalence élevée de l'inactivité physique et de la sédentarité chez les enfants est préoccupante, car elle est associée à des risques sur la santé qui se développent de manière insidieuse dès le plus jeune âge. L'entrée à l'école primaire revêt une importance particulière car c'est à ce moment-là que les capacités cognitives des enfants se développent en grande partie, ainsi que les habilités motrices. De nombreuses études ont démontré les bienfaits de l'AP régulière sur les performances académiques et cognitives des enfants et des adolescents, en établissant des liens avec les fonctions cognitives, les mesures objectives de l'AP et/ou les capacités cardiorespiratoires.

L'école constitue l'environnement où les enfants passent une grande partie de leur journée, et est accessible à tous les enfants quel que soit leur milieu social, bien que le temps scolaire soit majoritairement sédentaire. Toutefois, l'école offre un cadre propice pour promouvoir des comportements sains, qu'ils pourront reproduire à l'âge adulte mais aussi promouvoir dans leur famille.

*Pour relever ce défi, l'intégration de bureaux actifs peut permettre de favoriser des habitudes de mouvement saines sans compromettre l'enseignement traditionnel. Cette approche vise à encourager l'AP, diminuer les comportements sédentaires, tout en restant engagé dans les activités scolaires.*

### 3. Le vieillissement de la population : un réel enjeu de santé publique

Le vieillissement de la population est un phénomène mondial en constante augmentation, lié à l'allongement de l'espérance de vie et à la baisse de la fécondité. Cette tendance démographique est un enjeu de santé publique majeur car elle a des répercussions significatives sur de nombreux aspects de la société, notamment sur les systèmes de santé, les politiques sociales et économiques, ainsi que sur la qualité de vie des individus. Le vieillissement est souvent associé à une augmentation des maladies chroniques et des incapacités, ce qui entraîne une augmentation des coûts de santé et une demande croissante de soins. Pour faire face à ce défi, il est nécessaire de comprendre les effets du vieillissement sur la santé et de mettre en place des stratégies pour prévenir, traiter et gérer les problèmes de santé associés au vieillissement, comme peut l'être la promotion de l'AP dès le plus jeune âge, continuée à l'âge adulte et chez les seniors voire simplement commencée après la retraite ou encore plus tard. Dans cette perspective, une attention accrue doit être accordée aux effets de l'AP sur le vieillissement, ainsi qu'à la promotion d'un vieillissement en bonne santé pour améliorer la qualité de vie des individus via le dépistage des fragilités.

Dans cette perspective, l'enjeu majeur est de favoriser un vieillissement en bonne santé pour améliorer la qualité de vie des individus. Cela implique, entre autres, de dépister les fragilités et de promouvoir une AP régulière.

#### 3.1. Vieillissement, capacités fonctionnelles et fragilités

##### 3.1.1. *Vieillissement, limitations fonctionnelles et activité physique*

L'augmentation de l'espérance de vie est considérée comme l'un des plus grands succès de santé publique du 20<sup>ème</sup> siècle. En 2017, la population mondiale âgée de 60 ans ou plus était de 962 millions, et il est prévu qu'elle double d'ici à 2050 pour atteindre près de 2,1 milliards de personnes (United Nations Department of Economic and Social Affairs, Population Division, 2017). Dans les pays industrialisés, l'espérance de vie ne cesse d'augmenter ces dernières décennies. En France, l'espérance de vie d'une femme de 65 ans est de 21 ans, celle d'un homme du même âge de 16 ans (de Jaeger, 2018). En revanche, les années de vie en bonne santé ne sont que de 64,6 ans en 2020 (Eurostat, 2022).

Au fil du processus de vieillissement, il est indéniable que des conséquences significatives se manifestent notamment sous la forme de limitations d'ordre fonctionnelles et d'altérations des activités de la vie quotidienne (AVQ<sup>12</sup>) et des activités instrumentales de la vie quotidienne (AIVQ<sup>13</sup>) (Brunel & Carrère, 2018), ces limitations s'accroissant avec l'avancée en âge (Figure 18).

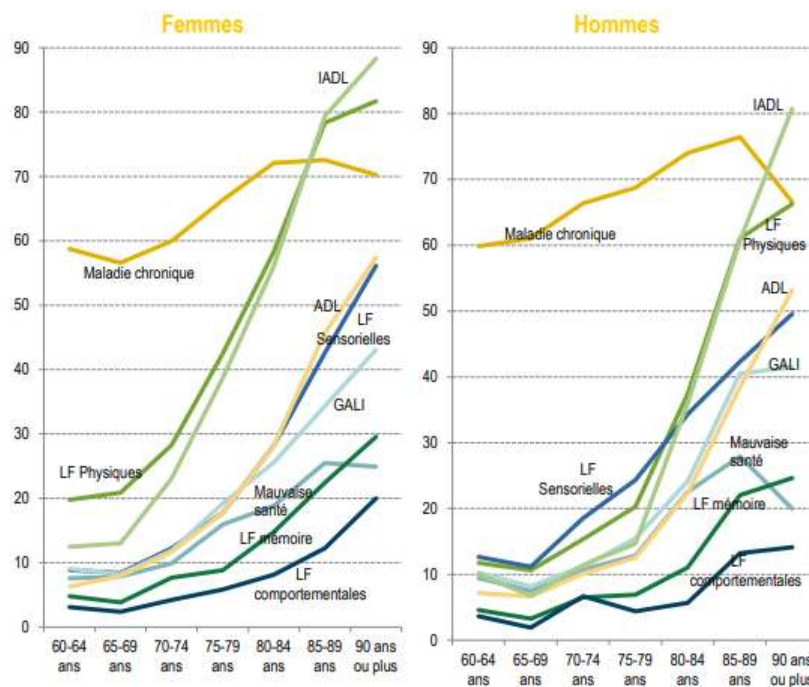


Figure 18 : Proportions associées aux diverses mesures de la dépendance et des incapacités, par tranche d'âge quinquennale pour les femmes et les hommes.

ADL : Activities of daily living, ou « activités de la vie quotidienne » ; IADL : Instrumental activities of daily living, ou « activités instrumentales de la vie quotidienne » ; GALI : Global Activity Limitation Indicator, ou « indicateur de limitations d'activité générales » ; LF : Limitations fonctionnelles.

Source : Brunel & Carrère. (2018)

Les limitations fonctionnelles peuvent induire des chutes, qui représentent l'un des facteurs de risque majeurs menant à la dépendance et à la perte d'autonomie (HCAAM, 2011). Elles constituent également la deuxième cause de décès dus à des blessures non intentionnelles et la principale cause de morbidité pour les personnes âgées (WHO, 2019b). Diverses études et méta-analyses ont estimé la prévalence de chutes à plus d'un tiers chez les personnes de 65 ans ou plus (National Institute for Health Care Excellence, 2013; Tricco et al., 2017) et 50 %

<sup>12</sup> AVQ : Comprendent se nourrir, se laver, aller aux toilettes, s'habiller, prendre soin de son apparence

<sup>13</sup> AIVQ : Comprendent notamment se préparer le repas, effectuer les tâches ménagères quotidiennes (faire la vaisselle, refaire son lit, prendre les poussières, ranger...), faire les courses, utiliser les transports en commun ou même conduire.

chez les personnes de 85 ans et plus. Les chutes survenues à un âge avancé peuvent induire des fractures, des lésions (Bergen et al., 2016; Gillespie et al., 2012; Karlsson et al., 2013; Lee et al., 2012), constituant une source importante de mortalité et morbidité (Hartholt et al., 2019; James et al., 2020). La pratique d'une AP régulière apparaît comme un moyen efficace de réduire le risque de chute (Cadore et al., 2014; Inokuchi et al., 2007), et le risque de fractures (Qu et al., 2014).

Les limitations fonctionnelles peuvent englober une variété de défis physiques et sensoriels, allant de la mobilité réduite à la perte d'autonomie dans les tâches courantes telles que se nourrir, se vêtir et se déplacer de manière indépendante. Une étude systématique a conclu que la pratique d'une APMV peut réduire d'environ 50 % le risque de limitations fonctionnelles ou d'altérations des AVQ ou AIVQ (Paterson & Warburton, 2010) (Figure 19). Dans cette étude, le NAP le plus bas était associé au plus haut niveau de limitations fonctionnelles (Paterson & Warburton, 2010), alors que le NAP le plus élevé était associé au plus faible niveau de limitations fonctionnelles, rendant crucial le maintien ou l'augmentation de l'AP et la limitation de l'inactivité physique pour préserver l'autonomie (Mlinac & Feng, 2016).

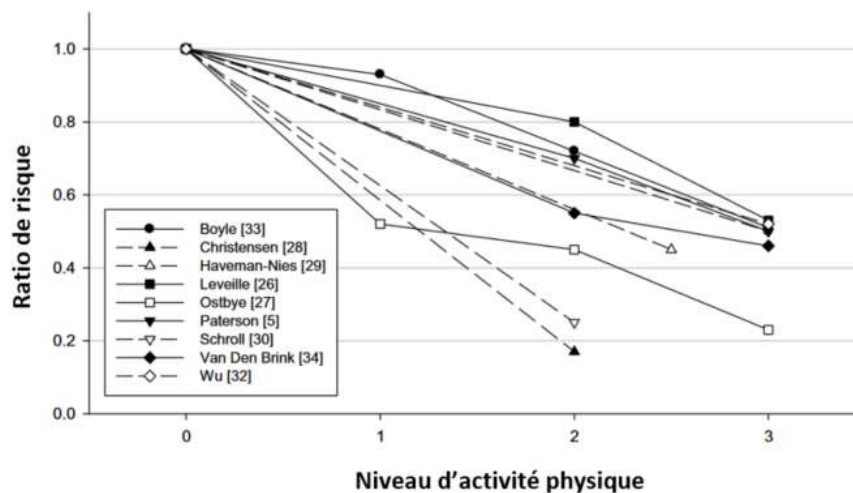


Figure 19 : Études de cohortes prospectives du risque relatif des limitations fonctionnelles ou de l'incapacité dans les AVQ et les AIVQ en relation avec le niveau d'activité physique.

AVQ : Activités de la Vie Quotidienne ; AIVQ : Activités Instrumentales de la Vie Quotidienne.

Source : Paterson & Warburton. (2010)

La littérature scientifique montre que les indicateurs individuels de fragilité physique, tels que la perte de poids, la vitesse de marche, la force de préhension, l'AP, l'équilibre et la fonction des membres inférieurs, sont des prédicteurs de l'incapacité future dans les AVQ chez les

personnes âgées vivant dans la communauté (Vermeulen et al., 2011). En effet, les résultats de la méta-analyse de Ramsey *et al.* basés sur des données objectives ont montré que les niveaux d'AP et de sédentarité étaient le plus souvent corrélés à la force et à la puissance musculaires des membres inférieurs (Ramsey et al., 2021). La puissance et la force musculaires sont essentielles pour la mobilité de l'Homme, et notamment la puissance musculaire des membres inférieurs afin de se mouvoir et de réaliser les AVQ (Foldvari et al., 2000; Wang et al., 2020), et donc maintenir l'autonomie (Luppa et al., 2010; Mlinac & Feng, 2016). Plus précisément, un niveau moyen à élevé d'APMV réduit le risque de limitation des AVQ de 49 % (Tak et al., 2013).

Une abondance de preuves atteste désormais que limiter l'inactivité physique et la sédentarité permet de réduire substantiellement les risques de limitations chez les personnes âgées (Cunningham et al., 2020). De plus, les personnes modérément sédentaires (2 à 4 heures par jour) et les moins sédentaires (< 2 heures par jour) ont 38 % et 43 % plus de probabilités d'avoir un vieillissement réussi par rapport à celles sédentaires plus de 4 heures par jour (Dogra & Stathokostas, 2012). Ainsi, nous pourrions questionner plus précisément des effets de l'AP et de la sédentarité sur la fragilité des séniors.

### 3.1.2. *Vieillesse et fragilité*

Plusieurs manifestations pathologiques peuvent émerger de manière spécifique à mesure de l'avancée en l'âge, engendrant diverses contraintes dans les AVQ, des limitations fonctionnelles, une détérioration des fonctions cardiorespiratoires, ostéomusculaires et neurosensorielles cognitives, des risques accrus de chutes et de fractures et engendrant une augmentation du nombre d'affections chroniques (Delamarche & Carré, 2021; Garin et al., 2014; Marengoni et al., 2011). Outre les limitations fonctionnelles évidentes, les syndromes gériatriques comprennent la fragilité, l'incontinence urinaire, les chutes, l'état confusionnel et les escarres (Fernández-Garrido et al., 2014; Inouye et al., 2007). Ces syndromes semblent être de meilleurs prédicteurs de survie que la présence ou le nombre de maladies spécifiques (Kane et al., 2012; Lordos et al., 2008).

En raison de facteurs génétiques et environnementaux, le vieillissement affecte les individus de manière hétérogène, ce qui permet de distinguer trois types d'évolution : le vieillissement réussi (ou robuste) caractérisé par l'absence ou une atteinte minimale des fonctions physiologiques, sans pathologie définie ; le vieillissement « *fragile* » caractérisé par des

atteintes physiologiques infra cliniques et une diminution des réserves physiologiques ; et le vieillissement « *pathologique* » caractérisé par des maladies chroniques, des troubles cognitifs et des handicaps fonctionnels qui limitent l'autonomie (Rowe & Kahn, 1987). La fragilité se réfère à l'état de transition entre le vieillissement en bonne santé et la dépendance (Figure 20).

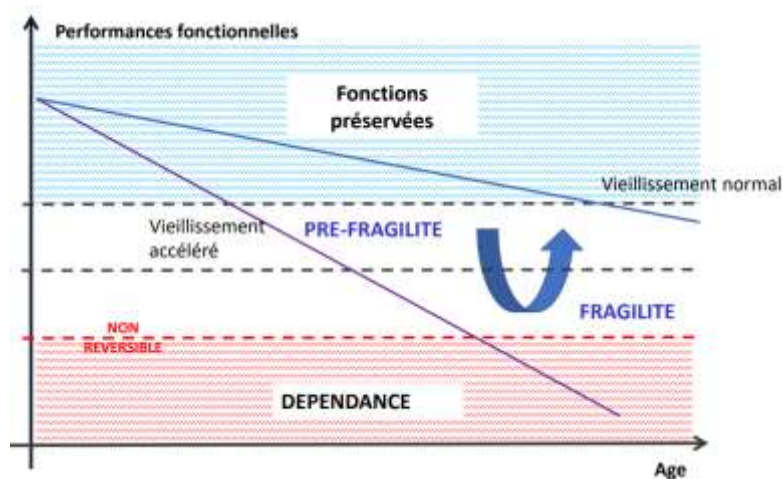


Figure 20 : Evolution vers la dépendance et concept de fragilité chez la personne avançant en âge.

Source : Gérontopole de Toulouse.

Ce schéma offre une illustration parfaite de l'inadmissibilité de la catégorisation des individus âgés selon leur âge chronologique, en raison de la grande hétérogénéité interindividuelle observée tout au long du processus de vieillissement. Cette diversité se reflète notamment dans la qualité de vie perçue, qui tend à s'améliorer avec l'avancée en âge selon certaines études (Blanchflower & Oswald, 2008; Steptoe et al., 2015), tandis que d'autres rapportent une diminution (Kowal et al., 2012). Cette disparité peut s'expliquer par la variation des capacités intrinsèques chez les individus âgés, définie comme la « *combinaison de toutes les capacités physiques et mentales d'un individu* » (Weltgesundheitsorganisation, 2015), qui devient plus significative que dans les groupes plus jeunes (Baltes & Baltes, 1990; Rowe & Kahn, 1987). Une approche intégrée du dépistage de la fragilité, de l'évaluation et de la prise en charge est donc nécessaire pour prévenir la dépendance aux soins.

La fragilité est un concept multidimensionnel et complexe dont la définition demeure sujette à débat. En effet, les diverses définitions de la fragilité dépendent des fondements théoriques et des mesures opérationnelles associées à l'instrument utilisé (Rasiah et al., 2022). Aucune



définition universelle n'a été proposée pour définir la fragilité. Le syndrome de fragilité a été défini comme « *un marqueur de risque de mortalité et d'événements péjoratifs, notamment d'incapacités, de chutes, d'hospitalisation et d'entrée en institution* » (Rolland et al., 2011). La fragilité peut être définie comme la « *régression progressive des systèmes physiologiques liée à l'âge, qui entraîne une diminution des réserves de capacités intrinsèques, ce qui confère une extrême vulnérabilité aux facteurs de stress et augmente le risque d'une série d'effets négatifs sur la santé* » (Cesari et al., 2016).

La fragilité est un concept multidimensionnel qui influence plusieurs domaines, tels que la mobilité, l'équilibre, la force musculaire, le traitement moteur, la cognition, la nutrition, l'endurance et l'AP (Gobbens et al., 2010). Aussi, la fragilité est directement liée à des conséquences négatives, telles que les chutes, l'invalidité, le besoin de soins de longue durée, l'hospitalisation, la vulnérabilité et même la mortalité (Fried et al., 2001; Fried et al., 2004; Morley et al., 2013; Rockwood et al., 2005).

### 3.1.3. *Sédentarité, activité physique et fragilité*

Plusieurs facteurs semblent influencer la fragilité : l'âge, le sexe et un faible niveau socio-économique (Fried et al., 2001; Newman et al., 2001; Shlipak et al., 2004). Les interventions proposant de l'AP ont montré leur efficacité, et notamment la pratique d'une APMV dans les cas de fragilités importantes (Cesari et al., 2015; Pahor et al., 2014). Le remplacement d'une heure de temps sédentaire par une heure d'APMV ou une heure d'AP de faible intensité chaque jour peut réduire le risque de mortalité, avec de plus grands bénéfices chez les personnes les plus fragiles (Godin et al., 2020) (Figure 21). En effet, selon les auteurs, afin de réduire le risque de mortalité de 50 %, les personnes vulnérables devraient remplacer 38 minutes de temps sédentaire par de l'APMV, contre 18 minutes d'APMV pour les personnes légèrement fragiles (Godin et al., 2020). Se pose néanmoins la question de la faisabilité de la pratique en autonomie d'une telle AP (nécessité d'un accompagnement par un professionnel de l'AP adaptée).

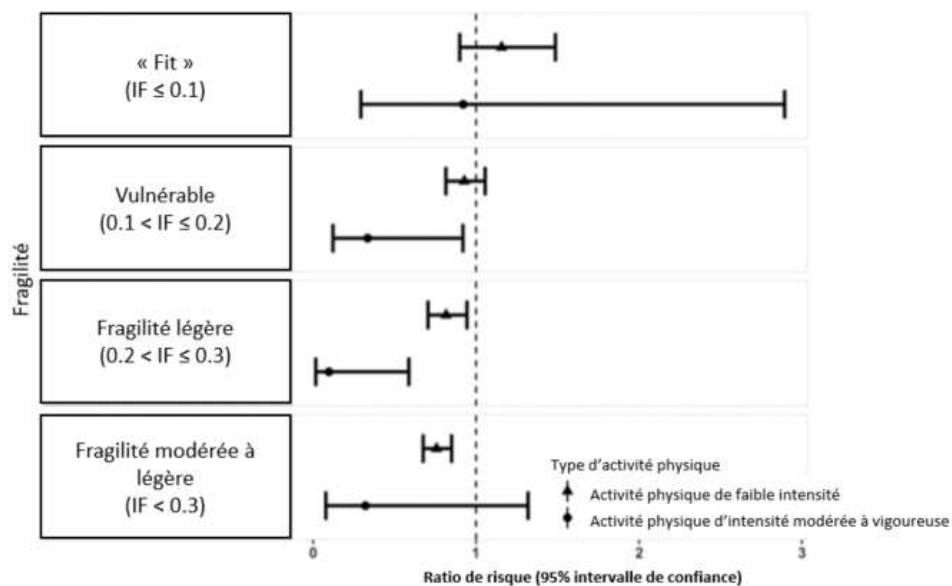


Figure 21 : Ratios de risque issus des régressions de Cox prédisant la mortalité à partir du remplacement du temps sédentaire par une activité physique de faible intensité et une activité physique modérée à vigoureuse.

IF = indice de fragilité.

Source : Figure traduite de Godin *et al.* (2019)

Il apparaît ainsi que l'augmentation du NAP pourrait jouer un rôle crucial dans la réduction des risques de mortalité liés à la fragilité. En plus de contribuer à la réduction des risques associés à la fragilité, la pratique régulière d'une AP et la réduction des temps sédentaires ont des effets bénéfiques sur la prévalence de la fragilité elle-même (Chen *et al.*, 2020; Tolley *et al.*, 2021) (Figure 22). Ces résultats, qui se basent sur des données d'accélérométrie, suggèrent une corrélation entre une pratique d'AP à une intensité plus élevée et un risque réduit de développer la fragilité, ce qui concorde avec les conclusions de revue analysant des données autodéclarées (Kehler *et al.*, 2018; Zhao *et al.*, 2022). Une étude semble montrer que l'AP de faible intensité et l'APMV présentent des effets bénéfiques similaires sur la réduction de la prévalence de la fragilité avec l'outil basé sur l'accumulation des déficits de santé (García-Esquinas *et al.*, 2021) (voir section 3.2.1.).

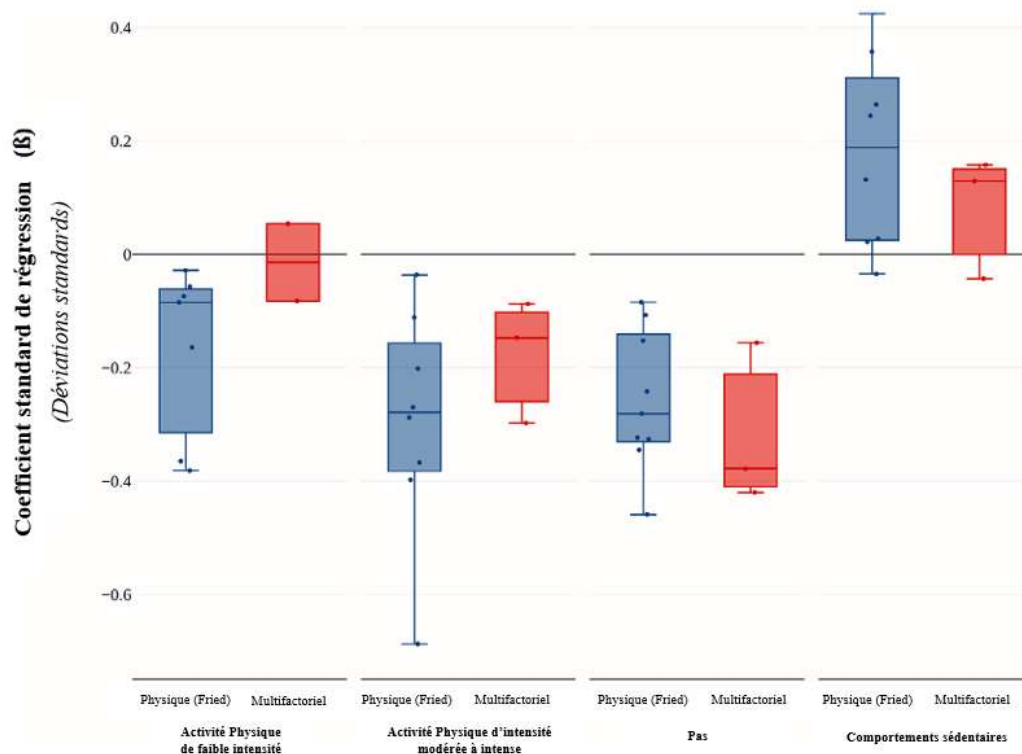


Figure 22 : Diagrammes en boîte des coefficients de régression standardisés des associations entre l'activité physique de faible intensité, l'APMV, les pas et la sédentarité et la fragilité.

APMV : activité physique d'intensité modérée à vigoureuse (APMV).

Source : Figure traduite de Tolley *et al.* (2021)

En ce qui concerne les effets de l'AP de faible intensité sur le niveau de fragilité, les résultats diffèrent selon l'outil de mesure de la fragilité utilisé (Tolley et al., 2021), ce qui pourrait s'expliquer en partie par le nombre limité d'études prenant en compte ce NAP, par rapport à l'APMV ou à la sédentarité. Une autre justification de ces divergences réside dans l'outil de mesure.

La revue de Tolley *et al.* soulève également des interrogations quant à la cohérence des données suggérant une association entre la sédentarité et la fragilité (Tolley et al., 2021). Ces résultats contredisent les conclusions d'autres études qui indiquent que la sédentarité (autodéclarée) a un effet préjudiciable sur la fragilité dans 80 % des articles inclus dans une revue (D. Scott Kehler et al., 2018), et qu'une association directe est observée dans deux cohortes européennes (García-Esquinas et al., 2017).

## 3.2. La fragilité : un concept robuste mais une méthode d'évaluation non consensuelle

### 3.2.1. *L'hétérogénéité des outils et du vieillissement*

Plusieurs modèles cliniques ont été développés pour identifier le syndrome de fragilité, chacun étant associé à différents outils de mesures (Buta et al., 2016; Faller et al., 2019). L'approche phénotypique de Fried (Fried et al., 2001) basée sur cinq critères de dépistage (épuisement, perte de poids, faible dépense énergétique, lenteur de marche et perte de force) est l'outil le plus largement utilisé. Un autre modèle fréquemment utilisé en pratique clinique est l'accumulation des déficits (Mitnitski et al., 2001) défini selon 70 critères. A l'échelle mondiale, selon le modèle phénotypique de Fried (Fried et al., 2001), la prévalence de la fragilité est estimée entre 4,9 % et 27,3 % (Choi et al., 2015; Collard et al., 2012; O'Caomh et al., 2021), tandis qu'avec le modèle d'accumulation des déficits, elle est estimée entre 13,6 % et 24 % (Collard et al., 2012; O'Caomh et al., 2021). L'étude SHARE<sup>14</sup> estime la prévalence de la fragilité à 7,7 % en Europe selon le modèle de Fried, et 9,1 % en France (Manfredi et al., 2019).

Une revue systématique confirme que la fragilité augmente avec l'âge, et ce quel que soit le pays : avec une prévalence estimée à 4,1 % chez les 50-64 ans, 17 % chez les plus de 65 ans, 15,7 % chez les 80-84 ans (Collard et al., 2012), et 26,1 % pour les personnes de 85 ans et plus (Collard et al., 2012). La prévalence de la fragilité est plus élevée chez les femmes (O'Caomh et al., 2021). Dans notre contexte, rares sont les études menées dans des territoires similaires qui ont abordé l'influence du milieu de vie sur le niveau de fragilité des personnes âgées, en différenciant les milieux rural et urbain (Xu et al., 2021). Néanmoins, les résultats disponibles suggèrent une tendance à observer un niveau de fragilité plus élevé parmi les personnes âgées résidant en milieu rural (Song et al., 2007).

### 3.2.2. *Le vieillissement en bonne santé et la démarche ICOPE*

En vieillissant, les capacités intrinsèques comprenant les capacités cognitives, les capacités locomotrices, la vitalité, les capacités visuelles, les capacités auditives et les capacités psychologiques (Beard et al., 2019) varient. Cette variabilité entre les individus âgés devient plus importante que dans les groupes plus jeunes (Baltes & Baltes, 1990; Rowe & Kahn,

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<sup>14</sup> SHARE: Survey of Health, Aging and Retirement in Europe

1987). Une approche intégrée du dépistage, de l'évaluation et de la prise en charge est donc nécessaire pour prévenir la dépendance aux soins. En 2015, l'OMS a publié un rapport mondial sur le vieillissement et la santé et définit le vieillissement en bonne santé comme « *le processus de développement et de maintien de la capacité fonctionnelle qui permet le bien-être des personnes âgées* » (WHO, 2015b) (Figure 23). Selon cette définition, ce terme est basé sur des perspectives fonctionnelles et de parcours de vie qui tend à favoriser la qualité de vie et à réduire le niveau de fragilité des séniors (Weltgesundheitsorganisation, 2015; WHO, 2017b, p. 4). C'est pour promouvoir le vieillissement en bonne santé qu'en 2020 l'OMS déclare « *la décennie 2020-2030 pour le vieillissement en bonne santé* » qui a pour objectifs de développer et de maintenir les capacités fonctionnelles des séniors afin de favoriser leur bien-être (WHO, 2020b).

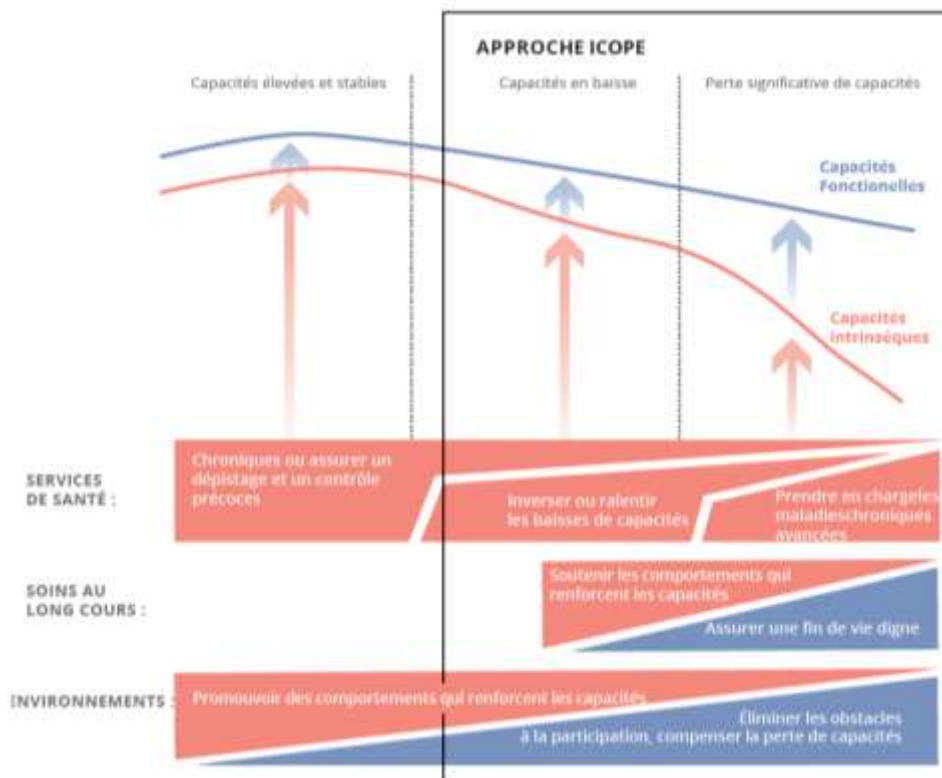


Figure 23 : Un cadre de santé publique pour un vieillissement en bonne santé : possibilités d'action en matière de santé publique à toutes les étapes de la vie.

Source : OMS. (2015)

Cette vision holistique du vieillissement en bonne santé prend en compte le fait que la fragilité varie d'un individu à l'autre et qu'une évaluation gériatrique complète est essentielle pour comprendre les altérations complexes impliquées dans la fragilité.

Le cadre de l'OMS sur les services de santé intégrés et centrés sur la personne a fourni une feuille de route pour l'intégration des soins tout au long de la vie en optimisant la manière dont les services sont conçus, financés, gérés et fournis (WHO, 2015a). Pour identifier les personnes à risque de dépendance aux soins, l'OMS a introduit les lignes directrices sur les soins intégrés aux personnes âgées nommées Integrated Care of Older People (ICOPE) (WHO, 2017c). Brièvement, l'ICOPE se compose de 5 étapes : 1) un dépistage, 2) une évaluation centrée sur la personne dans le cadre des soins primaires, 3) l'élaboration d'un plan de soins personnalisé, 4) l'assurance d'une filière d'orientation et le suivi du plan de soins 5) l'engagement des communautés et le soutien aux aidants (Figure 24). L'étape 1 consiste en un dépistage individuel basé sur les capacités intrinsèques. Selon ICOPE, ce dépistage doit être complété par les syndromes gériatriques du territoire.

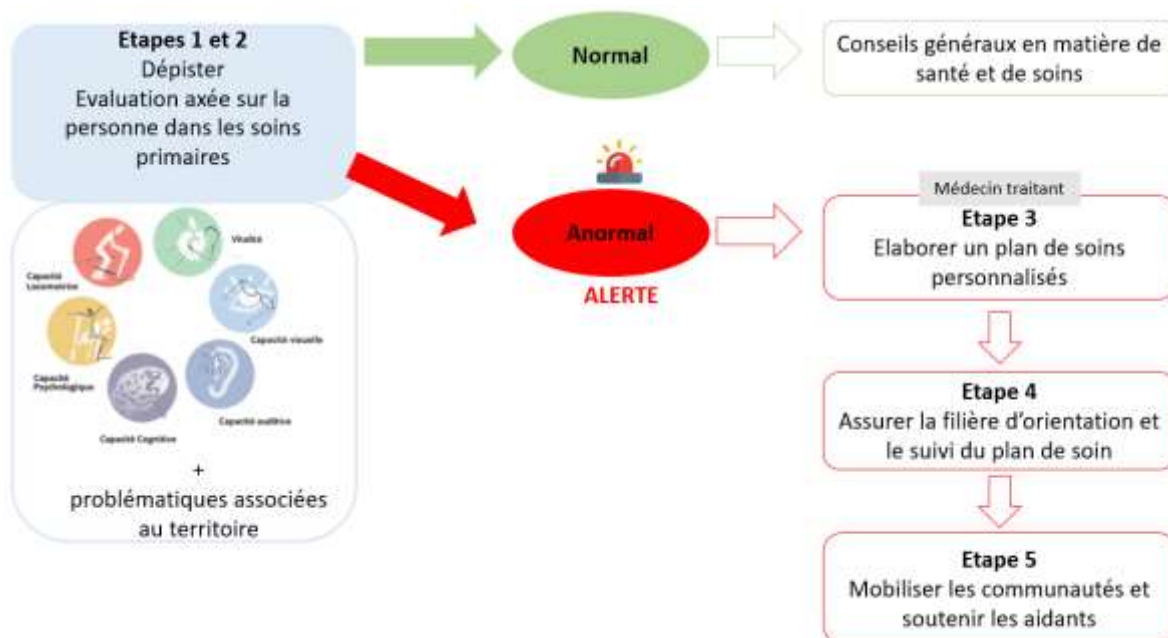


Figure 24 : Différentes étapes de la démarche ICOPE.

Source : Figure adaptée de l'OMS. (2019)

Une revue narrative a analysé l'ensemble des études mettant en œuvre la démarche ICOPE (Sum et al., 2022). Au total 18 études ont été incluses dont 4 en phase de développement, 7 études de faisabilité et 7 de mise en œuvre. Sur ce dernier point, les études de dépistage des fragilités présentent une diversité considérable, ce qui rend complexe la comparaison. En effet, la revue a montré que seulement trois des sept études évaluant la faisabilité ont suivi le

modèle ICOPE tel que proposé, mettant en avant la difficulté d'harmonisation de l'outil de dépistage des capacités intrinsèques, en raison des différences culturelles et contextuelles entre les sites d'étude dans le monde entier. Ces études ont mis en avant l'impossibilité de réaliser l'auto-dépistage via une tablette ou un mobile, des lacunes concernant les connaissances ou l'intérêt envers les personnes âgées et le manque de financement (Mathur et al., 2022; WHO, 2016b). Les outils d'évaluation de la fragilité étaient particulièrement hétérogènes concernant les domaines de la vitalité et de la psychologie.

Malgré une grande hétérogénéité d'outils et de publics cibles, cette revue a mis en avant de nombreux points. Tout d'abord, certaines études se concentrent sur des étapes spécifiques d'ICOPE, tandis que d'autres couvrent l'ensemble du processus. Peut-être s'agirait-il de s'adapter aux structures existantes en proposant seulement l'étape 1 axée sur le dépistage des fragilités si le système de santé est efficace (Figure 24). Si des lacunes sont identifiées, l'étape 2 consistant en l'évaluation axée sur la personne dans les soins primaires est préconisée. Dans un second temps, les outils de dépistage utilisés ne sont pas toujours les mêmes que ceux proposés dans le manuel ICOPE, mais une homogénéisation semble complexe aux vues des différences culturelles et contextuelles entre les sites d'études. Pour ce qui est des ressources à mobiliser, il est important d'identifier des stratégies prenant en compte les défis liés au personnel, notamment les contraintes de temps et de main-d'œuvre, le manque de connaissances et de compétences nécessaires, ainsi que les incitations financières limitées pour les professionnels de la santé et les autres intervenants. Il semblerait donc que le modèle ICOPE soit un outil d'appui de l'évaluation de la fragilité des seniors, et qu'il demande à être adapté au contexte dans lequel il se déroule.

## A retenir

Le processus de vieillissement engendre une altération des capacités fonctionnelles qui varie d'une personne à l'autre, rendant l'évaluation basée sur l'âge insuffisante. C'est dans ce contexte qu'émerge l'importance de la prise en compte de la fragilité en tant qu'indicateur individuel du risque de mortalité et de dépendance. Bien que les études s'accordent à dire que la fragilité croît avec l'âge et qu'elle est plus fréquente chez les femmes, aucune étude n'a questionné l'impact du milieu de vie (rural/urbain) sur le niveau de fragilité des personnes âgées. De plus, la littérature propose divers outils pour détecter la fragilité, mais ceux-ci présentent des limites et rendent les résultats difficilement comparables.

L'Organisation mondiale de la santé a publié le rapport mondial sur le vieillissement et la santé en 2015, suivi de la « *décennie du vieillissement en bonne santé 2020-2030* », pour promouvoir les capacités fonctionnelles et le bien-être des personnes âgées. Récemment développé, l'outil ICOPE vise à évaluer le niveau de fragilité en réalisant un dépistage des capacités intrinsèques et des besoins gériatriques spécifiques aux territoires. Il offre ainsi la possibilité d'élaborer un plan de soins personnalisé si nécessaire.

*À la vue de l'ensemble de ces données, il est important d'évaluer la prévalence des fragilités en Auvergne dans un milieu rural et un milieu semi-urbain via la démarche ICOPE.*



#### 4. Conclusion générale de la revue de littérature

Dans la première section de ce manuscrit de thèse, la revue de littérature a mis en exergue l'augmentation préoccupante de la prévalence de l'inactivité physique et de la sédentarité aux âges extrêmes de la vie. La revue a souligné les effets délétères de l'inactivité physique et de la sédentarité sur la santé globale, physique et psychique et les risques de mortalité prématurée, ce qui est un vrai signal d'alarme. En plus des implications pour la santé, les coûts financiers croissants liés à ces comportements sont rappelés car ils ne pourront être couverts par l'assurance maladie de façon pérenne. Par ailleurs, l'impact du COVID-19 sur les comportements de mouvements, en particulier chez les enfants qui ont suivi l'enseignement à distance, ainsi que les personnes âgées, considérées comme vulnérables au virus, est souligné. C'est un modèle quasi expérimental de diminution des comportements de mouvements, dont nous ressentons encore les conséquences. Les enjeux de la promotion de l'AP et de la diminution des comportements sédentaires sont donc considérables, et le signal d'alarme doit être tiré. C'est la raison pour laquelle ce travail de thèse a été entrepris afin tout d'abord d'alarmer les autorités sur les effets collatéraux du COVID-19. Aussi, il s'agissait d'identifier des stratégies et des méthodes pour limiter l'inactivité physique et la sédentarité, notamment pour les populations vulnérables que sont les enfants et les personnes âgées.

# **PARTIE II -CONTRIBUTION PERSONNELLE**

## OBJECTIFS DE LA THESE

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La première partie de la revue de littérature a mis en exergue l'importance de la prévalence de l'inactivité physique et de la sédentarité, tant en France que dans le monde, en particulier aux âges extrêmes de la vie. Les conséquences de l'inactivité physique et de la sédentarité sur la santé ont été largement mis en évidence. Par ailleurs, cette thèse a été impactée par la pandémie mondiale de COVID-19, dont nous avons saisi l'opportunité pour examiner, dans le cadre d'un objectif initial, les conséquences sur les comportements de mouvements ainsi que sur les incidences en termes de santé. Dans un second objectif, cette thèse a pour but d'identifier des stratégies innovantes pour contrer les comportements de mouvements délétères chez les populations vulnérables, notamment les enfants et les personnes âgées, exposées de manière accrue aux risques associés au manque d'AP et à la sédentarité.

Un premier axe « **Effets du COVID-19 sur les comportements de mouvements aux âges extrêmes de la vie** » est ainsi tout d'abord développé dans ce manuscrit. Cet axe est composé de deux études :

- Etude 1 : Effet du 1<sup>er</sup> confinement sur le niveau d'activité physique et de sédentarité des enfants et adolescents
- Etude 2 : Effet du 1<sup>er</sup> confinement sur le niveau d'activité et de sédentarité des seniors

Un second axe « **Effets de l'utilisation d'une stratégie active sur des paramètres de santé des élèves de primaire** » est ensuite développé. Cet axe est composé de deux études :

- Etude 3 : Effets du COVID-19 et des restrictions sanitaires associées sur les capacités physiques et cognitives des enfants de primaire.
- Etude 4 : Effets des vélo-bureaux sur les capacités physiques et cognitives des élèves de primaires : analyse du niveau socio-économique.

Enfin, un troisième et dernier axe « **Evaluation et détection des fragilités des séniors en milieu rural et semi-urbain** » est développé. Il s'articulera autour d'une étude :

- Etude 5 : Dépistage des fragilités en milieu rural et semi-urbain via la démarche ICOPE : analyses

## METHODOLOGIE

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Les études expérimentales de ces travaux de thèse se sont déroulées en plein cœur de la pandémie de COVID-19, impactant de ce fait la réalisation de la thèse. En effet, cette thèse débutée en octobre 2020 devait initialement se composer exclusivement de l'étude FRAGING s'intéressant au dépistage et au suivi des fragilités des séniors. Pour autant, les confinements successifs ont compromis notre étude BICLASS qui devait initialement débiter en 2020 lors de mon master 2. Ainsi, nous avons dû reporter cette étude en 2021, lorsque les conditions sanitaires nous l'ont permis, en parallèle de l'étude FRAGING.

Les méthodologies qui vont être décrites dans cette partie sont issues des études portant sur i) les impacts du COVID-19 sur les niveaux d'AP et de sédentarité aux âges extrêmes de la vie (Chambonnière et al., 2021a, 2021b) ; ii) l'étude BICLASS portant sur l'impact du COVID-19 sur certains paramètres de santé chez les enfants de primaire (Chambonnière et al., 2021c) et sur les effets de l'utilisation de vélo-bureaux sur des paramètres de santé chez les enfants d'école primaire, avec une analyse de l'impact du niveau socio-économique (Chambonnière et al., 2023); iii) l'étude FRAGING évaluant la prévalence de la fragilité ainsi que le niveau d'AP et de sédentarité chez les séniors en milieu rural et en milieu semi-urbain (**soumis**).

## Axe I : Impact du COVID-19 sur les comportements de mouvements

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- Plan général des études mesurant l'impact du COVID-19 sur les comportements de mouvements

L'évaluation des effets des confinements sur le NAP et le temps de sédentarité chez les enfants (**Publication N°1**) et chez les seniors (**Publication N°2**) sont issues d'une enquête nationale dont la méthodologie a été décrite dans un article dédié (Genin et al., 2021). Un groupe d'experts réuni collectivement par l'Observatoire National de l'Activité Physique et de la Sédentarité (ONAPS) et le ministère français des Sports a déterminé des indicateurs clés pour identifier, comprendre et estimer les effets potentiels du confinement lié au COVID-19 sur l'AP et les comportements sédentaires de la population (Figure 25). Toutes les catégories d'âge ont été ciblées par le questionnaire. L'étude a été approuvée par le Comité de Protection des Personnes (CPP Sud est VI. référence 2020/CE 27).

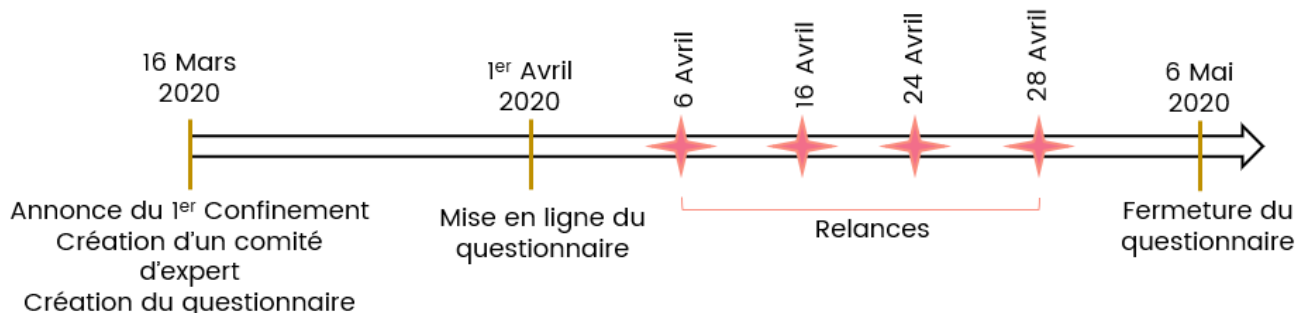


Figure 25 : Schéma des publications N°1 et N°2

- Protocole expérimental des études mesurant l'impact du COVID-19 sur les comportements de mouvements

En raison de la nature exceptionnelle de la conduite de ces études, les questionnaires et leurs méthodologies ont été adaptés et se sont inspirés de questionnaires existants : l'IPAQ (Craig et al., 2003), l'ONAPS-Q (adultes) (Charles et al., 2021) et le Youth Risk Behavior Surveillance System (Guedes & Lopes, 2010). Les participants étaient considérés comme initialement inactifs s'ils ne respectaient pas les recommandations d'AP (en fonction de leur âge) avant

le confinement. En ce qui concerne le temps sédentaire, les seuils de recommandations (<2 heures par jour de temps d'écran) ont été utilisés.

Les questionnaires ont été lancés pour la première fois au cours du premier confinement, le 1er avril 2020, soit quinze jours après l'annonce du premier confinement. Leur promotion a été facilitée par les médias sociaux et les réseaux (Facebook, LinkedIn par exemple) et d'autres réseaux. Plusieurs types de médias en ligne ont été utilisés pour diffuser l'enquête, ciblant différents types de réseaux et zones professionnels, associatifs, démographiques et géographiques. Les participants ont été invités à remplir l'enquête en ligne en utilisant le site web de l'ONAPS (<http://www.onaps.fr/>). Des relances ont été effectuées régulièrement jusqu'au 6 mai 2020, une semaine avant la fin du confinement.

## Axe II : Effets de l'utilisation d'une stratégie active sur des paramètres de santé des élèves de primaires

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- Plan général de l'étude évaluant les effets de l'utilisation d'une stratégie active à l'école

Une première phase de cette étude consistait à évaluer l'impact du confinement lié au COVID-19 sur les paramètres de santé des enfants (**Publication N°3**). Dans un second temps, nous nous sommes attachés à évaluer les effets de l'utilisation de bureau actif sur le temps scolaire à l'école primaire sur les mêmes paramètres de santé (**Publication N°4**). Le recrutement des participants a été réalisé au sein d'un établissement scolaire, dont les enseignants se sont portés volontaires. Pour être inclus, les enfants devaient être âgés de 8 à 11 ans. L'étude BICLASS a été approuvée par le Comité de Protection des Personnes (CPP Sud est VI) et a été enregistré sur ClinicalTrials.gov (NCT04880759).

- Protocole expérimental de la phase I mesurant l'impact du COVID-19 sur certains paramètres de santé chez les enfants de primaire

Les évaluations de références (T0) ont été réalisées en février 2020, avant le confinement, et la même batterie de tests a été conduite chez la même classe d'âge en janvier 2021, soit un an après (T1). L'ensemble des évaluations se sont déroulées dans l'établissement scolaire durant la même semaine (Figure 26). Pour chaque temps de mesure, les évaluations ont été organisées en deux sessions : une composée du test cognitif et du test de préférence en termes d'AP ; l'autre de l'évaluation de la composition corporelle et des capacités physiques.



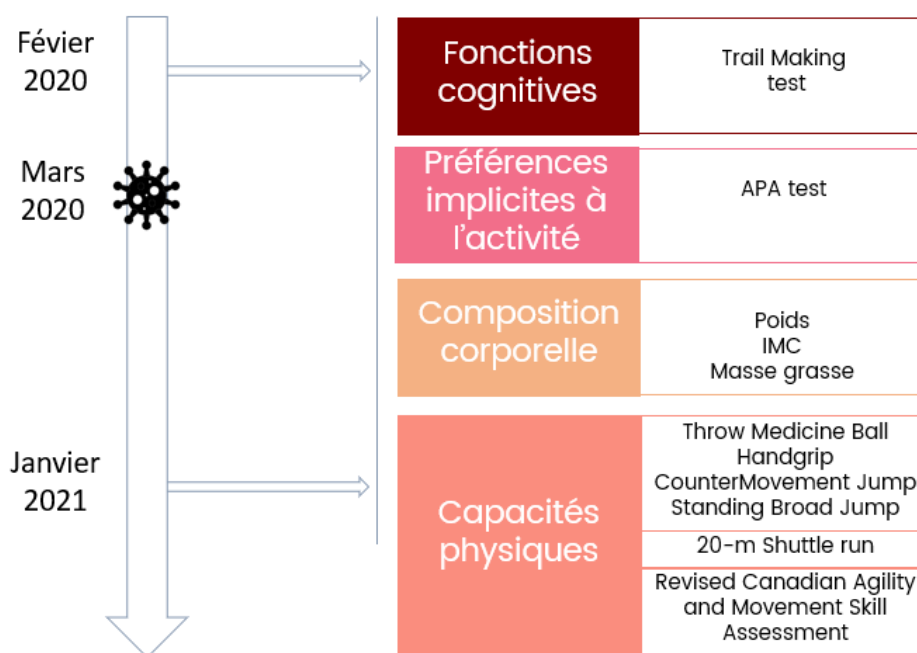


Figure 26 : Schéma de la publication N°3 mesurant l'impact du COVID-19 sur certains paramètres de santé chez les enfants de primaire

IMC : Indice de Masse Corporelle

- Protocole expérimental la phase 2 mesurant les effets de l'utilisation de vélo-bureaux sur des paramètres de santé chez les enfants d'école primaire

Pour cette deuxième phase de l'étude BICLASS, les enfants ont été répartis en deux groupes: niveau socio-économique élevé et niveau socio-économique faible. Pour être inclus, les enfants devaient également être capables d'utiliser un vélo-bureau (taille >1.30m).

Les enfants ont participé à deux sessions d'évaluations au sein de leur établissement scolaire : en amont (T0), et après neuf semaines d'utilisation des vélo-bureaux (T1) à raison de 3 à 4 fois 30 minutes dans la semaine pendant les temps de classe (Figure 27). Les évaluations ont été réparties en deux parties pour chaque session (T0, T1) : une composée du test cognitif, l'autre de l'évaluation de la composition corporelle et des capacités physiques. Les questionnaires de bien-être et de climat de classe font également partie des évaluations (T0, T1), bien qu'ils n'aient pas été traités dans ce manuscrit de thèse. Les mesures ont été réalisées durant la même semaine pour chacune des quatre classes participantes.

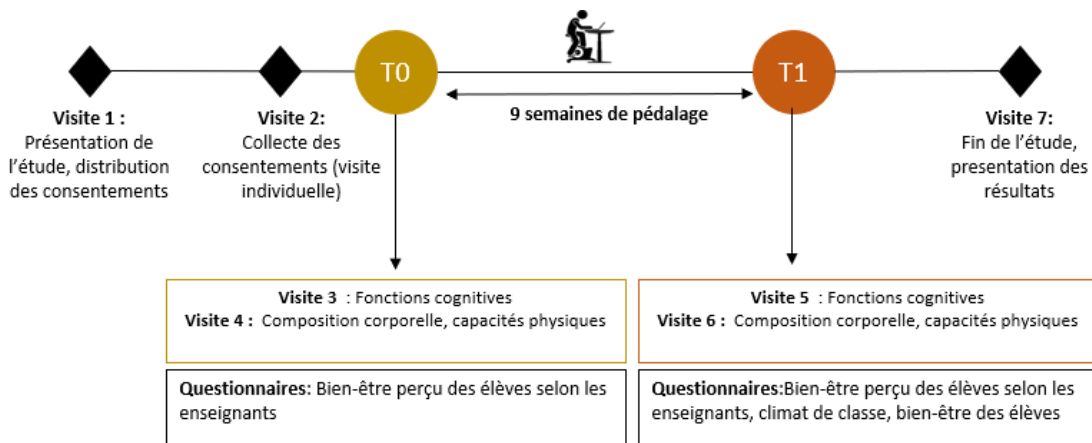


Figure 27 : Schéma de la publication N°4 du projet mesurant les effets de l'utilisation de vélo-bureaux sur des paramètres de santé chez les enfants d'école primaire

La mesure anthropométrique (taille) des élèves a été réalisée par l'IDE<sup>15</sup> de l'Education Nationale en amont des expérimentations afin de réaliser des groupes qui servent à mettre en place un planning de roulement des vélo-bureaux et ainsi faciliter les roulements. Les enfants mesurant moins de 1.30m et ne pouvant donc pas utiliser les vélo-bureaux se sont vu attribuer un swissball selon les mêmes conditions, bien qu'ils aient été exclus de l'analyse.

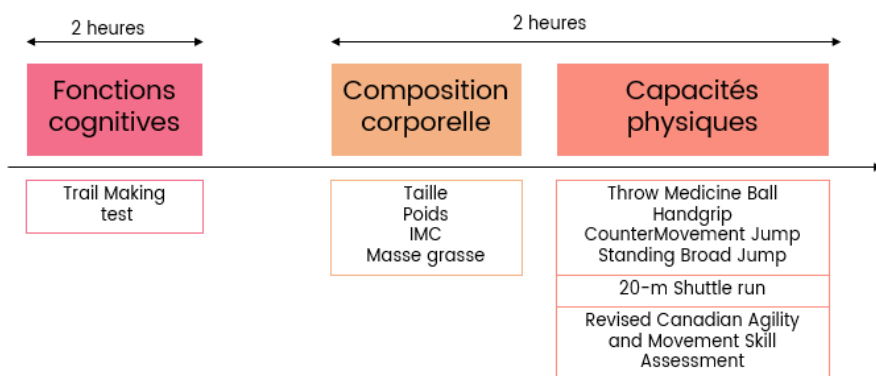


Figure 28 : Schéma des visites expérimentales de la publication N°4 mesurant les effets de l'utilisation de vélo-bureaux sur des paramètres de santé chez les enfants d'école primaire

IMC : Indice de Masse Corporelle

<sup>15</sup> IDE : Infirmier Diplômé d'Etat

- Mesures du projet BICLASS

Les évaluations réalisées et les modalités de réalisation sont identiques dans l'ensemble du projet BICLASS. La seule différence réside dans l'évaluation des préférences en matière d'AP qui n'est exploitée que dans la première phase de l'étude explorant les effets du COVID-19 sur des paramètres de santé des enfants de primaire.

- ✓ *Evaluation de la fonction cognitive*

Le Trail Making Test (TMT) est un test papier évaluant la flexibilité cognitive (Armitage, 1946; Reitan, 1971). Le test est composé de deux parties, tous les enfants l'ont débuté en même temps.

- ✓ *Les préférences en matière d'activité physique*

L'ensemble des participants a réalisé la version française de l'évaluation des préférences en matière d'activités (APA), une tâche comportementale par ordinateur conçue pour évaluer et quantifier les biais dans la prise de décision concernant plusieurs activités de loisirs (Fearnbach et al., 2020). Les scores positifs (+) représentaient une préférence relative pour les activités sédentaires et les scores négatifs (-) une préférence relative pour les AP.

- ✓ *Mesures anthropométriques et composition corporelle*

La toise a été utilisée par l'IDE pour mesurer les élèves. La composition corporelle des participants a été évaluée par une balance impédancemètre bioélectrique (Tanita MC 780 MA, Tanita Corporation, Tokyo, Japan) (Kabiri, Hernandez, & Mitchell, 2015) pour déterminer le poids, l'IMC, la masse grasse en pourcentage et en kilogramme.

- ✓ *Evaluation des capacités physiques*

Les capacités physiques ont été mesurées selon trois composantes : la force musculaire, la capacité cardiorespiratoire et les capacités motrices. Les participants ont effectué un test navette pour déterminer leur capacité cardiorespiratoire (Leger, Mercier, Gadoury, & Lambert, 1988). Les participants ont réalisé un parcours mesurant leurs capacités motrices, le Canadian Agility and Movement Skill Assessment (CAMSA) (Longmuir et al., 2017, 2018). Pour déterminer la force musculaire des participants, quatre tests ont été réalisés. Pour mesurer la force explosive du haut du corps, le Throw Medicine Ball test a été réalisé (Fernandez Santos, Ruiz, Gonzalez-Montesinos, & Castro-Piñero, 2016; Ortega, Artero, et al., 2008a), un test de handgrip sur les bras dominant et non-dominant a été effectué pour mesurer la force de préhension (Cadenas-Sanchez et al., 2016; Leong, 2015), le test du Standing Broad Jump afin de mesurer la force explosive du bas du corps deux fois (Castro-Piñero et al., 2010), le

Counter Movement Jump afin d'évaluer la force explosive du bas du corps (Microgate Co., 137 New York, NY, USA) (Kockum & Heijne, 2015).

- Modifications du protocole expérimental BICLASS

Initialement, l'ensemble des mesures devaient être réalisées à distance de 13 semaines, mais les restrictions sanitaires présentes en 2021 nous ont contraints à retarder la date de début des mesures (T0), réduisant le temps d'utilisation des vélo-bureaux à neuf semaines et non treize semaines. Ainsi, les adaptations apportées à la réalisation de cette étude se situent dans la durée totale d'investigation.

### Axe III : Evaluation et détection des fragilités des séniors en milieu rural et semi-urbain

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- Plan général de l'étude FRAGING

La méthodologie qui va être décrite est celle de l'étude exploratoire FRAGING pour laquelle une première publication vient d'être soumise (**Publication N°5**). L'étude FRAGING est multicentrique avec un suivi longitudinal de cohorte avec explorations non invasives. Cette étude s'est déroulée dans les bassins de santé de Mauriac et de Vichy-communauté en région Auvergne-Rhône-Alpes. Le recrutement des participants s'est fait sur le volontariat après avoir utilisé différentes stratégies de communication. Pour être inclus dans l'étude, les participants devaient être âgés de 65 ans ou plus, être venus assister à une journée de dépistage des fragilités. Les personnes ne devaient pas être porteur d'une maladie chronique prise en charge en Affection Longue Durée (ALD) ou être sous tutelle ou curatelle. L'ensemble des sujets ont été soumis à une journée de dépistage de la fragilité comportant de nombreuses mesures présentées succinctement dans la partie à suivre.

Cette étude a été approuvée par le Comité de Protection des Personnes (CPP Ouest II) et a été enregistrée sur ClinicalTrials.gov (NCT04992286).

- Protocole expérimental de l'étude FRAGING

En amont de la journée, un collectif d'expert s'est réuni pour identifier les problématiques de santé des territoires d'action et ainsi compléter le dépistage préconisé par le modèle ICOPE de l'OMS. Les professionnels de santé présents lors des journées (médecin, médecin gériatre et IDE) ont été préalablement formés à la réalisation du dépistage et à l'utilisation des outils. Les participants ont été soumis au dépistage, puis pour ceux qui ont été identifiés comme fragiles ( $\geq 1$  fragilité(s)), un rappel a été réalisé à +3 et +6 mois de la journée de dépistage (Figure 29).

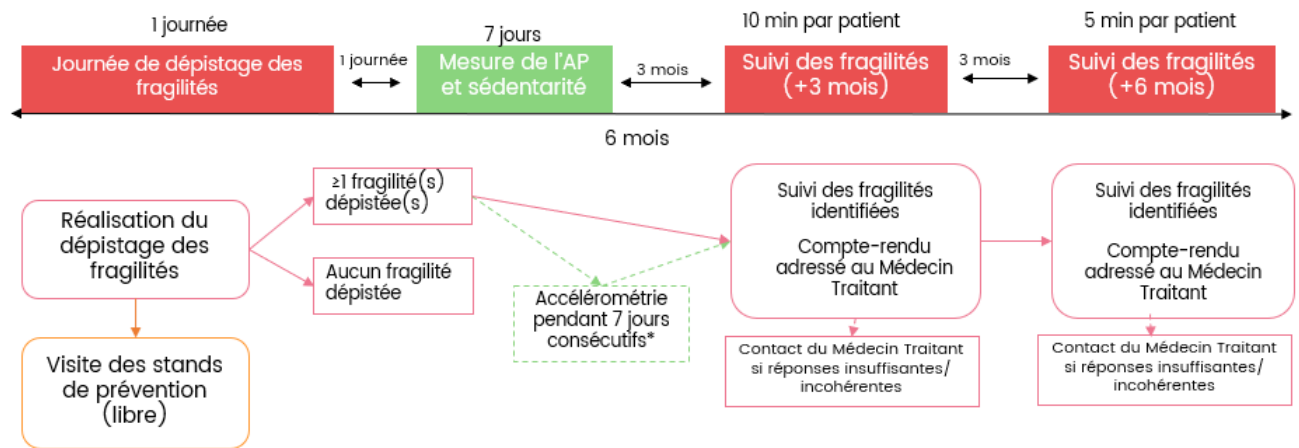


Figure 29 : Schéma du déroulement de l'étude FRAGING

Un total de huit journées en milieu rural et quatre journées en milieu semi-urbain se sont déroulées selon la même méthodologie afin de permettre le recrutement de 53 sujets sur le bassin de Mauriac et de 52 sujets sur le bassin de Vichy. Lors de chaque journée de dépistage des fragilités, il a été demandé aux participants de suivre le même parcours sous forme de paliers (Figure 30). Après une visite d'inclusion, puis la création du dossier médical sécurisé (paliers 1 et 2), le patient a rempli un auto-questionnaire (pallier 3), puis un IDE a administré au patient un second questionnaire accompagné de tests physiques (pallier 4). Par la suite, une analyse de l'iatrogénie ainsi qu'une synthèse des fragilités ont été réalisées (pallier 5 et 6). Pour les dix premières personnes volontaires, un accéléromètre mesurant l'AP et la sédentarité a été installé pour une durée d'une semaine à postériori de la journée. A la fin du parcours, les participants pouvaient se rendre sur les stands de prévention mis en place. Le compte rendu a été envoyé au médecin traitant via une messagerie sécurisée (MonSisra). A la suite de cette journée, une visite de suivi téléphonique ou l'envoi d'un mail a été initié si au moins une fragilité a été détectée lors de la journée de dépistage. Un nouveau compte-rendu a été adressé au Médecin Traitant pour assurer le suivi.

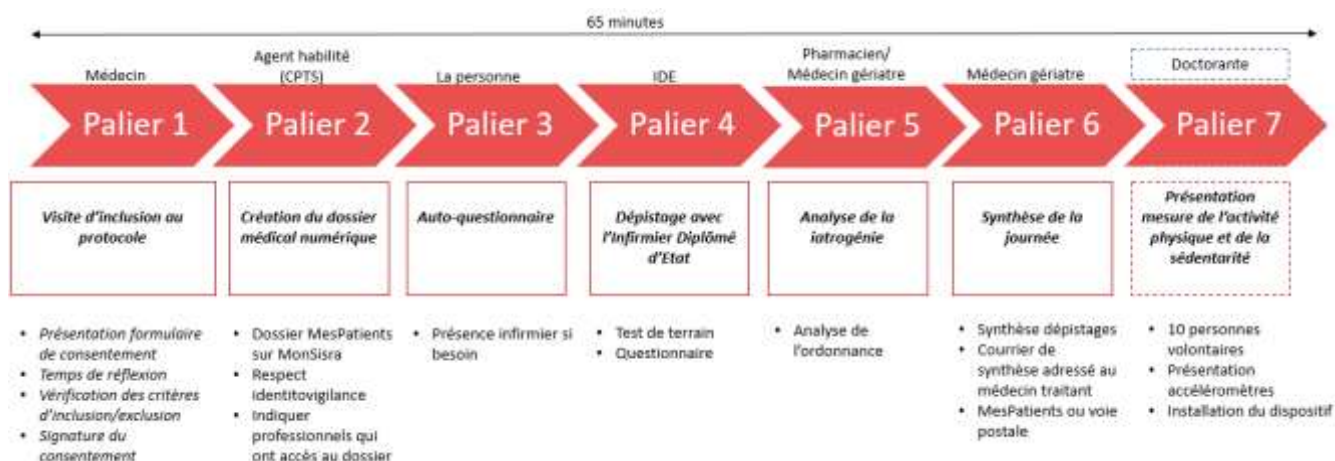


Figure 30 : Déroulement d'un parcours de dépistage des fragilités

Des mesures sanitaires ont été prises en compte afin de permettre aux participants et intervenants de respecter les règles sanitaires liées à la pandémie de COVID-19, les distanciations sociales et le respect des gestes barrières. Le dépistage s'est donc réalisé sous forme d'un parcours à sens unique, chaque personne étant pris en charge individuellement dans des espaces pouvant être aérés et désinfectés. Le remplissage des questionnaires s'est réalisé dans un espace permettant le respect des mesures sanitaires, le questionnaire a été amené à l'IDE puis au médecin gériatre par le participant lui-même pour limiter les contacts.

- Mesures du projet FRAGING

Les données recueillies lors de l'inclusion par le médecin concernaient les données sociodémographiques (âge à l'inclusion, sexe, niveau d'éducation, statut marital, mode de vie, aides à domicile).

Les paramètres ci-dessous ont été évalués par Auto-questionnaire

- ✓ Capacités sensorielles

Dans un premier temps, un auto-questionnaire papier a été proposé aux participants qui l'ont rempli seul. Tout d'abord, les capacités visuelles ont été évaluées par des questions générales sur la présence de pathologies connues et traitées, sur la présence d'une gêne, d'un suivi. Concernant la capacité auditive, si une maladie auditive ou une gêne étaient présentes, le questionnaire HHIE-S (Hearing Handicap Inventory for the Elderly) a été réalisé (Servidoni, Conterno, Servidoni, & Conterno, 2018).

✓ Qualité de vie

L'évaluation de la qualité de vie s'est faite avec la version française du LEIPAD questionnaire composé de 31 questions, dont l'exploitation s'est faite via un logiciel informatique qui nous a permis d'exploiter directement les résultats (De Leo et al., 1998; I. Jalenques et al., 2013a; Isabelle Jalenques, Guiguet-Auclair, Gerbaud, Rachez, & Rondepierre, 2019).

✓ Dépression

Le syndrome dépressif a été évalué avec le questionnaire PHQ-9 (Patient Health Questionnaire) (Cheng et al., 2010).

✓ Précarité socio-économique

La précarité socio-économique a été mesurée avec le score EPICES (Evaluation de la Précarité et des Inégalités de santé dans les Centres d'Examens de Santé) (Bongue, Colvez, Amsallem, Gerbaud, & Sass, 2016; Labbé et al., 2007; Sass, Guéguen, et al., 2006).

✓ Souffrance des aidants

La souffrance des aidants a été recueillie chez les personnes aidantes avec le mini-Zarit (J. Yu, Yap, & Liew, 2019; Zarit & Femia, 2008).

Les paramètres ci-dessous ont été évalués par l'IDE. L'administration des questionnaires ou l'évaluation des paramètres par un IDE ont été réalisées dans un lieu isolé.

✓ Statut Nutritionnel

La dénutrition (vitalité) a été mesurée par le MNA (Mini-Nutritional Assessment). Si le score MNA  $\leq$  11, le GLIM (Global Leadership Initiative on Malnutrition) a été soumis par l'IDE.

✓ Risque de chute

Le risque de chute a été évalué par le nombre de chute l'année passée, et le TUG (Time Up and Go) a été réalisé si des chutes avaient été notées.

✓ Force de préhension

La force de préhension a été évaluée par le test du handgrip sur le bras dominant et non-dominant (Cadenas-Sanchez et al., 2016; Leong, 2015), à la suite de quoi une Echelle Visuelle Analogique (EVA) allant de 0 à 10 a été utilisée afin d'évaluer la douleur potentielle ressentie lors de ce test par la personne. La mesure réalisée est la distance entre le sol et le sommet de la tête de l'élève, en cm à 0.1 cm près.

✓ Composition corporelle

La composition corporelle des participants a été évaluée par une balance impédancemètre bioélectrique (Tanita MC 780 MA, Tanita Corporation, Tokyo, Japan) (Kabiri et al., 2015) pour déterminer le poids, l'IMC, la masse grasse en pourcentage et en kilogramme. La Bio impédancemétrie n'a pas été utilisée pour les personnes porteuses de stimulateurs neurologiques aux vues des risques encourus.



✓ Dépendance à l'alcool

La dépendance à l'alcool a été évaluée par le FACE questionnaire (Formule pour Approcher la Consommation d'Alcool). Les facteurs de risques cardiovasculaires ont été analysés par le gériatre (Visseren et al., 2021).

✓ Capacités cognitives

L'évaluation du déclin cognitive a été réalisé avec le test the Cognitive Disorders Examination (CODEX) si le participant présentait des facteurs de risques (Belmin et al., 2007).

✓ Statut vaccinal et dépistage

Par la suite, au vu des recommandations détaillées dans la dernière version publiée au Bulletin épidémiologique hebdomadaire, une vérification de la mise à jour des vaccins (antitétanique, antigrippal et antipneumococcique) a été réalisée. Trois cancers ont été dépistés : le cancer du sein, le cancer colorectal et le cancer de la peau, conformément aux recommandations françaises. La conformité aux recommandations de dépistage des cancers du sein et colorectal a été vérifiée, et le questionnaire de l'INCa a été rempli pour le dépistage du cancer de la peau (INCa, 2019)

✓ *Niveaux d'activité physique et de sédentarité*

Ces paramètres ont été évalués dans un premier temps de façon subjective avec l'ONAPS-Q parties B et C (M Charles et al., 2021). Puis au lendemain de la journée de dépistage des fragilités, il a été demandé aux participants volontaires de porter pendant 7 jours avec au moins un jour de week-end un accéléromètre ActiGraph wGT3X-BT (ActiGraph, Inc., Pensacola, FL) pour déterminer le temps passé en AP et en comportements sédentaires. Cela a permis dans un deuxième temps une évaluation objective de ces paramètres. Les données ont été analysées si un minimum de 4 jours d'enregistrement (incluant un jour week-end) était indiqué avec un temps de port d'au minimum 10 heures par jour (Aguilar-Farias, Martino-Fuentealba, Salom-Díaz, & Brown, 2019; C Tudor-Locke, Camhi, & Troiano, 2012). Les données ont été recueillies et converties à l'aide du logiciel du fabricant (Actilife version 6.13.4). Le temps où l'appareil ne fut pas porté a été défini par l'algorithme de Choi et al. (L. Choi, Liu, Matthews, & Buchowski, 2011). Voici la définition des comportements : comportements sédentaires  $\leq 99$  cpm<sup>16</sup> (Freedson et al., 1998) ; l'AP de faible intensité : soustraction des données de comportements sédentaires avec les données inférieures à 2019 cpm ; 2020 < l'AP d'intensité modérée à vigoureuse  $\leq 5997$  cpm ; 5998 cpm  $\leq$  l'AP d'intensité vigoureuse (Troiano et al., 2008).

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<sup>16</sup> Cpm : counts per minutes

- Modifications du protocole expérimental FRAGING

Au sein des questionnaires proposés dans l'étude FRAGING, une analyse des besoins en aide humaine était initialement prévue par l'évaluation des Activity of Daily Living (ADL) et les Instrumental Activity of Daily Living (IADL) (S. Katz, Downs, Cash, & Grotz, 1970; Sidney Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963). L'ADL de Kratz est basé sur six gestes quotidiens : hygiène corporelle, habillage, aller aux toilettes, locomotion, continence, repas, tandis que l'IADL est basé sur l'utilisation du téléphone et des moyens de transport, la responsabilité pour la prise de médicament et la gestion du budget. Lors de l'administration de ce questionnaire, il a été constaté qu'il n'était pas approprié de les proposer à cette population, qui vivaient de manière autonome à leur domicile.

## AXE I : Effets du COVID-19 sur les comportements de mouvements aux âges extrêmes de la vie

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*Publication 1 : Effet du 1er confinement sur l'activité physique et la sédentarité des enfants et adolescents*

La mise en place du protocole BICLASS a été bouleversé par la pandémie de COVID-19 et les mesures sanitaires associées, nous obligeant à repousser le début de notre étude. Il apparaissait cependant nécessaire de mesurer l'impact du COVID-19 sur les habitudes de vie des enfants et adolescents, dont les écoles ont été fermées tout comme les clubs sportifs et les cours maintenus en distanciel. C'est pour mesurer du réel impact de la pandémie sur les comportements de mouvements de la population que l'ONAPS a mené une étude mesurant l'évolution des comportements de mouvements des enfants et adolescents pendant le 1er confinement en 2020.

Nous avons donc saisi cette opportunité afin d'analyser ces résultats et de proposer une étude évaluant les effets du 1er confinement lié à la pandémie de COVID-19 sur les niveaux d'AP et de sédentarité des enfants et adolescents. Une comparaison par rapport aux niveaux initiaux d'AP et de sédentarité a été réalisée, ainsi que l'impact du lieu de vie (Rural vs urbain) et des conditions de vie (accès à un extérieur ou non) ont été réalisées.



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## Research paper

## Effect of the COVID-19 lockdown on physical activity and sedentary behaviors in French children and adolescents: New results from the ONAPS national survey



C Chambonniere<sup>a,b,\*</sup>, C Lambert<sup>c,d</sup>, N Fearnbach<sup>e</sup>, M Tardieu<sup>c</sup>, A Fillon<sup>c</sup>, P Genin<sup>c</sup>, B Larras<sup>c</sup>, P Melsens<sup>c</sup>, J Bois<sup>c,f</sup>, B Pereira<sup>c,d</sup>, A Tremblay<sup>c,g</sup>, D Thivel<sup>a,c</sup>, M Duclos<sup>b,c,h,i</sup>

<sup>a</sup> Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions (AME2P), CRNH Auvergne, Clermont-Ferrand, France

<sup>b</sup> INRAE, UMR 1019, Clermont-Ferrand, France

<sup>c</sup> National Observatory for Physical Activity and Sedentary behaviors (ONAPS), Clermont-Ferrand, France

<sup>d</sup> Clermont-Ferrand University hospital, Biostatistics unit (DRCT), Clermont-Ferrand, France

<sup>e</sup> Pennington Biomedical Research Center, Baton Rouge, LA, USA

<sup>f</sup> Université de Pau & des Pays de l'Adour, e2i UPPA, MEPS, Tarbes, France

<sup>g</sup> Département de kinésiologie, G1V 0A6, Faculté de médecine, Université Laval, Québec City, Canada

<sup>h</sup> University Clermont 1, UFR Médecine, Clermont-Ferrand, France

<sup>i</sup> Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, Clermont-Ferrand, France

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## ABSTRACT

**Introduction:** In France March 14, 2020 a national lockdown was imposed in France for 55 days to prevent the spread of COVID-19 and all schools were closed. This study aimed to investigate the effects of home confinement as a result of lockdown on the activity (physical activity and sedentary behaviors), and their determinants, on French children (6-10 years) and adolescents (11-17 years).

**Methods:** The National Observatory for Physical Activity and Sedentary behaviors launched an online survey from April 1<sup>st</sup>, to May 6<sup>th</sup>, 2020 using popular social networks and websites. It compared the level of physical activity (PA), sitting and screen time before and during the lockdown and identified the impact of the initial PA (active vs. inactive), sedentary (high vs. low) profiles of the participants and their housing conditions.

**Results:** 6,491 children were included in this study. Initially active children and adolescents decreased their PA more than those initially inactive ( $p < 0.001$ ), while those who met the sitting time recommendations increased more their sitting time during lockdown ( $p < 0.001$ ). The same applied to screen time ( $p < 0.001$ ). Living in an urban environment was associated with a decrease in PA ( $p < 0.001$ ), an increase in sitting time ( $p < 0.001$ ) and children's screen time ( $p = 0.002$ ) during lockdown.

**Conclusion:** This study showed the deleterious effects of confinement caused by lockdown on physical activity and sedentary behaviors. Housing conditions were associated with lifestyle behaviors over this period of lockdown. Future public health policies should consider these results.

## 1. Introduction

Since early 2020, the SARS-CoV-2 virus has rapidly spread all over the world, leading governments to take national measures to protect the population's health. The World Health Organization (WHO) officially

declared the global COVID-19 pandemic on March 11, 2020. Since the first confirmed case, more than 63 million COVID-19 infections have been identified and more than 2,000,000 people have died over the globe (as of February 1, 2020) [1]. In addition to the high rate of COVID-

\* Corresponding author at: Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions (AME2P), BP 80026, F-63171 Aubière cedex, France.

E-mail addresses: [camille.chambonniere@uca.fr](mailto:camille.chambonniere@uca.fr) (C. Chambonniere), [clambert@chu-clermontferrand.fr](mailto:clambert@chu-clermontferrand.fr) (C. Lambert), [Nicole.Fearnbach@pbcc.edu](mailto:Nicole.Fearnbach@pbcc.edu) (N. Fearnbach), [m.tardieu@onaps.fr](mailto:m.tardieu@onaps.fr) (M. Tardieu), [alicia.fillon@ext.uca.fr](mailto:alicia.fillon@ext.uca.fr) (A. Fillon), [p.genin@onaps.fr](mailto:p.genin@onaps.fr) (P. Genin), [b.larras@onaps.fr](mailto:b.larras@onaps.fr) (B. Larras), [p.melsens@onaps.fr](mailto:p.melsens@onaps.fr) (P. Melsens), [julien.bois@univ-pau.fr](mailto:julien.bois@univ-pau.fr) (J. Bois), [bruno.pereira@ext.uca.fr](mailto:bruno.pereira@ext.uca.fr) (B. Pereira), [angelo.tremblay@kin.ulaval.ca](mailto:angelo.tremblay@kin.ulaval.ca) (A. Tremblay), [david.thivel@uca.fr](mailto:david.thivel@uca.fr) (D. Thivel), [mduclos@chu-clermontferrand.fr](mailto:mduclos@chu-clermontferrand.fr) (M. Duclos).

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19-related deaths, some collateral damage to physical and mental health during the imposed lockdown have been identified, such as increased anxiety, depression, or stress [2,3].

In France, stage 3 was reached on March 14, 2020 (corresponding to the free circulation of the COVID-19 virus on national territory), and a national lockdown was imposed 3 days later for a total of 55 days, in attempts to prevent the spread of the COVID-19 virus. All primary and secondary schools were completely closed and all the teaching activities were conducted virtually. As a direct consequence, physical activity (PA) and sedentary behaviors (SB) have been negatively affected, which has been associated with impaired well-being, mental, physical, and metabolic health [4–8].

In several countries, surveys have been conducted to evaluate the exact impacts of this lockdown on movement behaviors, collectively observing a drastic decrease of the physical activity level (PAL) altogether with an increased time spent sedentary [4–6,8,9]. In France, the National Observatory for Physical Activity and Sedentary Behaviors (ONAPS), conducted a major survey that revealed that both initially active and inactive individuals (did or did not meet the PA recommendations) were negatively impacted by this lockdown [9].

Although the majority of studies have been conducted among adults, some results are available among children and adolescents. A Canadian study conducted among 1,472 parents of children and youth aged 5–17 years showed that only 4.8% (2.8% girls, 6.5% boys) of children (5–11 years) and 0.6% (0.8% girls, 0.5% boys) of youth (12–17 years) had reached the recommendations for a healthy lifestyle (24h movement guidelines) during this lockdown [10]. According to this research group, having parents who encourage and are involved in PA [10,11], having a domestic animal that needs to be walked [10], having an environment and neighborhood favoring PA [12] have been key determinants. This survey also revealed an increase in screen time among the youngest children [10–12] and determined the parents' ability to restrict screen time as the major factor associated with this progression [11]. Similar results have been observed among 12-year-olds ( $n=113$ ) [13] Spanish youth aged 3 to 16 years ( $n=860$ ) [14]; adolescents from Bosnia-Herzegovina ( $n=688$ , 15–18 years old) [15], and young people in Egypt [16]. While Pombo et al. obtained similar results regarding the effect of the lockdown of Portuguese children's PA level ( $n=2,159$ ; mean age of 13 years), the authors also found that the access to a large outdoor area, having at least one parent who did not have to work from home, or sharing the house with other children were strong positive predictors of PA during the lockdown [17].

Based on the data from the French national survey conducted in about 28,000 individuals from all ages (ONAPS COVID-19 Survey; [9]), the present paper assessed the effect of the COVID-19-related lockdown on the movement behaviors (PA and SB), and their determinants, on French children and adolescents. Importantly, these effects were analyzed considering the initial PA (active vs. inactive) and sedentary (high vs. low) profiles of the participants.

## 2. Methods

As previously detailed (global ONAPS COVID-19 survey; [9]), an expert committee (composed of representatives of public health, academics and scientific, governmental, medical and collectivity areas) were gathered by the ONAPS and the French Ministry of Sports, to determine at the national level, key indicators to identify, understand and evaluate the changes induced by this lockdown on the population's PA and SB.

### 2.1. Elaboration of the survey

Different questionnaires following the same basic structure were developed for children between the age of 6 and 10 years and for adolescents (11–17 years old). The questionnaires and their methodology were adapted and inspired from the IPAQ [18] and ONAPS-Q (in progress)

questionnaires in adults and YRBSS (Youth Risk Behavior Surveillance System) investigation in children and adolescents [19]. Briefly, the internal structure of the questionnaires were developed using the same type of questions and structure with possible answers (for instance: time being active over a period of 7 days; screen time per day; etc.). Geographical, socio-demographic, and health status information were first requested before properly addressing the participants' behaviors in terms of PA levels, sitting time and screen time. The participants were also asked to indicate whether they increased or decreased their time devoted to PA and SB compared with their lockdown down habits. Concerning PA, participants are considered as initially inactive if they did not engage in at least 5 hours and 30 minutes per week of moderate to vigorous PA (5 hours and 30 minutes being the highest range proposed in by questionnaire). Concerning SB we used the recommendations thresholds like not exceed 2h/day of screen time [11]. More precisely, the participants were asked to declare their (or their children's) PA and sedentary habits at the time of the lockdown (when they completed the questionnaires) and retrospectively, what they were doing before the lockdown. Parents of children below 10 years of age were asked to fill out the questionnaires while older children and adolescents completed the questionnaire themselves. The final version of these questionnaires resulted from a back-and-forth consultation between the members of the expert committee, until a consensus was reached.

### 2.2. Launch and relaunch of the questionnaires

The survey was made available online at the ONAPS website (<http://www.onaps.fr/>) on April 1<sup>st</sup>, 2020 (after 15 days of lockdown). Social media platforms were used to promote the survey regularly until May 6<sup>th</sup>, 2020, the date at which the survey was closed. Social media (Facebook, LinkedIn for example) and other networks were used for its promotion. Several types of online media were used to disseminate the survey, targeting different kinds of professional, associations, demographic and geographical networks and areas. In the context of the COVID-19 lockdown, particular efforts were deployed to reach a large and representative sample. On a regular basis (April 6<sup>th</sup>, 16<sup>th</sup>, 24<sup>th</sup>, 28<sup>th</sup>, May 6<sup>th</sup> (the last day of the lockdown)), the operational office of the ONAPS relaunched the survey in order to optimize the success of the questionnaires. The survey was closed 36 days after it officially started (on May 6<sup>th</sup>), one week before the end of the lockdown.

### 2.3. Ethical consideration

This work received ethical agreement from the appropriate authorities (Committee for the Protection of Persons Sud est VI. reference 2020 / CE 27).

### 2.4. Data management

The survey was administered online using the LimeSurvey software version 2.67.3. Data were collected anonymously and none of the provided answers allowed any potential for participant identification. Of the 22,895 properly completed questionnaires, 1,588 concerned children ages 6 to 10 years old and 4,903 were completed by adolescents (11–17 years old). Three indicators (physical activity levels, sitting time and screen time) have been transformed into quantitative data by taking the central value of each class (example: less than 30 minutes per week were encoded as 15 minutes of PA per week). Originally we had chosen to propose qualitative values in order to avoid inconsistent values and data entry errors. Data were then gathered into an Excel sheet before being analyzed by the biostatistician team (CL, BP).

### 2.5. Statistical considerations

Statistical analysis was performed separately for children and adolescents using Stata software (version 15; StataCorp, College Station, Texas,

**Table 1**

Proportion of children and adolescents who increased, decreased or did not change their PA level during the confinement depending on gender and initial level of PA.

	Children Decreased	Similar	Increased	p	Adolescents Decreased	Similar	Increased	p
<b>Sex</b>				0.10				<0.001
Girls	293 (39.9%)	151 (20.6%)	290 (39.5%)		1791 (59.7%)	560 (18.6%)	651 (21.7%)	
Boys	374 (43.8%)	187 (21.9%)	293 (34.3%)		1085 (57.1%)	508 (26.7%)	308 (16.2%)	
<b>Physical activity level</b>								
Initially inactive (<5h30/week)	486 (40.8%)	122 (10.2%)	583 (49.0%)		1560 (53.7%)	388 (13.3%)	959 (33.0%)	
Initially active (>5h30/week)	181 (45.6%)	216 (54.4%)	0 (0.0%)		1316 (65.9%)	680 (34.1%)	0 (0.0%)	

Data are presented as number of subjects (row percentages). Boldfaced values: P &lt; 0.05

**Table 2**

Changes in PA level during the lockdown confinement depending on the housing situation of the children and adolescents.

	Children Decreased	Similar	Increased	p	Adolescents Decreased	Similar	Increased	p
<b>Housing area</b>				<0.001				<0.001
Rural	248 (35.2%)	159 (22.5%)	298 (42.3%)		1566 (55.6%)	637 (22.6%)	612 (21.8%)	
Suburban	156 (46.7%)	62 (18.6%)	116 (34.7%)		655 (62.0%)	219 (20.8%)	182 (17.2%)	
Urban	263 (47.9%)	117 (21.3%)	169 (30.8%)		655 (63.5%)	212 (20.5%)	165 (16.0%)	
<b>Housing conditions</b>				<0.001				0.13
No outdoor access	52 (64.2%)	14 (17.3%)	15 (18.5%)		111 (63.8%)	36 (20.7%)	27 (15.5%)	
Balcony	100 (62.1%)	23 (14.3%)	38 (23.6%)		243 (64.8%)	70 (18.7%)	62 (16.5%)	
Shared outdoor access	50 (43.1%)	26 (22.4%)	40 (34.5%)		204 (58.6%)	80 (23.0%)	64 (18.4%)	
Individual outdoor access	465 (37.8%)	275 (22.3%)	490 (39.9%)		2318 (57.9%)	882 (22.0%)	806 (20.1%)	

USA). All tests were two-sided, with a Type I error set at 0.05. All variables were categorical and presented as number of subjects and percentages. The factors associated with the evolution before/during lockdown (increase, similarity, decrease) of the three indicators (PA level, sitting time, and screen time) were studied by chi-squared tests.

### 3. Results

#### 3.1. Description of sample

Data were collected from 6,491 children and adolescents (57.6% female). One-quarter (24.5%) of the sample was between the ages of 6 to 10 years (46.2% female), while 75.5% of responses were from young people between the ages of 11 to 17 years (61.2% female).

A total of 5.1% of the children and 3.6% of the adolescents did not have access to an outdoor area during the lockdown, while 10.1% of children and 7.6% of adolescents had access to a balcony only, 7.3% of children and 7.1% of adolescents had access to a shared outdoor area and 77.5% of children and 81.7% of adolescents lived in accommodation with an individual backyard. Concerning the housing area, 34.6% of children and 21.1% of adolescents lived in an urban area, 44.4% of children and 57.4% of adolescents lived in rural areas, and 21.0% of children and 21.5% of adolescents lived in a suburban area.

#### 3.2. Physical activity

A total of 42.0% of children and 58.7% of adolescents reported decreased PA during the lockdown, compared to 21.3% of children and 21.8% of adolescents maintained a similar volume of PA, and 36.7% of children and 19.6% of adolescents declared an increase their PA. The proportion of participants who increased, decreased or did not change their PAL during the lockdown was significantly associated with gender in adolescents ( $p < 0.001$ ) but not in children ( $p = 0.10$ ). The Table 1 presents the proportions of children and adolescents who declared increased, decreased or unchanged overall level of PA depending on gender and initial level of PA.

As depicted in Table 1, being physically active before lockdown was associated with the change in PA level during lockdown in both age groups ( $p < 0.001$ ). A total of 45.6% of children and 65.9% of adolescents

who were initially active admitted a decrease of their level of PA during lockdown. Forty-eight percent of children and 53.7% of adolescents who were initially inactive declared a decrease of their PA during lockdown. A total of 49.0% and 33.0% of initially inactive children and adolescents respectively, increased their PA level during lockdown. Of note, the fact that our questionnaire could not identify PAL above 5h30min per week, explains the absence of initially active children and adolescents who increased their PAL.

The geographic location (rural, suburban, urban) of the accommodation was significantly associated with the children and adolescent's PA during the lockdown ( $p < 0.001$ ), while the housing condition (access to an outdoor area or not) was associated with PA changes in children only ( $p < 0.001$  in younger children and  $p = 0.13$  in adolescents). As presented in Table 2, PA decreased among 35.2% of children who lived in rural areas, decreased among 46.7% of children who lived in suburban areas, and decreased among 47.9% of children who lived in urban areas. Access to an outdoor area moderated the change in PA levels of children, such that 64.2% reported a decrease in PA when they did not access to an outdoor area, compared to a decrease in PA among only 37.8% who had individual outdoor area access ( $p < 0.001$ ).

According to our results, the initial level of sitting time in children was associated with their PAL changes during lockdown while their initial screen time did not affect their PAL during lockdown ( $p = 0.04$  and  $p = 0.95$  respectively). In adolescents, pre-lockdown screen time ( $p < 0.001$ ) and sitting time ( $p = 0.01$ ) was associated with their PAL changes. A total of 32.8% of children who did not exceed the 6h/day of sitting increased their PAL and 37.6% among those whose daily sitting time was higher than 6h/day.

#### 3.3. Sitting time

Based on our results, as presented in the Table 3, not exceeding sitting time recommendations (<6h/day) before the lockdown was associated with the sitting time during lockdown for both children and adolescents ( $p < 0.001$ ). Concerning children and adolescents who respected the recommendations of 6h/day of sitting time before lockdown, they mainly declared an increase of their sitting time during lockdown (71.7% and 72.1% respectively), while among those who exceeded the

**Table 3**  
Changes in sitting time during the lockdown confinement presented by gender, initial PAL, sitting time, screen time, and housing situation of children and adolescents.

	Children Decreased	Similar	Increased	p	Adolescents Decreased	Similar	Increased	p
<b>Sex</b>				0.54				<b>&lt;0.001</b>
Girls	215 (29.3%)	242 (33.0%)	276 (37.7%)		428 (14.3%)	1847 (61.6%)	721 (24.1%)	
Boys	256 (30.0%)	298 (34.9%)	299 (35.1%)		357 (18.8%)	1014 (53.4%)	528 (27.8%)	
<b>Physical activity level</b>				0.98				<b>&lt;0.001</b>
Initially inactive	355 (29.8%)	405 (34.1%)	430 (36.1%)		470 (16.2%)	1,758 (60.6%)	672 (23.2%)	
Initially active	116 (29.3%)	135 (34.1%)	145 (36.6%)		315 (15.6%)	1,103 (55.3%)	577 (28.9%)	
<b>Sitting time</b>				<b>&lt;0.001</b>				<b>&lt;0.001</b>
>6h/day	462 (35.5%)	468 (36.0%)	370 (28.5%)		763 (17.5%)	2,735 (62.6%)	867 (19.9%)	
<6h/day	9 (3.1%)	72 (25.2%)	205 (71.7%)		22 (4.1%)	126 (23.8%)	382 (72.1%)	
<b>Screen time</b>				<b>&lt;0.001</b>				<b>&lt;0.001</b>
>2h/day	87 (31.3%)	140 (50.4%)	51 (18.3%)		488 (14.2%)	2,345 (68.2%)	603 (17.6%)	
<2h/day	384 (29.3%)	400 (30.6%)	524 (40.1%)		297 (20.3%)	516 (35.4%)	646 (44.3%)	
<b>Housing area</b>				<b>&lt;0.001</b>				<b>&lt;0.001</b>
Rural	243 (34.5%)	247 (35.0%)	215 (30.5%)		499 (17.8%)	1,626 (57.8%)	685 (24.4%)	
Suburban	91 (27.3%)	107 (32.0%)	136 (40.7%)		157 (14.9%)	596 (56.6%)	300 (28.5%)	
Urban	137 (25.0%)	186 (34.0%)	224 (41.0%)		129 (12.5%)	639 (61.9%)	264 (25.6%)	
<b>Housing conditions</b>				<b>&lt;0.001</b>				<b>0.004</b>
No outdoor access	9 (11.1%)	24 (29.6%)	48 (59.3%)		13 (7.5%)	105 (60.3%)	56 (32.2%)	
Balcony	33 (20.5%)	49 (30.4%)	79 (49.1%)		43 (11.5%)	232 (62.0%)	99 (26.5%)	
Shared outdoor access	30 (25.9%)	49 (42.2%)	37 (31.9%)		56 (16.2%)	209 (60.2%)	82 (23.6%)	
Individual outdoor access	399 (32.5%)	418 (34.0%)	411 (33.5%)		673 (16.8%)	2,315 (57.9%)	1,012 (25.3%)	

Data are presented as number of subjects (row percentages). Boldfaced values:  $P < 0.05$

6h/day of sitting time before lockdown, only 28.5% of children and 19.9% of adolescents admitted an increase in their sitting time.

The initial screen time of children and adolescents was also associated with their sitting time during the lockdown ( $p < 0.001$ ). A total of 40.1% children and 44.3% adolescents who were exposed to screens  $< 2$ h/day declared an increase of their sitting time against respectively 18.3% and 17.6% for those who were exposed to screens  $> 2$ h/day before the lockdown ( $p < 0.001$  for both children and adolescents).

As presented in Table 3, the housing area (urban, suburban, rural) of adolescents and children was significantly associated with the evolution of their sitting time before and during lockdown ( $p < 0.001$ ). More children who lived in urban areas declared an increased sitting time during lockdown (41.0%) than those who lived rural areas (30.5%) ( $p < 0.001$ ).

The access to an outdoor area was found to be significantly related to the sitting time modifications during the lockdown in children ( $p < 0.001$ ) and adolescents ( $p = 0.004$ ). Indeed, higher proportions of children ( $p < 0.001$ ) and adolescents ( $p = 0.04$ ) who had no access to an outdoor admitted an increased sitting time during lockdown (59.3% and 32.2% respectively) than those who had access to an individual backyard (33.5% and 25.3% respectively).

### 3.4. Screen time

While only 1.4% of children and 3.2% of adolescents admitted to a decrease their screen time during the lockdown, 62.0% of children and 68.9% of adolescents reported an increased screen time.

As displayed in Table 4, adherence to screen time recommendations before lockdown ( $< 2$ h/day) influenced changes in screen time during lockdown in both children and adolescents ( $p < 0.001$ ). A higher proportion of children and adolescents who complied with the recommendations before lockdown reported an increase in their screen time (65.0% and 78.7% respectively) compared to those who exceeded the 2h/day of screen time before the lockdown (respectively 47.8% and 64.8%).

According to our results, the PAL before lockdown was significantly associated with the screen time of adolescents during lockdown ( $p < 0.001$ ) but not for children ( $p = 0.62$ ). A total of 64.2% of initially inactive adolescents before the lockdown reported an increase of their screen time during lockdown against 75.8% of the initially active participants ( $p < 0.001$ ).

Meeting the sitting time recommendations ( $< 6$ h/day) before the quarantine was significantly associated with the screen time during lockdown in children ( $p = 0.02$ ) and adolescents ( $p < 0.001$ ). A higher proportion of adolescents who had a sitting time  $> 6$ h/day before the lockdown declared an increase of their screen time during lockdown (70.3%) compared to those who showed a sitting time  $< 6$ h/day before the lockdown (57.6%) ( $p < 0.001$ ).

The housing area of children was significantly associated with their screen time during the quarantine ( $p = 0.002$ ), but not for adolescents ( $p = 0.10$ ). All declared an increase in their screen time during the lockdown but the higher proportion of children and adolescents who lived in urban areas reported an increase in their time spent in front of screen (respectively 66.4% and 70.6%) compared 56.7% and 67.4% of those who lived in the countryside respectively.

Access to outdoor areas was significantly associated with changes in screen time for both children and adolescents ( $p = 0.01$  and  $p = 0.002$ , respectively). Higher proportions of children and adolescents who had not access to an outdoor before the lockdown admitted to increasing their screen time (Table 4).

## 4. Discussion

The global pandemic of COVID-19 led to lockdown of the national and international populations. A large number of regional and national surveys have been carried out during and following this lockdown to assess its impact on individual movement behaviors, collectively describing an overall decline in PA levels, combined with an increased time devoted to SB, particularly screen time. Since most of these surveys have been conducted in adults, less is known regarding the impact of this quarantine on movement behaviors in children and adolescents. In that context, based on the French National ONAPS Covid-19 Survey, the present work evaluated the effect of the quarantine on PA and SB of children (aged 6 to 10 years old) and adolescents (11-17 years old).

In line with national and international statistics [20,21], a large proportion of the children and adolescents who composed our sample were identified as inactive before the lockdown (75.0% of children and 59.3% of adolescents). Considering the strong associations between health and healthy movement behaviors [22,23], the situation was already alarming in youth before the institution of social and physical restrictions. Based on the current results, 42% of children and 58.7% of adolescents

**Table 4**  
Changes in screen time during the lockdown confinement by gender, initial PAL, sitting time, screen time and housing situation of the children and adolescents.

	Children Decreased	Similar	Increased	p	Adolescents Decreased	Similar	Increased	p
<b>Sex</b>				0.15				<b>0.02</b>
Girls	7 (1.0%)	283 (38.6%)	443 (60.4%)		99 (3.3%)	792 (26.4%)	2105 (70.3%)	
Boys	15 (1.8%)	298 (34.9%)	540 (63.3%)		58 (3.0%)	571 (30.1%)	1270 (66.9%)	
<b>Physical activity level</b>				0.62				<b>&lt;0.001</b>
Initially inactive	18 (1.5%)	430 (36.1%)	752 (62.4%)		122 (4.2%)	915 (31.6%)	1,863 (64.2%)	
Initially active	4 (1.0%)	151 (38.0%)	241 (60.9%)		35 (1.8%)	448 (22.4%)	1,512 (75.8%)	
<b>Sitting time</b>				<b>0.02</b>				<b>&lt;0.001</b>
>6h/day	21 (1.6%)	459 (35.3%)	820 (63.1%)		149 (3.4%)	1,146 (26.3%)	3,070 (70.3%)	
< 6h/day	1 (0.4%)	122 (42.6%)	163 (57.0%)		8 (1.5%)	217 (40.9%)	305 (57.6%)	
<b>Screen time</b>				<b>&lt;0.001</b>				<b>&lt;0.001</b>
>2h/day	22 (7.9%)	123 (44.3%)	133 (47.8%)		157 (4.6%)	1,052 (30.6%)	2,227 (64.8%)	
<2h/day	0 (0.0%)	458 (35.0%)	580 (65.0%)		0 (0.0%)	311 (21.3%)	1,148 (78.7%)	
<b>Housing area</b>				<b>0.002</b>				0.10
Rural	8 (1.1%)	297 (42.2%)	400 (56.7%)		95 (3.4%)	820 (29.2%)	1,895 (67.4%)	
Suburban	4 (1.2%)	110 (32.9%)	220 (65.9%)		34 (3.2%)	268 (25.5%)	751 (71.3%)	
Urban	10 (1.8%)	174 (31.8%)	363 (66.4%)		28 (2.7%)	275 (26.7%)	729 (70.6%)	
<b>Housing conditions</b>				<b>0.01</b>				<b>0.002</b>
No outdoor access	0 (0.0%)	27 (33.3%)	54 (66.7%)		7 (4.0%)	36 (20.7%)	131 (75.3%)	
Balcony	3 (1.9%)	43 (26.7%)	115 (71.4%)		8 (2.1%)	105 (28.1%)	261 (69.8%)	
Shared outdoor access	4 (3.5%)	35 (30.1%)	77 (66.4%)		18 (5.2%)	121 (34.9%)	208 (59.9%)	
Individual outdoor access	15 (1.2%)	476 (38.8%)	737 (60.0%)		124 (3.1%)	1,101 (27.5%)	2,775 (69.4%)	

Data are presented as number of subjects (row percentages).

reported a decrease in PA during the lockdown, which was particularly pronounced among adolescents girls (59.7%). These results are in line with what has been observed in other countries such as Spain [13,14], Bosnia- Herzegovina [15], Egypt [16] or Canada [10–12] among others. Gilic et al. estimated that 50% of their Bosnian adolescents reached PA recommendations before the lockdown, dropping to only 24% during the lockdown [15]. Interestingly, our results are the first to evaluate the effect of this COVID-19-related lockdown stratified by the initial (pre-lockdown) level of PA in youth. Our results show that this drastic global decline in PA during this particular period affected both initially active and inactive children and adolescents. Indeed, high proportions of both active (45.6% in children and 65.9% in adolescents) or inactive (40.8% of children and 53.7% of adolescents) youth reported a decrease in PA levels. Importantly, our survey also highlights that none of the children and adolescents initially (before the lockdown) identified as inactive, reported an increase of their PA during this lockdown. While our results clearly highlight that initially inactive youth might be particularly concerned by the deleterious effects of such lockdown, they also show that a higher initial level of PA of children and adolescents might not prevent them from decreasing their PA during the lockdown. Indeed, some may argue that they have “more to lose” when it comes to declines in PA. While some authors previously underlined the role of the parental encouragement [10,11] or a family’s neighborhood [12] to avoid such a decrease in PA, our results also identified the living conditions (rural-urban) of the accommodation and the access to outdoor facilities as primary influences. High proportions of children (47.9%) and adolescents (63.5%) living in urban areas or whose accommodation did not allow access to outdoor facilities (64.2% and 63.8%, respectively), declared a significant decrease in PA as a result of stay-at-home orders.

These results are in line with those from Zenic et al., who also described adolescents living in urban areas as more prone to reduce their PA levels during the lockdown when compared with their counterparts living in rural areas [24]. Our findings also align with results from Canada, identifying the access to outdoor (as parks) as influences on PA during periods of home lockdown [12].

Although our results show that 22% of children and 27.9% of adolescents admitted to increase their sitting time during the French lockdown, they also underline an alarming increase in screen time among 62% and 68.9% of children and adolescents, respectively. This finding is in line with previously published results from other countries showing an

increase of the time exposed to screens [10–14], which is at least partly attributable to the immediate transition to home-based virtual schooling. This was true among Chinese youth, with an increase in screen time of more than 4 hours per day reported during the lockdown [25]. Moreover, Pietrobelli and colleagues underlined that while 60.3% of the Italian children and adolescents already exceed the screen time recommendations, 68.9% of adolescents with obesity increased screen time during the first COVID-19-related lockdown [26]. As for PA, our results also underline that this increased sitting and screen time affects children and adolescents independently of previously meeting recommendations for time spent in SB. Interestingly, sitting and screen time were also similarly increased regardless of initial PA levels. As already noted for PAL, our results reinforce the important role of the living conditions on both sitting and screen time during the lockdown, with children from urban areas most affected. Similarly, higher proportions of both children and adolescents who had no or limited access to outdoor areas reported an increase in sitting and screen time.

As most of the surveys were conducted during the lockdown period, the online and self-reported nature of the collected data and the use of subjective self-reported questionnaires are the main limitations of the current study. Questionnaires were submitted online, which may have limited access for poorer and migrant sectors of the population without internet access. However, conducting and analysing the data for a large-scale national survey can be logistically challenging, and conducting it online makes it feasible. Another limitation lies in the categorization of PAL and SB that do not showed changes in levels within a category, a child may have increased or decreased his PAL or SB without changing categories and therefore without this being apparent. The large number of participants who completed this French national survey however, should be considered as a strength of this work, with more than 6400 children and adolescents, making this survey one of the largest samples worldwide. Importantly, while previous questionnaires addressing healthy behaviors might attract people who are interested in and concerned by such behaviors. The proportion of youth determined as inactive or did not meet the sedentary guidelines prior to the COVID-19 pandemic indicates that our sample might be slightly different of the general French population concerning PA in children (25% of active against 67% in the ESTEBAN survey), while closer among adolescents (40% vs. 30%)[27] and widely different concerning screen time in children, (25% who do not exceed 2h/day against 55% do not exceed 3h/day in ESTE-



BAN survey) and adolescent (41% against 74%)[27]. These differences can be explained by the threshold used to identify participants as active or inactive (5h 30min per week of PA in the present work against 7h/week for the general recommendations), the evolution of screen time recommendations (2h/day and 3h/day) and the retrospective nature of the data collected. The threshold used for PA (5h 30min /week) is one of the main limitations of the present work that is due to the internal construction of the survey, and that must be considered when interpreting our results. Concerning living conditions, large differences were observed between the proportion of children and adolescents who lived in urban areas (34.6% against 21.1%) and rural areas (44.4% against 57.4% of adolescents), which can be explained by the different number of respondents (1586 children and 4895 adolescents). The lack of information regarding the geographical situation of the participants, and the lack of anthropometric information, also compose some limitations of the present analysis. Finally, the retrospective nature of the estimation of the participants' physical activity level and sedentary time before the lockdown composes another important limitations of the present analysis that must be considered.

## 5. Conclusion

In line with previously published results in other countries, the present results confirm the negative impact of the first COVID-19-related lockdown period on movement behaviors in children and adolescents. Our study reinforces the need to orient future public health policies towards improving the accessibility of outdoor facilities, particularly in urban areas, in order to encourage greater physical activity. It also indicates that such a period of isolation has deleterious effects on both physical activity and sedentary behaviors among youth, regardless of whether or not they were previously meeting public health guidelines. Finally, there is a need for more informative and preventive public health strategies clearly warning the population that every child, regardless of age or usual movement behaviors, may be negatively impacted by physical and social restrictions.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## CRedit authorship contribution statement

**C Chambonniere:** Formal analysis, Project administration, Writing - original draft. **C Lambert:** Data curation, Formal analysis, Methodology, Writing - original draft. **N Fearnbach:** Writing - original draft. **M Tardieu:** Conceptualization, Funding acquisition, Investigation, Project administration, Writing - review & editing. **A Fillon:** Data curation, Methodology, Project administration, Writing - review & editing. **P Genin:** Data curation, Formal analysis, Methodology, Project administration, Writing - original draft. **B Larras:** Data curation, Project administration, Writing - review & editing. **P Melsens:** Data curation, Resources. **J Bois:** Funding acquisition, Resources. **B Pereira:** Conceptualization, Formal analysis, Methodology, Resources. **A Tremblay:** Funding acquisition, Resources, Writing - review & editing. **D Thivel:** Formal analysis, Investigation, Resources, Writing - original draft. **M Duclos:** Conceptualization, Funding acquisition, Investigation, Writing - original draft.

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## Data availability

Complementary data (questionnaires) are supplied as supplementary file.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eujim.2021.101308.

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## Conclusion de l'étude

La présente étude confirme les répercussions néfastes du premier confinement liée à la pandémie de COVID-19 sur les comportements de mouvement chez les enfants et les adolescents. Ainsi, la baisse générale et drastique de l'AP concerne à la fois les enfants et les adolescents, qu'ils soient initialement actifs ou inactifs. De plus, une proportion importante d'enfants et d'adolescents résidant dans des zones urbaines ou n'ayant pas accès à des installations extérieures ont déclaré une diminution significative de leur AP pendant le confinement.

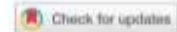
Globalement, les temps passés assis et devant les écrans augmentent de manière similaire et alarmante pendant le confinement chez les enfants et les adolescents, et ce indépendamment du respect initial des recommandations. Aussi, nos résultats renforcent le rôle important des conditions de vie sur le temps passé assis et devant un écran pendant le confinement, les enfants des zones urbaines étant les plus touchés.

Cette étude met en évidence les effets préjudiciables des restrictions sanitaires à la fois sur l'AP et sur les comportements sédentaires chez les jeunes, indépendamment de leur respect des directives de santé publique existantes. Il est impératif de développer des approches en matière de santé publique plus axées sur l'information préventive, capables de sensibiliser efficacement la population au fait que chaque enfant, indépendamment de son âge ou de ses habitudes de déplacement, peut subir les conséquences des mesures sanitaires restrictives.

*Publication 2 : Effet du 1er confinement sur l'activité physique  
et la sédentarité des séniors*

Chez les séniors, la pratique d'AP et la limitation du temps passé à des comportements sédentaires sont motivés par l'adéquation de l'environnement (par exemple, la sécurité du quartier), la disponibilité des interactions sociales et les stéréotypes socioculturels liés au vieillissement et les gains de santé et l'expérience d'émotions positives (comme le plaisir) (Meredith et al., 2023). La pandémie de COVID-19 a considérablement bouleversé les habitudes de vie de la population, et particulièrement les séniors considérés comme vulnérables aux effets du virus. De façon similaire à l'étude précédemment détaillée, l'ONAPS s'est intéressée aux effets du virus de COVID-19 sur les séniors.

Nous avons donc saisi cette opportunité afin d'analyser ces résultats et de proposer une étude évaluant les effets du 1<sup>er</sup> confinement lié à la pandémie de COVID-19 sur les niveaux d'AP et de sédentarité des séniors, population particulièrement à risques pendant cette période. Une comparaison par rapport aux niveaux initiaux a été réalisée, ainsi que l'impact du lieu de vie (rural vs urbain) et des conditions de vie (accès à un extérieur ou non) ont été réalisées.



## Physical Activity and Sedentary Behavior of Elderly Populations during Confinement: Results from the FRENCH COVID-19 ONAPS Survey

C Chambonniere <sup>a,b</sup>, C Lambert <sup>c,d</sup>, M Tardieu<sup>c</sup>, A Fillon <sup>e</sup>, P Genin <sup>e</sup>, B Larras <sup>e</sup>, P Melsens<sup>e</sup>, Js Baker<sup>g</sup>, B Pereira<sup>c,d</sup>, a Tremblay <sup>c,f</sup>, D Thivel <sup>a,c</sup>, and M Duclos <sup>b,c,g,h</sup>

<sup>a</sup>Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions (AME2P), CRNH Auvergne, Clermont-Ferrand, France; <sup>b</sup>Inrae, Umr Clermont-Ferrand, France; <sup>c</sup>National Observatory for Physical Activity and Sedentary Behaviors (ONAPS), Clermont-Ferrand, France; <sup>d</sup>Clermont-Ferrand University Hospital, Biostatistics Unit (DRCI), Clermont-Ferrand, France; <sup>e</sup>Centre for Health and Exercise Science Research, Department of Sport, Physical Education and Health, Hong Kong Baptist University, Kowloon Tong, Hong Kong; <sup>f</sup>Department of Kinesiology, Faculty of Medicine, University of Laval, Quebec City, Canada; <sup>g</sup>University Clermont 1, UFR Medicine, Clermont-Ferrand, France; <sup>h</sup>Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, Clermont-Ferrand, France

### ABSTRACT

**Introduction:** A national confinement was imposed in France in March 2020 during 55 days to prevent the spread of the virus and protect vulnerable people such as older individuals. This study aimed to describe the movement behaviors, and their determinants, of elderly people ( $\geq 65$  years) during the confinement.

**Methods:** An online survey was conducted from April 1<sup>st</sup>, 2020 to May 6<sup>th</sup>, 2020 by the National Observatory for Physical Activity and Sedentary behaviors. This study compared the level of physical activity (PA), sitting and screen time before and during the confinement and identified the impact of initial PA, sedentary profiles of the participants and housing conditions.

**Results:** 1,178 people were included in this study. Reaching PA recommendations before lock-down was associated with the change in PA level during lock-down ( $p < .001$ ). Besides, geographic location was associated with the change in PA, sitting time and screen time during lock-down (respectively  $p = .03$ ,  $p = .02$ ,  $p = .02$ ).

**Conclusion:** This study confirm the negative impact of confinement on senior movement behaviors, whether or not they met with public health recommendations prior to the pandemic. The housing conditions of older people must be also taken into future public health policies.

### ARTICLE HISTORY

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## Introduction

Since the onset of the COVID-19 global pandemic, about 48 million individuals have been diagnosed with the virus and more than 1,700,000 people have died (as of December, 08, 2020) (WHO, 2020). Globally, vulnerability criteria for COVID-19 have been identified, and includes being 60 years old and over, cancer, obesity, heart conditions, COPD (chronic obstructive

**CONTACT** C Chambonniere  camille.chambonniere@uca.fr  Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions (AME2P), Bp 80026, F-63171 Aubière Cedex, France.

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pulmonary disease) or type 2 diabetes (Moujaess, Kourie, & Ghosn, 2020; Shafi, Shaikh, Shirke, Iddawela, & Harky, 2020; Tamara & Tahapary, 2020; Zhao et al., 2020; Zheng et al., 2020).

In France, stage 3 was reached on March 14, 2020 (corresponding to the free circulation of the virus on national territory), and a lock-down was imposed on March 17, 2020 for a total of 55 days, in an attempt to prevent the spread of the virus. Since the elderly have been identified as a particularly at-risk group for the development of serious forms of the Coronavirus, the respect for social and physical distancing for individuals greater than 60 years of age has been particularly reinforced. Among the consequences of the quarantine, a decline in daily physical activities (PA) and an increase in the time devoted to sedentary behaviors (SB) have been emphasized in the general population (Carriedo, Cecchini, Fernández-Río, & Méndez-Giménez, 2020; Meyer et al., 2020; Qi, Li, Moyle, Weeks, & Jones, 2020). In seniors, such changes in the movement behaviors might unfortunately affect older individuals independence, frailty, sarcopenia, well-being and overall mental health (Lautenschlager, Almeida, Flicker, & Janca, 2004; Marzetti et al., 2017; Sun, Norman, & While, 2013; Brooks et al., 2020; (Carriedo et al., 2020; Chouchou et al., 2020; Meyer et al., 2020; Schuch et al., 2020; Ugbolue et al., 2020; Werneck et al., 2020).

Most of the surveys that have been conducted previously have concerned middle aged adults and only few results are available regarding the effect of the COVID-19-related lock-down on the physical activity level (PAL) and sedentary time of older people ( $\geq 60$  years). In Japan, Yamada and colleagues reported a decline in the physical activity level of 65-84 years old individuals ( $n = 1,600$ ) of about 65 minutes per week ( $-26.5\%$ ) independent of their level of fragility (Yamada et al., 2020). Werneck and colleagues also reported an increase in physical inactivity and sedentary time (screen time exposure mainly) among Brazilian people over 60 years of age (Werneck et al., 2020). According to Goethals et al. for French individuals aged 60 and above, the decline in their PAL can be explained by a lower attendance to organized collective physical activity sessions, in order to avoid social contacts, and for the lack of available sports equipment in the home (Goethals et al., 2020). In Italy, Di Santo et al. reported that one-third of seniors 60 years and over ( $n = 126$ ) with mild cognitive impairment or subjective cognitive decline decreased their physical activity levels during the lock-down and nearly 70% of them reported an increase in idle time (Di Santo, Franchini, Filiputti, Martone, & Sannino, 2020).

The French National Observatory for Physical Activity and Sedentary Behaviors (ONAPS) conducted a national survey questioning the effects of the first COVID-19 confinement on the movement behaviors of about 28,000 individuals of all ages (Genin et al., 2021). While this survey confirms among French people the internationally observed decline in PAL and increased sedentary time; the present work proposes to describe the physical activity and sedentary behaviors, and their determinants, in elderly population ( $\geq 65$  years old) during this confinement.

## Materials and Methods

The methods employed in the survey have been detailed previously (Genin et al., 2021). An expert panel (composed of individuals working in public health, academic and scientific, governmental, medical areas) collectively gathered by the ONAPS and the French Ministry of Sports determined key indicators to identify, understand and estimate the potential

effects of the COVID-19-related confinement on the population's physical activity and sedentary behaviors.

### **Conception of the Questionnaire**

Briefly, different questionnaires adapted for different age groups were designed, and developed for adults and older people using the IPAQ12 and ONAPS-Q (Charles et al., 2021). The ONAPS-Q, has good reliability concerning the assessment of moderate and vigorous physical activity (ICC = 0.95, ranged from 0.91 to 0.98) and sedentary behavior (ICC = 0.88, ranged from 0.78 to 0.94). Compared to the GPAQ, the coefficient of validity is 0.77 concerning PA and 0.64 for SB (Charles et al., 2021). The internal structure and design of both questionnaires have been elaborated on based on the structures of validated questionnaires using the same type of questions and answers (for instance: time being active over a period of 7 days; screen time per day; etc.). The survey first gathered information regarding the geographical location, socio-familial characteristics and well as the health status of the participants before covering the main dimensions of physical activity levels, sitting time and screen time. Concerning PA, participants are considered as initially inactive if they did not engage in at least 2 hours and 30 minutes per week of moderate to vigorous PA (2 hours and 30 minutes being the highest range proposed by the questionnaire). Concerning SB, we used the recommendation thresholds of not exceeding 2 h/day of screen time. Participants were asked to declare their physical activity and sedentary habits during the confinement (when they completed the questionnaires) and retrospectively, what they were doing before the confinement (to estimate any potential changes). The final results and outcomes of these questionnaires resulted from a back-and forth consultation between the members of the expert committee, until a consensus was reached. The duration to complete the questionnaires was estimated to be 20 minutes.

### **Dissemination**

The questionnaires were first launched during the first phase of the confinement period on the 1st of April 2020 and their promotion was facilitated through social media and networks. Social media (Facebook, LinkedIn for example) and other networks were used for promotion. Several types of online media were used to disseminate the survey, targeting different kinds of professional, associative, demographical, geographical networks and areas. The participants were asked to complete the survey online using the ONAPS website (<http://www.onaps.fr/>). Relaunches were performed regularly until May 6<sup>th</sup> 2020, one week before the end of the confinement.

### **Data Management**

A total of 22,895 questionnaires were completed anonymously (all age ranges confounded) and included 1,178 participants aged 65 and above who were free of any complications or diseases that could have interfered with their PA or SB. The survey was administrated online using the LimeSurvey version 2.67.3 software.

### **Description of Sample**

Data were collected from 1,178 people aged 65 years and over (51.8% female). The present analysis concerns participant whose average age is  $69.7 \pm 4.2$  (min = 65, max = 96). A total of one-third (30.4%) of the sample lived in rural areas, 32.3% lived in suburban areas and 37.3% lived in urban areas. Concerning housing conditions, 3.1% of elderly people had no access to the outdoors, 14.7% had a balcony, 7.1% had access to a collective outdoor area and 75.1% had access to an individual outdoor area. None of the participants presented cognitive impairment and all of them were able to fill in the survey by themselves. None of the participants lived in a retirement home.

### **Ethical Consideration**

This work received ethical approval from the appropriate authorities (CPP Sud est VI. reference 2020/CE 27). Before accessing the online questionnaire, participants were informed of the objectives of this survey and had to give their consent to participate by checking the appropriate box.

### **Statistical Analysis**

Statistical analysis was performed using Stata software (version 15; StataCorp, College Station, Texas, USA). All tests were two-sided, with a Type I error set at 0.05. All variables were categorical and presented as number of subjects and percentages. The factors associated with the evolution before/during lock-down (increase, similarity, decrease) of the three indicators (PA level, sitting time, and screen time) were examined using chi-squared tests. Degrees of freedom (df) had been informed. Effect sizes (ES) were measured by Cramér's V and were interpreted as: 0.1 = small effect, 0.3 = medium effect and 0.5 = large effect (Cramer, 1946).

## **Results**

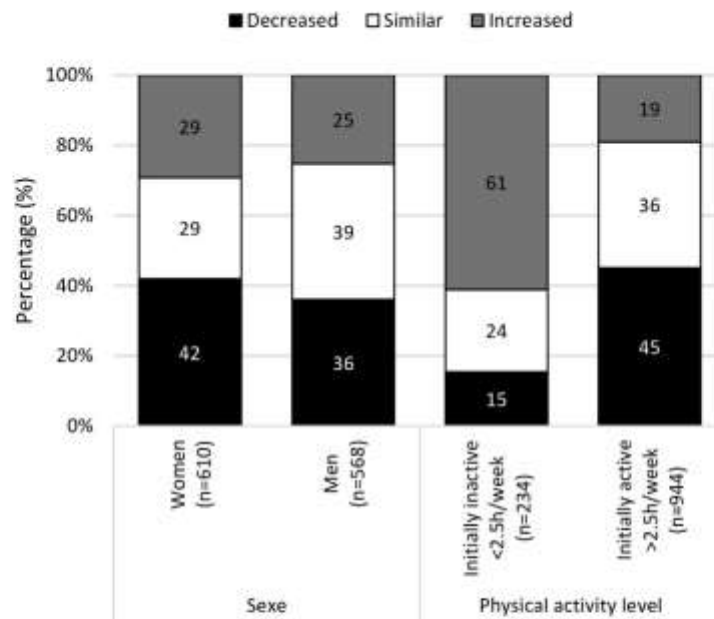
### **Physical Activity**

A total of 39.2% of elderly people ( $\geq 65$  years) reported decreased PA during the confinement, compared to 33.5% maintaining a similar volume of PA, with 27.3% declaring increases in their PA. The proportion of participants who increased, decreased or did not change their PAL during the confinement was significantly associated with gender ( $p = .002$ ,  $df = 2$ ,  $ES = 0.10$ ). According to the results presented in Figure 1, the decrease of PA during the lock-down was higher for women (42.0%) than men (36.3%).

As depicted in Figure 1, reaching PA recommendations (at least 150 minutes of PA per week) before lock-down was associated with the change in PA level during lock-down ( $p < .001$ ,  $df = 2$ ,  $ES = 0.38$ ). 45.1% of initially active old people decreased and 19.0% increased their PA during the lock-down. In the initially inactive old people only 15.4% decreased and 61.1% increased their PA during confinement.

Concerning time spent in front of a screen (sitting and screen time) before the lock-down was not associated with the PA variation between before and during lock-down (respectively  $p = .62$ ,  $p = .53$ ).





**Figure 1.** Proportion of people aged 65 years and over who increased, decreased or did not change their PA level during the confinement depending on gender and initial level of PA (> or < 2.5 h/week) (n = total number of subjects).

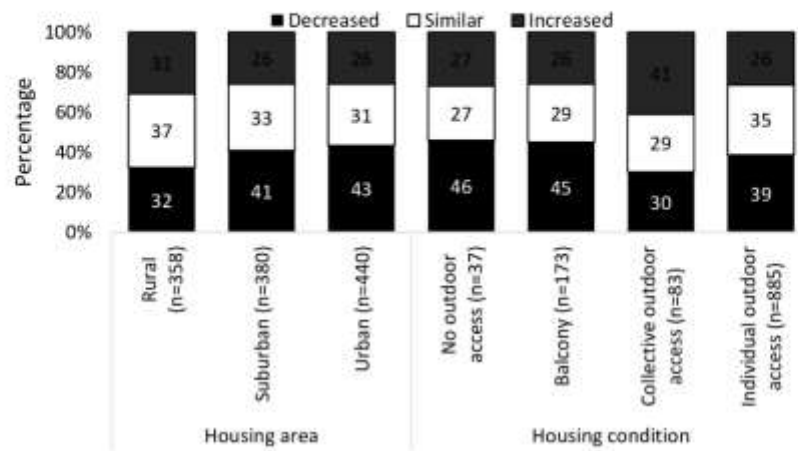
As presented in Figure 2, the geographic location (rural, suburban, urban) of the accommodation was associated with elderly people's PA variation between before and during lock-down ( $p = .03$ ,  $df = 4$ ,  $ES = 0.07$ ), while there was only a tendency regarding housing conditions (access to an outdoor area or not) ( $p = .051$ ,  $df = 6$ ,  $ES = 0.07$ ). Based on our results, PA decreased among 43.4% of old people who lived in urban areas, while those who lived in rural areas decreased of only 32.4% ( $p = .001$ ).

### Sitting Time

A total of 17.7% of seniors reported decreased sitting time during the confinement, compared to 46.2% who maintained a similar time spent of sitting, and 36.1% who declared increases in their sitting time.

Based on our results, as presented in Table 1, not exceeding sitting time recommendations (<6 h/day) before the lock-down was associated with sitting time variation between before and during confinement ( $p < .001$ ,  $df = 2$ ,  $ES = 0.25$ ). Concerning seniors who respected the recommendations of 6 h/day of sitting time before confinement, they mainly increased their sitting time during lock-down (50.9%), while those who exceeded the 6 h/day of sitting time before lock-down increased their sitting time by only 28.7%.

According to our results, PAL before lock-down was significantly associated with the variation of sitting time between before and during confinement ( $p = .02$ ,  $df = 2$ ,  $ES = 0.08$ ). A total of 37.9% of initially active seniors increased their sitting time during confinement compared to 28.4% of the inactive individuals ( $p = .007$ ).



**Figure 2.** Changes in PA level during the confinement depending on the housing situation (living area and access or not to an outdoor) of the elderly people ( $n$  = total number of subjects).

**Table 1.** Changes in sitting time during the confinement presented by initial PAL, sitting time, screen time, and housing situation of people of 65 years and over.

	Decreased	Similar	Increased	df	Chi2	Cramer's V	p-value
<b>Physical activity level</b>				2	7.45	0.08	<b>0.02</b>
Initially inactive <2.5 h/week ( $n$ = 229)	47 (20.5%)	117 (51.1%)	65 (28.4%)				
Initially active >2.5 h/week ( $n$ = 943)	160 (17.0%)	425 (45.1%)	358 (37.9%)				
<b>Sitting time</b>				2	70.98	0.25	<b>&lt;.001</b>
>6 h/day ( $n$ = 783)	177 (22.6%)	381 (48.7%)	225 (28.7%)				
<6 h/day ( $n$ = 389)	30 (7.7%)	161 (41.4%)	198 (50.9%)				
<b>Screen time</b>				2	28.22	0.16	<b>&lt;.001</b>
>2 h/day ( $n$ = 56)	12 (21.4%)	42 (75.0%)	2 (3.6%)				
<2 h/day ( $n$ = 1116)	195 (17.5%)	500 (44.8%)	421 (37.7%)				
<b>Housing area</b>				4	12.31	0.07	<b>0.02</b>
Rural ( $n$ = 354)	72 (20.3%)	175 (49.5%)	107 (30.2%)				
Suburban ( $n$ = 380)	64 (16.8%)	183 (48.2%)	133 (35.0%)				
Urban ( $n$ = 438)	71 (16.2%)	184 (42.0%)	183 (41.8%)				
<b>Housing conditions</b>				6	12.11	0.07	<b>0.06</b>
No outdoor access ( $n$ = 37)	7 (18.9%)	12 (32.4%)	18 (48.7%)				
Balcony ( $n$ = 172)	29 (16.9%)	69 (40.1%)	74 (43.0%)				
Collective outdoor access ( $n$ = 82)	16 (19.5%)	31 (37.8%)	35 (42.7%)				
Individual outdoor access ( $n$ = 881)	155 (17.6%)	430 (48.8%)	296 (33.6%)				

**Data are presented as number of subjects (row percentages), degree of freedom (df), Chi2 test, effect size (Cramer's V) and p-value. Boldfaced values:  $p < 0.05$**

The initial screen time of seniors was also associated with a variation in sitting time between before and during the lock-down. A total of 37.7% of seniors who were exposed to screens <2 h/day before confinement increased their sitting time during the lock-down, while only 3.6% of them exceed >2 h/day before the lock-down ( $p < .001$ ,  $df = 2$ ,  $ES = 0.16$ ).

As displayed in Table 1, the housing situation of seniors was significantly associated with their sitting time during confinement ( $p = .02$ ,  $df = 4$ ,  $ES = 0.07$ ) and a tendency was found for the access to an outdoor area ( $p = .06$ ,  $df = 6$ ,  $ES = 0.07$ ). According to our results, people

who lived in urban areas increased by a higher proportion their sitting time than those who lived in rural areas (41.8% vs 30.2% respectively,  $p = .001$ ).

### Screen Time

While only 7.0% of seniors decreased their screen time during the lock-down, 60.9% maintained a similar time spent in front of the screen and 32.1% of seniors increased screen time.

According to our results presented in Table 2, the time spent in front of a screen before the lock-down is associated with evolution of screen time between before and during confinement ( $p < .001$ ,  $df = 2$ ,  $ES = 0.21$ ). People of 65 years and over who reached the screen time recommendations before the lock-down (<2 h/day) increased their screen time by 33.0%, while increases of 16.1% was recorded for individuals who exceeded the recommendations before confinement ( $p = .008$ ).

According to our results, the PAL before lock-down was significantly associated with the evolution of screen time for people of 65 years and over between before and during confinement ( $p = .001$ ,  $df = 2$ ,  $ES = 0.11$ ). Seniors who were initially active increased their PAL by 34.5%, or maintained a similar volume of PA of 59.2% or decreased by 6.3%, while those who were initially inactive increased by 22.6% their PAL, maintained their PAL by 67.8% and decreased their PAL by 9.6%.

Meeting the sitting time recommendations (<6 h/day) before the confinement was significantly associated with the evolution of screen time between before and during confinement in seniors ( $p < .001$ ,  $df = 2$ ,  $ES = 0.14$ ). Seniors who had a sitting time >6 h/day before the lock-down increased their screen time during confinement by 28.6% compared to those who showed a sitting time <6 h/day before the lock-down (39.2%).

**Table 2.** Changes in screen time during the confinement presented by initial PAL, sitting time and screen time of people of 65 years and over.

	Decreased	Similar	Increased	df	Chi2	Cramer's V	p-value
<b>Physical activity level</b>				2	13.07	0.11	<b>0.001</b>
<i>Initially inactive &lt;2.5 h/week (n = 230)</i>	22 (9.6%)	156 (67.8%)	52 (22.6%)				
<i>Initially active &gt;2.5 h/week (n = 943)</i>	60 (6.3%)	558 (59.2%)	325 (34.5%)	2	21.45	0.14	<b>&lt;.001</b>
<b>Sitting time</b>				2	51.17	0.21	<b>&lt;.001</b>
<i>&gt;6 h/day (n = 783)</i>	69 (8.8%)	490 (62.6%)	224 (28.6%)				
<i>&lt;6 h/day (n = 390)</i>	13 (3.3%)	224 (57.5%)	153 (39.2%)	2	51.17	0.21	<b>&lt;.001</b>
<b>Screen time</b>				2	51.17	0.21	<b>&lt;.001</b>
<i>&gt;2 h/day (n = 56)</i>	17 (30.3%)	30 (53.6%)	9 (16.1%)				
<i>&lt;2 h/day (n = 1117)</i>	65 (5.8%)	684 (61.2%)	368 (33.0%)	2	51.17	0.21	<b>&lt;.001</b>
<b>Housing area</b>				4	11.46	0.07	<b>0.02</b>
<i>Rural (n = 354)</i>	29 (8.2%)	232 (65.5%)	93 (26.3%)				
<i>Suburban (n = 380)</i>	25 (6.6%)	235 (61.8%)	120 (31.6%)	4	11.46	0.07	<b>0.02</b>
<i>Urban (n = 439)</i>	28 (6.4%)	247 (56.2%)	164 (37.4%)	4	11.46	0.07	<b>0.02</b>
<b>Housing conditions</b>				6	14.43	0.08	<b>0.03</b>
<i>No outdoor access (n = 37)</i>	4 (10.9%)	18 (48.6%)	15 (40.5%)				
<i>Balcony (n = 173)</i>	16 (9.2%)	92 (53.2%)	65 (37.6%)	6	14.43	0.08	<b>0.03</b>
<i>Collective outdoor access (n = 82)</i>	9 (11.0%)	42 (51.2%)	31 (37.8%)				
<i>Individual outdoor access (n = 881)</i>	53 (6.0%)	562 (63.8%)	266 (30.2%)	6	14.43	0.08	<b>0.03</b>

Data are presented as number of subjects (row percentages), degree of freedom (df), Chi2 test, effect size (Cramer's V) and p-value. Boldfaced values:  $p < 0.05$

Based on our results presented in Table 2, the housing conditions and area were significantly associated with screen time (significantly  $p = .02$ ,  $df = 4$ ,  $ES = 0.07$  and  $p = .03$ ,  $df = 6$ ,  $ES = 0.08$ ). Seniors who lived in urban areas increased their screen time by 37.4% against 26.3% for those who lived in rural areas ( $p = .001$ ).

## Discussion

This study aimed to describe the movement behaviors (physical activity and sedentary behaviors), and their determinants, of elderly people aged 65 or over during the confinement. In March 2020, a national and international lock-down of the population was established to slow down the deleterious effects of the global COVID-19 pandemic. Some national surveys have been conducted to evaluate the impact of this pandemic on individuals' movement behaviors. All of these studies found that physical activity levels decreased during the lock-down combined with an increase in sedentary behaviors (screen time, sitting time). The majority of these studies have investigated adult populations but not seniors ( $\geq 60$  or  $\geq 65$  years). For this reason, the French National ONAPS COVID-19 Survey assessed the effect of the confinement on physical activity levels and sedentary behaviors in seniors. Importantly, this work seems to be the first to describe the impact of this confinement among elderly French individuals, particularly considering their initial sedentary and physical activity profiles as well their housing conditions as potential determinants of these impacts.

According to national statistics (INCA 3, 2017), a large proportion of people aged 65 or over (63%) did not reach the recommended physical activity levels, with men being more likely to achieve these recommendations than women (68% against 57%) (Larras, 2018). These results are not in agreement with our findings, where only 20% of people were not achieving physical activity recommendations. Functional ability is key to increase the quality of life of seniors, reduce frailty and maintain independence and activity during daily life and associated aging (Christensen, Doblhammer, Rau, & Vaupel, 2009; Geirsdottir et al., 2012; OMS, 2019). Considering the positive impact of PA on health and specifically diseases associate with aging such as sarcopenia or cognitive decline (Blondell, Hammersley-Mather, & Veerman, 2014; Lautenschlager et al., 2004; Marzetti et al., 2017; Sun et al., 2013), the health status of seniors was already at alarming levels prior to the lock-down. In our study, more than one-third (39.2%) of the sample decreased their PA during the lock-down, and this was more pronounced in women (42.0%) than men (36.3%). These results agree with observations in other countries such as Italy who reported that one-third of old people with cognitive impairment or decline decreased their PA during lock-down (Di Santo et al., 2020). Japan reported a decrease of 26.5%, for all frailty categories (Yamada et al., 2020) as did France (Goethals et al., 2020). Interestingly, our results are the first to evaluate the effect of the lock-down stratified by the initial (pre-confinement) level of PA in seniors. Our results showed that this drastic decline in PA during this particular period affected more initially active seniors than inactive seniors. Indeed, high proportions of active (45.1%) reported a decreased PA contrary to those who were inactive with only 15.4% reporting a decrease in PA levels. Even more striking, 61.1% of initially inactive seniors increased their PA during lock-down, with only 19.0% recording an increase for active individuals. Our results clearly highlight that initially active seniors might be particularly concerned by the deleterious effects of the confinement, they also show that a higher initial

level of PA of seniors might not prevent them from decreasing their PA during the lock-down. While some authors previously underlined the role of the vulnerability of older persons (avoiding contact), material conditions for the practice of PA (Goethals et al., 2020) in the decrease of PA during the lock-down, our results also identified the geographical location of the accommodation and the access to outdoor facilities as primary influences. High proportions of seniors (43.4%) living in urban areas who did not have access to outdoor facilities (46.0%), showed a significant decrease in PA as a result of stay-at-home orders.

These results are not in concordance with those of a recent French survey in adults ( $n = 386$ ) conducted during the lock-down, who identified only the habitat areas as an influencing factor for the engagement in PA during confinement but not the access to an outdoor area (Teran-Escobar et al., 2020). Other characteristics related to the living areas such as access to recreational facilities or parks, living in high-walkable neighborhoods or living in a rural environment (especially concerning women) need consideration as factors influencing PA in seniors (Cook, Alberts, & Lambert, 2012; Strath et al., 2012; Van Cauwenberg, Nathan, Barnett, Barnett, & Cerin, 2018).

Although our results demonstrated that 36.1% of old people increased their sitting time during the French lock-down, they also underline an increase in screen time of 32.1%. These results are lower than those of an Italian study conducted among old people with cognitive impairment who showed an increase of SB of 70% (Di Santo et al., 2020) and a Brazilian survey who showed an increase in time spent in front of TV + PC between before and during the lock-down (Werneck et al., 2020). Interestingly, sitting and screen time increased regardless of initial PAL, but would seem to be more important for people with cognitive impairment. As indicated concerning PAL, our results reinforce the important role of the housing environment (conditions and areas) on both sitting and screen time during the lock-down, with seniors from urban areas that had no access to an outdoor most affected. The lower PA levels observed may be related to lower social interactions, that may have a negative impact on mental health.

A survey conducted during the lock-down in France and Switzerland showed the positive impact of PA on physical health but the negative impact of SB on physical health, mental health and subjective vitality (Cheval et al., 2020). The lock-down imposed in March 2020 in France has accelerated behaviors already identified as being detrimental to health, such as the lack of PA and increased SB. Yet, low PAL and high SB are associated with an increase in the risks of frailty, leading to a decrease in autonomy (Da Silva et al., 2019; Kehler et al., 2018; Vagetti et al., 2014), promoting PA and reducing SB are essential to promote healthy aging of the elderly.

The present study has some limitations. The first is the nature of the collected data which was online and subjective self-reported. The questionnaire was submitted online, which may have had limited access for poorer, migrant sectors of the population or elderly population without internet access, which is a bias related to recruitment. However, conducting and analyzing the data for a large-scale national survey can be logistically challenging, and conducting it online makes it feasible. The presence of any diseases or complications that could interact with the practice of PA and encourage SB has not been analyzed. This could also represent a limitation. There is also a possibility of change in PA and SB during the confinement (intra-confinement change) (López-Bueno et al., 2020). These potential modifications of movement behaviors should be attenuated as they were

shown to occur in the last two weeks of confinement and the online survey stopped one week before the end of the confinement (Pépin et al., 2020). Another limitation lies in the categorization of PAL and SB that did not show changes in levels within a category, seniors may have increased or decreased PAL or SB without changing subcategories without this change being apparent. More than 1,000 older adults completed this French survey, outlining the strength of this work, but few people exceeded screen time's recommendations and did not have access to an outdoor area, which represents a limitation. This also makes our sample not representative of the general population, which must also be considered.

To conclude, the present results confirm the negative impact of the first COVID-19-related confinement period on senior movement behaviors. During the confinement, ONAPS published some recommendations that could be considered to promote PA for elderly populations during confinement. These include encouragement to engage in simple activities such as walking and keeping in mind that exercising does not have to be painful and we have to listen to our own feelings and capacities to progressively improve. It is important to minimize sedentary behaviors from the early days of confinement, to avoid lethargy and adopt healthy movement behaviors and habits (Thivel et al., 2021). Knowledge and consideration of the factors influencing the practice of physical activity during confinement, and conversely those which increase the risk of sedentary behaviors, are essential in order to propose future public health actions for the needs of populations. The influence of the environment and the housing for older people will therefore have to be considered in future strategies to reduce sedentary lifestyles and increase physical activity levels.

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### ORCID


C Chambonniere  <http://orcid.org/0000-0003-4998-6221>


C Lambert  <http://orcid.org/0000-0002-6459-4800>

A Fillon  <http://orcid.org/0000-0002-0614-8909>

P Genin  <http://orcid.org/0000-0002-4565-8143>

B Larras  <http://orcid.org/0000-0002-9774-1803>

a Tremblay  <http://orcid.org/0000-0002-0824-0530>

D Thivel  <http://orcid.org/0000-0003-4687-3555>

M Duclos  <http://orcid.org/0000-0002-7158-386X>

### Declaration Of Interest Statement

The authors have no conflict of interest to disclose.

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## Conclusion de l'étude

En accord avec les résultats rapportés dans d'autres pays, la présente étude confirme les répercussions néfastes du premier confinement liées à la pandémie de COVID-19 sur les comportements de mouvement chez les personnes âgées. Nos résultats montrent que cette diminution drastique de l'AP chez plus d'un tiers des personnes durant cette période a touché plus de séniors initialement actifs que de séniors inactifs. Nos résultats ont également identifié le fait de vivre en milieu urbain et de ne pas avoir accès à un extérieur dans son logement comme des facteurs influençant la pratique d'AP pendant le confinement.

Nos résultats démontrent également que le temps passé assis et devant un écran ont considérablement augmenté pendant le confinement en France. Comme indiqué pour le niveau d'AP, nos résultats renforcent le rôle important de l'environnement du logement sur le temps passé en position assise et devant un écran pendant le confinement, les personnes âgées des zones urbaines n'ayant pas accès à un espace extérieur étant les plus touchées.

## AXE II : Effets de l'utilisation d'une stratégie active sur des paramètres de santé des élèves de primaires

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*Publication 3 : Effets du COVID-19 et des restrictions sanitaires associées sur les capacités physiques et cognitives des enfants de primaire.*

Ces dernières décennies, il a été observé un accroissement de la prévalence de l'inactivité physique et de la sédentarité chez les enfants et les adolescents. Comme décrit dans l'étude précédemment détaillée, la pandémie de COVID-19 a également impacté les habitudes de vie des enfants et adolescents.

Dans ce contexte, l'objectif de la présente étude est d'évaluer si le confinement et les restrictions sociales liés à COVID-19 ont affecté les niveaux de condition physique et de capacités cognitives chez les enfants de l'école primaire.



Article

# Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children

Camille Chambonnière <sup>1</sup> , Nicole Fearnbach <sup>2</sup>, Léna Pelissier <sup>1,\*</sup>, Pauline Genin <sup>3</sup>, Alicia Fillon <sup>1,3</sup> , Audrey Boscaro <sup>1</sup>, Line Bonjean <sup>1</sup>, Mélina Bailly <sup>1</sup>, Julie Siroux <sup>1</sup>, Terry Guirado <sup>1</sup> , Bruno Pereira <sup>4</sup> , David Thivel <sup>1,3,5</sup> and Martine Duclos <sup>3,5,6,7,8</sup>

- <sup>1</sup> Laboratory of Metabolic Adaptations to Exercise under Physiological and Pathological Conditions, Clermont Auvergne University, 63000 Clermont-Ferrand, France; camille.chambonniere@uca.fr (C.C.); fillonalicia@gmail.com (A.F.); audrey.boscaro@uca.fr (A.B.); line.bonjean@etu.uca.fr (L.B.); melina.bailly@uca.fr (M.B.); julie.siroux@etu.uca.fr (J.S.); terry.guirado@uca.fr (T.G.); david.thivel@uca.fr (D.T.)
- <sup>2</sup> Clinical Sciences Division, Pennington Biomedical Research Center, Baton Rouge, LA 70808, USA; nicole.fearnbach@pbrc.edu
- <sup>3</sup> National Observatory for Physical Activity and Sedentary Behaviors, 63000 Clermont-Ferrand, France; p.genin@onaps.fr (P.G.); mduclos@chu-clermontferrand.fr (M.D.)
- <sup>4</sup> Biostatistics Unit, Clermont-Ferrand University Hospital, 63000 Clermont-Ferrand, France; bpereira@chu-clermontferrand.fr
- <sup>5</sup> Clermont Auvergne University Foundation, 63000 Clermont-Ferrand, France
- <sup>6</sup> UFR Medicine, Clermont Auvergne University, 63000 Clermont-Ferrand, France
- <sup>7</sup> INRA, UMR 1019, 63000 Clermont-Ferrand, France
- <sup>8</sup> Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, 63000 Clermont-Ferrand, France
- \* Correspondence: lena.pelissier@uca.fr



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**Abstract:** The aim of the present study was to evaluate whether the COVID-19-related confinement and social restrictions affected the levels of physical fitness and academic achievement in primary school French children. A total of 206 primary school children (106 before confinements and 100 after restrictions) completed a test battery evaluating their anthropometric characteristics, body compositions, activity preferences, cognitive performances and physical fitness. The performance of the Standing Long Jump was better at T0 ( $169.9 \pm 142.5$  cm) compared to T1 ( $135.2 \pm 31.4$  cm) ( $p = 0.0367$ ), and the Medicine Ball Throw performance declined from T0 to T1 ( $297.3 \pm 81.1$  cm vs.  $249 \pm 52$  cm;  $p < 0.0001$ ). Motor skills ( $26.9 \pm 6.2$  s vs.  $30.9 \pm 5.4$  s;  $p < 0.0001$ ), the shuttle-run test (stages completed), Maximal Aerobic Speed, and the estimated  $\dot{V}O_{2max}$  were lower at T1 compared to T0 ( $p < 0.0001$ ). Executive functioning was found to be greater at T0 compared to T1 ( $p < 0.0001$ ). Explicit liking or wanting for sedentary or physical activities did not change between T0 and T1. Both overall physical fitness and cognitive performance drastically declined among primary school French children with the COVID-19-related public health restrictions, which reinforces the need to urgently develop preventive strategies in anticipation of further mitigation measures.

**Keywords:** COVID-19; physical fitness; executive function; confinement; children

## 1. Introduction

After its appearance in Wuhan, China, in December 2019, the worldwide transmission of the SARS-CoV-2 virus (COVID-19) led to an unprecedented public health crisis, leading the World Health Organization (WHO) officially declaring a global pandemic on 11 March 2020. In the span of about 7 days, the progression of the virus led to global school closures in order to reduce the amount of social contact between students. Nearly 850 million children and adolescents were subjected to stay-at-home orders and engaged

in virtual learning [1–3]. In France, a general national confinement was imposed on 17 March 2020, for a total of 55 days, with all primary and secondary schools closed and all teaching activities conducted online. Although the restrictions were removed in May 2020, protective measures and preventive precautions, which encouraged social distancing, were maintained throughout 2020.

As a direct consequence, the movement behaviors of both adults and youth have been affected and a plethora of international publications have clearly described an alarming decline in physical activity levels, with a simultaneous increase in sedentary behaviors (SED) in children and adolescents [4]. While these COVID-19-related alterations of PAL and SED time in youth have been associated with impaired mental, physical, and metabolic health and overall well-being [5–9], few results are available regarding the impact on objectively measured physical fitness. In a recent work, Wahl-Alexander and Camic assessed 9- to 14-year-old children's cardiorespiratory fitness (20 m Progressive Aerobic Cardiovascular Endurance Run PACER) and muscle strength (curl-up and push-up tests) between August 2019 and July 2020 [10]. Although their baseline evaluation occurred about 7 months before the lockdown itself, the authors observed a significant decline in both cardiovascular endurance (26.7%) and muscle strength (20% decline at the push-up test and 35.6% decline at the sit-up test) in both boys and girls [10]. Lopez-Bueno et al. [11] also assessed cardiovascular fitness among 89 adolescent boys and girls aged  $13.3 \pm 0.9$  years old using the multi-stage 20 m shuttle-run test, which showed that only girls experienced a significant decrease in estimated  $VO_{2max}$ . However, the data for this study were collected between November 2019 and November 2020, which does not exclusively isolate the lockdown period. More recently, Jarnig and colleagues reported a decreased cardiorespiratory fitness among 764 7- to 10-year-old Austria children, all of whom exhibited a significantly increased body mass index [12]. These few studies provide, to our knowledge, the only available evidence regarding the potential effect of the COVID-19 period on objectively assessed fitness in youth. Given that fitness is associated with children's leisure time activity preferences [13], it is important to investigate whether declines in fitness during the COVID-19 pandemic are associated with a greater desire to be sedentary, as this may pose a barrier to intervention.

Little is known regarding the effect of the COVID-19 confinement on academic achievement and executive functioning in children, while the imposed public health precautions kept the kids away from face-to-face teaching. In young adults, the lockdown negatively impacted executive function, particularly among individuals with pre-existing deficits [14]. In children, the early data from online-learning platforms indicate a drop in completed coursework [15] and an increased dispersion of test scores [16]. In their recent landmark study based on a database involving about 350,000 children aged 8- to 11-year-old from the Netherlands, Engzell and collaborators clearly underlined that children made little or no progress while learning from home during the confinement compared to a normal academic year [17]. Importantly, this learning loss was more pronounced among kids from disadvantaged homes [17]. Such cognitive and academic declines can be attributed to the stress induced by the lockdown conditions and the pandemic situation, the lower intellectual stimulation during virtual classes, and the increased sedentary time, especially screen time [18–20]. We hypothesize that a decline in physical fitness could also be involved, based on previous studies of the association between fitness and academic achievement in children and adolescents [21,22].

In this context, the aim of the present study is to evaluate whether the COVID-19-related confinement and social restrictions affected the levels of physical fitness and academic achievement in primary school French children. Using a forced-choice paradigm to understand implicit activity preferences [13], we also questioned the effect of this specific lockdown period on primary school children's desires to be sedentary vs. physically active.

## 2. Materials and Methods

### 2.1. Population and Design

This study is part of the French National Observatory for Physical Activity and Sedentary Behaviors (ONAPS) national survey evaluating the impact of the 2020 COVID-19-related confinement. The baseline evaluations were taken in February 2020 (T0), right before the lockdown and the intervention that was supposed to last from March to May 2020 was cancelled. The same test battery was then conducted among children in 3rd and 4th grade after the lockdown and end of restrictions limiting social interactions in France (January 2021, T1).

A total of 206 primary school children from 3rd and 4th grades participated, 106 at T0 and 100 in T1. Children completed a test battery evaluating their anthropometric characteristics, body compositions, activity preferences, cognitive performances and physical fitness. Both parents and children received initial and adapted information sheets and signed consent forms as required by local ethical regulations (CPP Sud est VI. reference 2020/CE 27).

### 2.2. Anthropometric Characteristics and Body Composition

Body mass weight (kg) and height (cm) were measured by using a standard apparatus (Seca, Lea Mureaux), to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI) was calculated as body weight divided by height squared (kilogram per square meter). Children were classified as having obesity (OG, [95th–99th] percentile) or extreme obesity (EOG, >99th percentile), according to BMI curves, chronological age and sex (Centers for Disease Control and Prevention—CDC) [23]. Body composition was assessed by bioelectrical impedance using a Tanita MC-780 multi-frequency, segmental body-composition analyzer. This consisted of a stand-alone unit which the participant had to step on with bare feet (standard mode). Information about the participant (age, sex, and height) was entered by the experimenter. Once body mass had been assessed by the Tanita scale, the participant had to take grips in both hands (alongside his/her body) during the impedance measurement (hand to foot). A full segmental analysis was performed in less than 20 s. This technology has been validated in children of various adiposity levels, showing a good level of validity and sensitivity to changes [24,25].

### 2.3. Executive Function

Executive function was assessed through the Trail Making Test (TMT), a 5 min pen-and-paper test with two sub-parts (A and B). The TMT-A evaluates the speed of treatment and attention while the TMT-B evaluates mental flexibility and executive functioning [26]. The TMT-A required children to connect, as quickly as possible, circles numbered from 1 to 25 in ascending order. The TMT-B contains circles, numbers and letters (from 1 to 25 and from A to Y) and the children were asked to connect them as quickly as possible in ascending order (e.g., 1-A, 2-B, 3-C). The time taken to complete each task (in seconds) and the number of mistakes was noted. This test has been validated in children [27].

### 2.4. Physical Fitness

#### 2.4.1. Cardiorespiratory Fitness

The 20 m shuttle-run test developed by Léger et al. was used as an indirect measurement of aerobic fitness [28]. This test is based on the linear relationship between the increase in oxygen consumption and the increase in running speed. The reliability of this test in both children and adults for the determination of maximum oxygen uptake has already been described [29]. During the test, participants were instructed to run as long as possible between two lines drawn 20 m apart at an increasing speed, which was imposed by a recording that emitted tones at appropriate intervals. For the first few minutes of the test, the speed was set to 8 km/h and then increased by 0.5 km/h every minute. Children ran in groups of no more than five and were encouraged by a member of the research team. As soon as a child was not able to complete a whole stage, the test was stopped and the child's

score corresponding to the last fully completed stage was recorded. The Maximal Aerobic Speed (MAS) was then calculated. The maximum oxygen intake ( $VO_{2max}$ ) was estimated using the following validation equation:  $Y = 31.025 + 3.238X - 3.248A + 0.1536AX$ , where X refers to the MAS and A to the age [29]. The 20 m shuttle-run test has been validated and found to be reliable for the prediction of  $VO_{2max}$  in children and adolescents [30] with a good reproducibility in children and adolescents between ages 8 and 18 [29,31–33].

#### 2.4.2. Upper-Body Muscular Strength

Upper-body muscular strength was measured with a handgrip dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan). A previous study reported acceptable inter-trial reliability for the hand dynamometer [34]. The participants were asked to adjust the handgrip bar so that the second joint of the fingers was bent to grip the handle of the dynamometer. The participants stood upright with their arms in a vertical position and the dynamometer close to the body. They were then asked to squeeze the hand dynamometer as hard as possible. The test was completed twice, in the left and right arms, and the best recordings of both the arms were averaged. Participants also performed a Medicine Ball Throw test that measures the explosive power of the upper limbs when throwing a medicine ball as far as possible. Participants were seated in a chair with their feet shoulder-width apart and their backs supported so that only upper-body strength was used. The medicine ball was held at shoulder height and thrown forward with a counter movement of the forearms. The test was performed twice, and the research staff recorded the distance between front chair leg and the medicine ball landing site (to the nearest 0.5 cm). The Medicine Ball Throw test has been validated and is reliable for children and adolescents with an ICC = 0.98 [35].

#### 2.4.3. Lower-Body Muscular Strength

Lower-body muscular strength was measured using the Standing Long Jump test. The test was performed on a non-slip hard surface. Participants were asked to jump the longest distance possible from a standing start while swinging both arms. The distance from the take-off line to the point where the back of the heel touched the surface was measured using a measuring tape. The test was conducted twice, and the best score was used [36]. The Counter Movement Jump test was also performed using an Optojump (Microgate Co., New York, NY, USA) [37]. The starting position was a standing position with a straight torso and knees fully extended with the feet shoulder-width apart [37]. Participants were asked to keep their hands on their hips throughout the whole jump. They were instructed to perform a quick downward movement (approximately 90° of knee flexion), and afterward a fast upward movement to jump as high as possible.

#### 2.5. Implicit Activity Preferences

The Activity Preference Assessment (APA) is a computerized behavioral task designed to assess and quantify biases in decision making across multiple leisure time activities [13]. The APA is administered on a desktop computer via E-Prime (Psychology Software Tools, Sharpsburg, PA, USA) and takes approximately 10 min to complete. Each participant was first asked how much they like taking part and want to take part in a variety of common physical activities (e.g., ball sports, swimming) and sedentary activities (e.g., arts and crafts, watching TV) using visual analog scales (VAS) to quantify explicit liking and explicit wanting (range 0 to 100). They then complete a forced-choice paradigm, or “would you rather?” game. Out of each pair of activity images (4 sets of 30 pairs, with breaks between sets), they were asked to select, as quickly as possible, the activity they most want to do in order to assess implicit wanting. Sixty-four of the 120 pairs were sedentary vs. physical activities, with the remaining pairs falling within category. Every pair is unique and all possible comparisons were made. Implicit wanting scores from the head-to-head comparisons of sedentary vs. physical activities take into account the choices made and reaction times. These scores were used to compute the bias score (range of –100

to +100), thereby quantifying the relative implicit preference. Positive (+) scores represent a relative preference towards sedentary activities and negative (−) scores represent a relative preference towards physical activities. The data were processed via an automated scoring procedure in Anaconda3 (Austin, TX, USA). The APA was originally developed and validated in English [13], but herein we present data from the French version. All text within the APA and the corresponding participant instructions were translated to French by a bilingual French and English speaker and then back-translated to English to confirm that the original meaning of all the text was retained.

### 2.6. Statistical Analysis

Continuous data are expressed as mean and standard deviation. The assumption of normality was assessed by using the Shapiro-Wilk test. The comparisons between baseline (T0) and after the lockdown and end of restrictions evaluations (T1) were performed using Student's *t* test or Mann-Whitney test if the assumptions to apply *t*-tests were not met. The homoscedasticity was analyzed using the Fisher-Snedecor test. Particular attention was paid to the magnitude of T0–T1 differences. The results were expressed using Hedge's effect size (ES) and 95% confidence interval, and were interpreted according to the rules of thumb reported by Cohen [38], who defined the ES bounds as: small (ES = 0.2), medium (ES = 0.5), and large (ES = 0.8). To analyze the relationships between continuous parameters, Pearson and Spearman correlation coefficients were estimated according to the statistical distribution of variables, and were interpreted as follows: <0.2 negligible, 0.2 to 0.4 weak, 0.4 to 0.7 moderate, >0.7 strong [39]. All statistical analyses were carried out using Stata software (version 15, StataCorp, College Station, TX, USA) for a two-sided Type I error at 5%, with a Sidak's type I error correction to take into account multiple comparisons.

## 3. Results

A total of 206 healthy-weight kids of ages 9 to 10 participated in the study. At T0, 106 children ( $9.9 \pm 1.03$  y) completed the evaluations, including 55 girls ( $9.9 \pm 1.03$  y) and 51 boys ( $9.8 \pm 1.06$  y). At T1, 100 kids completed the evaluation ( $9.4 \pm 0.6$  y), including 47 girls ( $9.4 \pm 0.6$  y) and 53 boys ( $9.4 \pm 0.6$  y).

The participant characteristics, fitness, and executive function scores from T0 and T1 are detailed in Table 1. Weight (kg), BMI ( $\text{kg}/\text{m}^2$ ) and the percentage of fat mass (FM%) did not differ. While there was not significant difference in the Counter Movement Jump height, the performance of the Standing Long Jump was better at T0 ( $169.9 \pm 142.5$  cm) compared to T1 ( $135.2 \pm 31.4$  cm) ( $p = 0.0367$ ). Regarding physical fitness in the upper limbs, handgrip strength did not differ over time, but Medicine Ball Throw performance declined from T0 to T1 ( $297.3 \pm 81.1$  cm vs.  $249 \pm 52$  cm;  $p < 0.0001$ ). The performance of the motor skills test was found to be significantly better (lower execution time) at T0 compared with T1 ( $26.9 \pm 6.2$  s vs.  $30.9 \pm 5.4$  s;  $p < 0.0001$ ) (Figure 1A). The shuttle-run test (stages completed), MAS, and estimated  $\text{VO}_{2\text{max}}$  were all significantly lower at T1 compared to T0 ( $p < 0.0001$ ) (Figure 1B). Results from the cognitive functioning task are presented in Table 1 and Figure 2, with better performances seen in part A, part B, and the total score at T0 compared to T1 ( $p = 0.0009$ ;  $p = 0.0008$  and  $p < 0.0001$ , respectively).

There were associations between the TMT total score and the shuttle-run test performance ( $r^2 = -0.292$ ;  $p = 0.0043$ ), handgrip strength ( $r^2 = -0.279$ ;  $p = 0.0069$ ) and Standing Long Jump performance ( $r^2 = -0.221$ ;  $p = 0.0336$ ) at T0. The TMT total score was associated with handgrip strength ( $r^2 = -0.366$ ;  $p = 0.0003$ ) and Counter Movement Jump performance ( $r^2 = -0.279$ ;  $p = 0.0098$ ) at T1.

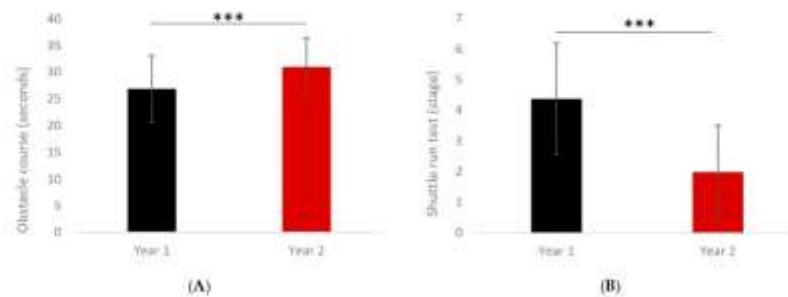
A subsample of participants ( $n = 51$  at T0;  $n = 51$  at T1) completed the APA. Children did not show a difference in explicit liking or wanting for sedentary or physical activities between T0 and T1 (all  $p > 0.05$ ). Similarly, there was not a statistically significant difference in bias scores (relative preference) from the forced-choice task between T0 ( $-9.5 \pm 44.4$ , physical activity preference) and T1 ( $6.2 \pm 53.5$ , sedentary preference) ( $p = 0.12$ ).



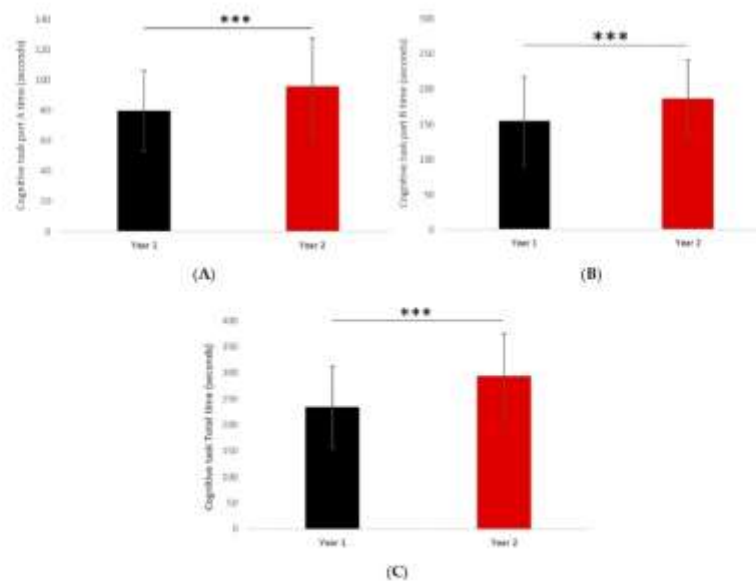
**Table 1.** Anthropometric characteristics, physical fitness, and cognitive functioning results between T0 and T1.

	T0		T1		p	ES
	Mean	SD	Mean	SD		
Weight (kg)	32.96	8.71	35.13	10.26	0.1862	−0.22 [−0.56; 0.11]
BMI (kg/m <sup>2</sup> )	17.23	3.51	18.20	3.94	0.1425	−0.25 [−0.59; 0.09]
FM (%)	24.23	7.20	24.41	6.85	0.9031	−0.02 [−0.42; 0.37]
CMJ (cm)	18.01	4.60	17.36	3.51	0.3213	0.15 [−0.15; 0.46]
SBJ (cm)	169.87	142.57	135.23	31.40	0.0367	0.33 [0.01; 0.64]
Handgrip (N)	14.30	3.54	14.02	3.04	0.5892	0.08 [−0.22; 0.39]
TMB (cm)	297.28	81.11	249.06	52.13	<0.0001	0.70 [0.38; 1.01]
Motor skills (s)	26.88	6.26	30.97	5.43	<0.0001	−0.69 [−1.01; −0.37]
MAS (km/h)	9.68	0.90	9.00	0.75	<0.0001	0.80 [0.48; 1.12]
VO <sub>2max</sub> (mL/min/kg)	45.66	4.25	43.05	3.69	<0.0001	0.65 [0.33; 0.96]
Shuttle run stage	4.37	1.81	1.98	1.52	<0.0001	1.41 [1.06; 1.75]
TMT-A (s)	79.69	26.47	95.60	32.36	0.0009	−0.53 [−0.85; −0.22]
TMT-B (s)	154.43	62.95	186.44	54.63	0.0008	−0.53 [−0.85; −0.22]
TMT-Tot (s)	234.12	77.90	293.24	80.98	<0.0001	−0.74 [−1.05; −0.41]

T0: Baseline; T1: Time 1; BMI: Body Mass Index; CMJ: Counter Movement Jump; ES: Effect Size; FM: Fat Mass; MAS: Maximal Aerobic Speed; p: p value; SBJ: Standing Broad Jump; SD: Standard Deviations; TMB: Throw Medicine Ball; TMT: Trail Making Test.



**Figure 1.** Performances at the Motor Skills Obstacle Course (A) and shuttle-run test (B) between T0 (year 1) and T1 (year 2). \*\*\*  $p < 0.0001$ .



**Figure 2.** Results of the parts A and B (A,B) of the Trail Making Test and Total score (C) at T0 (year 1) and T1 (year 2). \*\*\*  $p < 0.0001$ .

#### 4. Discussion

While there has been a consistently growing body of scientific literature describing an alarming overall decline in physical activity levels and an increase in sedentary time during the COVID-19-related confinement [40], few studies have examined downstream effects on physical fitness and cognitive functioning, especially in children. Prior to the COVID-19 crisis, Tomkinson and collaborators described a reduction in physical fitness by about 25% over the last 40 years in children, which was a function of reduced physical activity levels and increased sedentariness [41]. In line with this trend, our concern is that the unprecedented acceleration of children's inactivity and sedentariness induced by the lockdown has negatively impacted physical fitness beyond the usual declines over time. Moreover, this public health crisis has resulted in poorer school engagement, which can have detrimental effects on academic performance and executive function. Previous studies have clearly shown that physical fitness, particularly cardiorespiratory fitness, is strongly associated with executive functioning and academic achievement in children and adolescents [21]. Therefore, concomitant declines in these markers can be expected under such extreme circumstances.

In the current study, both muscle strength and cardiorespiratory fitness were significantly reduced among 3rd- and 4th-grade children after the COVID-19 lockdown period compared with pre-pandemic performances. These results are in accordance with previously published findings showing a decline in both cardiovascular [10,11,13] and muscle performances [10] of children and adolescents. Importantly, while the previous studies assessed physical fitness in the same participants before and after, the time intervals between their two evaluations were larger than the lockdown periods, and therefore did not isolate the effects of the consecutive COVID-19-related restrictions.

The present study is the first to also question the potential effect of the pandemic mitigation measures on children's activity preferences. Using a computerized behavioral task designed to assess and quantify biases in decision making across multiple physical and sedentary activities [13], our results suggest that despite a clear decline in physical activity levels [40], increase in sedentary time [40], and reduction in overall fitness, the explicit liking and wanting were not detrimentally affected. Though there was a slight shift from a mean preference for physical activities towards a mean preference for sedentary activities, the difference in bias scores was not statistically significant. Indeed, scores at T0 and T1 were close to 0, indicating an equal preference. This result is encouraging, indicating that the observed deleterious effects of the lockdown on movement behaviors and physical health might not be irreversible, and that children might be willing to re-engage in active behaviors, pending adapted and appropriate interventions and messaging.

Although our results show only modest correlations between fitness and executive function task outcomes both at T0 and T1, we observed an alarmingly lower cognitive performance in 3rd- and 4th-grade children after the confinement compared with age-matched participants before the public health restrictions. As previously described, the stress induced by the sanitary crisis [18–20] as well as the lower intellectual stimulation induced by a reduction in school time and the use of virtual classes could explain such a decline. Importantly, while some studies showed that this confinement-related cognitive decline was more pronounced among children from disadvantaged socio-economic backgrounds [17], 50% of the re-enrolled classes of the present study were located in low socio-economic areas and 50% in high socio-economic areas, and no differences were observed between these school-types. In other words, our results suggest that the negative impact of the lockdown on children's executive function might have been independent of the socio-economic origin of the kids. It is also possible that the alarming reductions in children's healthy movement behaviors, combined with the decline in their physical fitness, might have directly impacted their executive and cognitive abilities, but additional studies are needed [21,22]. The modest correlations between fitness and performance of the cognitive task in the current study may be explained by the indirect nature of the physical test and the sample size.

The present work contributes to the international literature regarding the detrimental effects of the COVID-19 pandemic on multiple inter-related physical and cognitive health outcomes, with new evidence on French schoolchildren. However, our results must be interpreted in light of some limitations. First, despite the fact that the children at T0 and T1 were matched for age, gender, and their socio-economic statuses, and that the evaluations were performed in the same schools, the samples remain modest for school-based work and larger studies would help to clarify the interactions amongst health behaviors and outcomes. Additionally, although all the field tests that were used have been validated in children and adolescents, direct laboratory-based evaluation of fitness would have provided more objective results. Finally, the children in the sample had predominantly healthy weights, and therefore we cannot generalize these findings to children with obesity. However, studies in adults suggest that the negative effects of the lockdown on health behaviors disproportionately affected those with obesity [42].

## 5. Conclusions

To conclude, the present work highlights an alarming decline in both overall physical fitness and cognitive performance among primary school French children due to the public health restrictions imposed in order to slow down the spread of the COVID-19 virus. In concordance with the existing evidence describing the deleterious effects of the confinement on our children's movement behaviors and overall health, our results reinforce the need to urgently develop preventive strategies in anticipation of further mitigation measures. We must work to encourage a healthy, active lifestyle in children in order to preserve their physical, mental, and social health during this continued public health crisis.

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## Conclusion de l'étude

La présente étude rapporte une diminution alarmante de la combinaison des capacités physiques et des capacités cognitives chez les enfants d'école primaire, l'année suivant les restrictions imposées pour ralentir la propagation du virus de COVID-19. Ces résultats sont en accord avec les autres études existantes menées en France et à l'international, montrant les effets délétères du confinement sur la santé des enfants et adolescents.

Nos résultats renforcent le besoin de développer des stratégies innovantes de manière urgente limiter les effets délétères dus à l'inactivité et l'augmentation des comportements sédentaires.

*Publication 4 : Effets des vélo-bureaux sur les capacités physiques et cognitives des élèves de primaires : analyse du niveau socio-économique*

Des études ont montré que l'AP régulière améliore les performances académiques et cognitives des enfants. Bien que l'école soit souvent associée à un temps passé assis relativement important, elle offre l'opportunité de promouvoir des comportements sains à tous les enfants, indépendamment de leur milieu socio-économique. L'introduction de bureaux actifs peut encourager l'AP tout en maintenant un enseignement traditionnel. Cette approche vise à encourager l'AP, diminuer les comportements sédentaires, tout en restant engagé dans les activités scolaires.

L'objectif de cette étude était d'étudier les effets d'un programme de 9 semaines utilisant un vélo-bureau pendant le temps scolaire sur la composition corporelle, la condition physique et les fonctions exécutives d'enfants d'école primaire en fonction de leur statut socio-économique.

# The Effects of Using a Cycling Desk at School on Executive Function, Physical Fitness, and Body Composition in Primary School Children: Impact of Socioeconomic Status

Camille Chambonnière,<sup>1,2</sup> Lore Metz,<sup>1,2</sup> Alicia Fillon,<sup>3</sup> Pauline Demonteix,<sup>3</sup> Nicole Fearnbach,<sup>4</sup> Méлина Bailly,<sup>1</sup> Audrey Boscaro,<sup>1</sup> Bruno Pereira,<sup>5</sup> David Thivel,<sup>1,3</sup> and Martine Duclos<sup>2,3,6</sup>

<sup>1</sup>Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions, Clermont Auvergne University, Clermont-Ferrand, France; <sup>2</sup>Auvergne Research Center for Human Nutrition (CRNH), Clermont-Ferrand, France; <sup>3</sup>National Observatory for Physical Activity and Sedentary Behaviors, Clermont-Ferrand, France; <sup>4</sup>Office of Research, Florida State University, Tallahassee, FL, USA; <sup>5</sup>Biostatistics Unit, Clermont-Ferrand University Hospital, Clermont-Ferrand, France; <sup>6</sup>Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, Clermont-Ferrand, France

**Context:** Physical inactivity and sedentary behaviors are associated with adverse health outcomes in both adults and children. The purpose of this study was to investigate the effects of a 9-week program using a Cycle Desk during school time in French primary school children from high or low socioeconomic status (SES) on body composition, physical fitness (PF), and executive function. **Methods:** Seventy-five ( $n = 75$ ) children completed a test battery before and after 9 weeks of use of Cycle Desk to evaluate anthropometric characteristics, body composition, PF, and executive function. **Results:** Body mass index increased significantly ( $P = .0095$ ), while body fat decreased after the use of Cycle Desks ( $P < .0001$ ). Specifically, lean mass increased in the high-SES group while it decreased in the low-SES group ( $P < .0001$ ). After 9 weeks, there was an improvement in motor skills ( $P < .0001$ ), upper and lower limbs' strength ( $P < .0001$ ), and executive function performance ( $P < .0001$ ). More specifically, the low-SES group had a greater improvement in motor skills and maximal aerobic speed between T0 and T1, compared to the high-SES group ( $P = .001$ ,  $P = .023$ , respectively). In contrast, the high-SES group had a greater improvement in executive function at 9 weeks of use of Cycle Desk compared with the low-SES group ( $P = .0084$ ). **Conclusions:** The promotion of low-intensity physical activity with the use of a Cycle Desk at school may help offset some adverse effects of excess sedentary behavior among children. Moreover, this strategy appears to be particularly effective in children from low-SES backgrounds. **What's New:** The use of a Cycle Desk during school time has no deleterious effects on PF as well as cognitive executive functions in primary children. Modifications are more beneficial in children from low SES.

**Keywords:** cycle desk, physical activity, sedentary behaviors, active school

The increase in physical inactivity and sedentary behaviors in children is a major concern for health during and after the transition to adulthood. A recent systematic review suggests that moderate to vigorous physical activity declines begin in early to mid-childhood and occurs in both sexes (20). At the same time, sedentary time, corresponding to the time spent sitting between waking and going to bed, increases during childhood with a daily seated time occupying 45% of the day at 7 years old compared with 75% of the day at age 15 years (27). Physical inactivity and sedentary behaviors are associated with adverse health outcomes including obesity, and cardiometabolic conditions (eg, hypertension and diabetes), as well as diminished health-related quality of life (14,25,28,54,65,66,74). Moreover, these risks are more pronounced among low socioeconomic families compared with families with a high socioeconomic status (SES; 23). The World Health Organization (WHO) recommends reaching at least 60 minutes of

moderate to vigorous physical activity per day for children and adolescents aged 5–17 years (71). Data from recent epidemiological studies indicated that only 20.9% of girls and 27.7% of boys aged 7–10 years, and 30.1% of girls and 45.6% of boys aged 11–14 years are meeting the WHO's physical activity (PA) guidelines (3). The school environment can promote PA but also requires spending around 70% of the school day in a sitting position, generating a significant volume of daily sedentary time (15).

The health benefits associated with engagement in regular PA have been well demonstrated. Indeed, regular PA in children can decrease adiposity and improve cardiometabolic health regardless of the child's body mass index (BMI; 1,29,32,43,50,59). Positive effects of regular PA on white matter anisotropy in children were observed, suggesting more efficient communication between gray matter regions and the integration of regions into networks (13). Furthermore, higher physical fitness (PF) levels seem to be linked to better academic performance via executive function regions in the brain (18,31). Executive function includes higher-order cognitive functions that are responsible for initiating, adapting, regulating, monitoring, and controlling information processes and behavior (17,44,70). These cognitive functions are fundamental for mental and motor development in children. Thus, strategies to limit sedentary behavior and increase PA time at school may have downstream effects on academic and cognitive performance via improved PF, highlighting the need for targeted programs.

Metz <https://orcid.org/0000-0002-0957-2174>  
Fillon <https://orcid.org/0000-0002-0614-8909>  
Demonteix <https://orcid.org/0000-0002-4565-8143>  
Fearnbach <https://orcid.org/0000-0001-9208-830X>  
Bailly <https://orcid.org/0000-0002-9202-9358>  
Thivel <https://orcid.org/0000-0003-4687-3555>  
Duclos <https://orcid.org/0000-0002-7158-386X>  
Chambonnière (camille.chambonniere@uca.fr) is corresponding author. <https://orcid.org/0000-0003-4998-6221>



In order to limit the time spent in sedentary activities at school and to promote low-intensity exercise, innovative strategies have emerged in recent years. The international recommendations of the Sedentary Behavior Research Network describe that a healthy day should break up extended periods of sedentary behavior and incorporate different types of movement in youth (55). The effects of implementing active desks in classrooms have also been investigated in primary school (24). Active workstations such as sit-to-stand and cycle desks provide the opportunity for all children to engage in PA through educational lessons (24). Some studies have measured the effects of active desks on cognitive function (42,51,63,73) in secondary school children, but it is still not clear to what extent a cycle desk program can impact cardiorespiratory fitness (CRF), motor skills, strength, and executive function in primary school children. Furthermore, studies have not investigated differences in response by demographic characteristics (eg, SES) of children.

The objective of this study was to investigate the effects of a 9-week cycle desk program (~1 h and 45 min/wk) during school time in primary school children (aged 8–11 y; range of low and high SES) on body composition, PF, and executive function.

## Materials and Methods

### Classroom and Participants' Eligibility Criteria

A school located in the city of Vichy gave prior agreement to participate in this study, within which 4 teachers volunteered to use cycling desks in class. We conducted a preliminary visit to the classrooms to describe the study to kids, their parents, and the educational team. Primary school children in 4 classes from third and fourth grades participated. Eligible children were required to: (1) be aged 8–11 years enrolled in classes, and (2) not have medical or surgical history judged by the investigator to be incompatible with the study. After recruitment, children were classified as high or low SES by the school on the basis of: the household educational level and the occupational status. High education is defined as at least a first/bachelor's university degree, requiring 3 of full-time study, at the tertiary level. Low education is defined as no qualification beyond the "expected standard" of graduating from the French high school system. Occupational status was defined depending on the parents' job. High occupational status included artisans, traders, and senior managers;

low/intermediate occupational status level included jobs like primary school teachers, nurses, administrative officers or sales agents, workers, and employees. Both parents and children received information sheets and signed consent forms as required by local ethical regulations. This study has been approved by the ethical authorities (CPP Sud est VI) and registered as a clinical trial under the reference number NCT04880759 (clinicaltrials.gov).

### Study Design

After a medical examination conducted by a nurse to confirm the eligibility of the children, measurements were taken at baseline (T0: April 2021) and after 9 weeks in the last phase of the intervention (T1: June 2021). The test procedures were identical at both time points: 4 experimental sessions included assessments of executive function (visits 1 and 3) and body composition and PF (visits 2 and 4; Figure 1).

### Intervention

Every classroom had 4 cycling desks (TekActive, FIRST model) for students and teacher. The cycling desk is an active desk with an adjustable seat height (from 1.30 m) and a large shelf that can hold books, notebooks, or even a computer (in the same way as a traditional classroom desk; see Supplementary Figure S1 [available online]). The school nurse measured each student to allow for the creation of groups of students of similar heights to share the same desk and avoid seat adjustments at each 30-minute cycling session. The planning of the shifts was done according to the stature of each student. Active desks contained a pedal board and resistance, and were located at the back of the classroom to not interfere with classmates sitting in their traditional chairs.

The different classrooms were equipped with the cycling desk during the 9 weeks of intervention, and each child used the desk during sessions of 30 minutes 3 to 4 times a week for an average of 1 hour and 45 minutes per week. The pedal speed and resistance of the cycle desk were left to the children's choice. They were asked to pedal at the preferred speed with a minimum brake of 2 out of 8. To avoid a group effect, the children were randomized for the scheduled cycle desk use. Children were assigned to use a cycle desk according to their size. However, rotations on the cycle desk were not predetermined, allowing for variations in the composition of the children's groups.

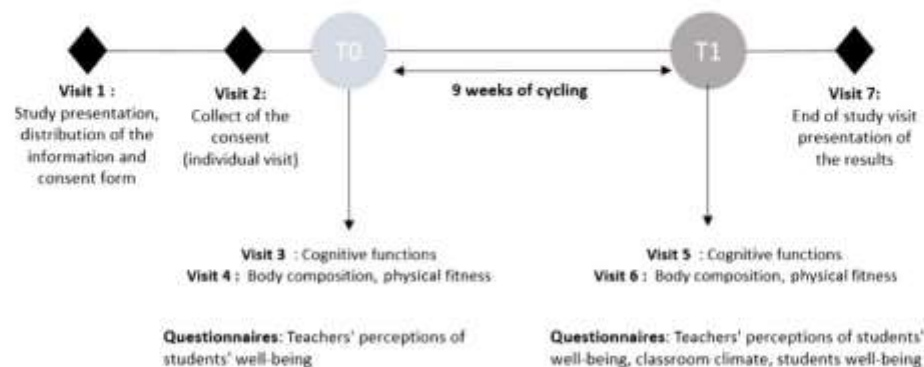


Figure 1 — Study design.

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## Measurements

### Anthropometric Characteristics and Body Composition

Body weight (in kilograms) and height (in centimeters) were measured by using a standard apparatus (Seca), to the nearest 0.1 kg and 0.5 cm, respectively. BMI was calculated as body weight divided by height squared (in kilograms per square meter). Fat mass (FM) percentage and fat-free mass (FFM—in kilograms) were evaluated by bioelectrical impedance (Tanita MC-780), following the manufacturer's instructions. This technology has been validated in children of various adiposity levels, showing a good level of validity and sensitivity to changes (60,68). Fat-Free Mass Index (FFMI) was calculated (67) with the following equation:  $FFMI = FFM \text{ (kg)} / \text{height (m)}^2$ .

### Physical Fitness

**Cardiorespiratory Fitness.** The 20-m shuttle-run test developed by Léger and Lambert (35) was used as an indirect measurement of aerobic fitness. The number of stages completed was used. The 20-m shuttle-run test has been validated and found to be reliable for the prediction of maximal oxygen uptake in children and adolescents (41) with a good reproducibility in children and adolescents between ages 8 and 18 years (9,36,39,40).

**Motor Skills.** Children were asked to complete an obstacle course as quickly as possible, and the time needed to complete this course was measured with a stopwatch. The score was determined with a systematic observation grid that contains 20 process- and product-oriented motor skill criteria. During this test, children used various means of locomotion (running, not chased, and feet together), handling (hand throwing and kicking), and balance (jumping from hoops to hoops and rotate). Participants completed the obstacle course 3 times, the first trial was practice trial, the last 2 trials were timed, and the best score was used (34,38). This test has been validated in 8- to 12-year-olds (38).

**Upper-Body Muscular Strength.** Upper-body muscular strength was measured with a handgrip dynamometer (Takei Scientific Instruments Co, Ltd) as previously detailed (46). The test was completed twice on each arm (left and right), and the best recordings of both arms were averaged. Participants also performed a Medicine Ball Throw test in a seated position (TMB) that measures the explosive power of the upper limbs when throwing a medicine ball as far as possible. The test was performed twice with the best performance recorded. TMB test has been validated and is reliable for children and adolescents (22).

**Lower-Body Muscular Strength.** Lower-body muscular strength was measured using the Standing Broad Jump test (SBJ). Participants were asked to jump the longest distance possible from a standing start while swinging both arms. The test was conducted twice, and the best score was used (30). The countermovement jump test was also performed using an Optojump (Microgate Co; (26). They were instructed to perform a quick downward movement (approximately 90° of knee flexion), and afterward a fast upward movement to jump as high as possible. The test was performed twice with the best performance recorded.

### Executive Function

Executive function was assessed through the Trail Making Test (TMT), a 5-minute pen-and-paper test with 2 subparts (A and B).

The TMT-A evaluates the speed of treatment and attention, while the TMT-B evaluates mental flexibility and executive functioning (4). The TMT-A required children to connect, as quickly as possible, circles numbered from 1 to 25 in ascending order. The TMT-B contains circles, numbers, and letters (from 1 to 25 and from A to Y), and the children were asked to connect them as quickly as possible in ascending order (eg, 1-A, 2-B, and 3-C). The time taken to complete each task (in seconds) and the number of mistakes were noted. This test has been validated in children (48).

### Statistical Analysis

Statistical analyses were performed with Stata software (version 15, StataCorp). The assumption of normality was assessed by using the Shapiro–Wilk test. The comparisons between baseline (T0) and after the use of cycling desk evaluations (T1) were performed using Student's *t* test or Mann–Whitney test if the assumptions to apply *t* tests were not met. The tests were 2-sided, with a type I error set at 5%. Hedges *g* effect size (ES) was interpreted according to the rules of thumb reported by Cohen who defined the ES bounds as: small (ES = 0.2), medium (ES = 0.5), and large (ES = 0.8). To analyze the relationships between continuous parameters, Pearson and Spearman correlation coefficients were estimated according to the statistical distribution of variables and were interpreted as follows: <2 negligible, .2 to .4 weak, .4 to .7 moderate, and >.7 strong (16). Continuous data were expressed as mean (SD).

Participants were described at inclusion according to body composition, PF, and executive functions. The primary analyses have measured the effect of the use of the cycling desks on all components by comparing the results before and after the intervention by an analysis of variance or a Kruskal–Wallis test if the conditions of the *t* test were not met. In a second step, multivariable analyses adjusted were also performed to evaluate Group effect by Sex and SES subgroups, before (T0) and after (T1) the use of cycling desks. The secondary analyses evaluated the relationships between continuous parameters at T0 and T1 and were assessed using correlation coefficients (Pearson or Spearman, in accordance with statistical distribution), applying an Idak type I error correction for multiple comparisons.

## Results

From the 99 children with informed consent, 1 was dismissed from the school from the school, 2 moved to another school, and 21 kids were exempt from sport (including injured children) or were absent for more than one evaluation session and were excluded of analysis. Accordingly, the final sample presented here consisted of 75 children (9.4 [0.6] y, 53.3% girls) including 42 schoolchildren (56%) classified as low-SES group and 35 classified in high-SES group (44%; Figure 2). Age and grade did not differ between SES groups.

### Body Composition

#### Time Effect

As detailed in Table 1, weight and BMI for the whole group significantly increased over time ( $P < .0001$ ,  $P = .0095$ , respectively) while FM significantly decreased between T0 and T1 ( $P < .0001$ ). Height, FFMI, and BMI percentile did not differ between the 2 evaluation sessions.

#### SES Effect

As detailed in Table 2, children in low-SES group experienced an increase in BMI percentile (T1-T0) during the intervention

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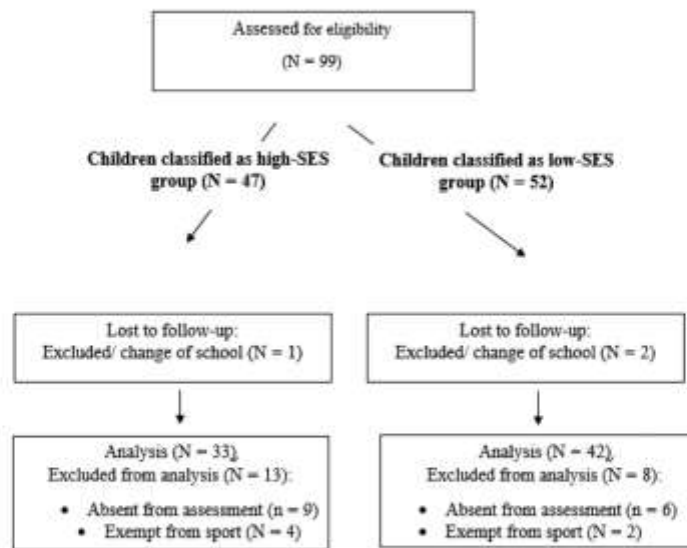


Figure 2 — Flowchart of participants.

Table 1 Representation of Individual Variability of Body Composition, Physical Fitness, and Executive Functions at T0 and T1 of Use of Cycling Desks in Primary School Children (n = 75)

	T0		T1		P	ES (95% CI)
	Mean	Median	Mean	Median		
Age	9.41 (0.64)	9.00	9.55 (0.64)	9.00	.038	0.06 (-0.23 to -0.01)
Body composition						
Height, cm	138.92 (7.43)	139.00	139.59 (7.26)	139.00	.253	0.08 (0.07 to 0.16)
Weight, kg	36.02 (10.03)	33.45	37.96 (10.64)	33.15	<b>&lt;.0001</b>	0.63 (1.40 to 1.85)
BMI, kg/m <sup>2</sup>	18.4 (3.9)	17.6	18.7 (4.3)	17.6	<b>.0095</b>	0.26 (0.03 to 0.48)
FM, kg	9.45 (5.28)	8.00	8.55 (5.32)	7.06	<b>&lt;.0001</b>	-0.85 (-1.08 to -0.62)
FFMI, kg/m <sup>2</sup>	13.60 (2.06)	14.00	14.24 (3.85)	14.00	.0770	0.04 (-0.46 to 0.26)
BMI percentile, <sup>a</sup>	64.12 (38.32)	50	61.12 (35.18)	90	.368	0.06 (0.03 to 0.12)
Physical fitness						
CMJ, cm	17.84 (3.89)	17.6	18.41 (3.96)	18.4	<b>.0355</b>	0.25 (0.24 to 0.48)
SBJ, cm	137.39 (2.95)	140	153.39 (2.70)	154	<b>&lt;.0001</b>	0.65 (0.42 to 0.88)
Handgrip, kg	14.38 (3.41)	14.1	16.33 (4.07)	15.8	<b>&lt;.0001</b>	0.75 (0.52 to 0.97)
TMB, cm	247.17 (51.71)	238	240.31 (46.21)	244	.1963	-0.14 (-0.37 to 0.87)
Motor skills, CAMSA, 1-24	16.97 (2.175)	17	21.94 (2.905)	22	<b>&lt;.0001</b>	-1.27 (-1.5 to -1.04)
MAS, km/h	9.04 (0.77)	9	9.17 (0.84)	9	.0574	0.22 (0 to 0.45)
Shuttle-run stage	2.08 (1.54)	2	3.31 (1.73)	3	<b>&lt;.0001</b>	1.08 (0.85 to 1.3)
Executive functions						
TMT-A, s	89.13 (33.04)	79	70.77 (29.71)	65	<b>&lt;.0001</b>	-0.62 (-0.84 to -0.39)
TMT-B, s	189.80 (58.85)	186	162.78 (63.40)	151	<b>.0004</b>	-0.47 (-0.69 to -0.24)
TMT-Tot, s	278.83 (82.12)	268	233.55 (82.24)	215	<b>&lt;.0001</b>	-0.59 (-0.82 to -0.37)

Abbreviations: BMI, body mass index; CAMSA, Canadian Agility and Movement Skill Assessment; CI, confidence interval; CMJ, countermovement jump; ES, effect size; FFM, fat-free mass index; FM, fat mass; MAS, maximal aerobic speed; SBJ, standing broad jump; T0, baseline; T1, time 1; TMB, throw medicine ball; TMT-A, Trail Making Test part A; TMT-B, Trail Making Test part B; TMT-Tot, Trail Making Test Total. Note: Boldfaced values:  $P < .05$ .

**Table 2 Comparison of Executive Functions, Physical Fitness, and Body Composition Results According to SES at T0 Using Cycling Desks in Primary School Children (n = 75)**

	High-SES group (n = 33)				Low-SES group (n = 42)				Time x group effect P
	T0 Mean (SD)	T1 Mean (SD)	$\Delta(T1-T0)$ (SD)	Time effect P	T0 Mean (SD)	T1 Mean (SD)	$\Delta(T1-T0)$ (SD)	Time effect P	
Age	9.09 (0.29)	9.48 (0.52)	0.26 (0.54)	.865	9.61 (0.54)	9.85 (0.78)	0.36 (0.87)	.647	.785
<b>Body composition</b>									
Height, cm	134.94 (6.51)	135.42 (6.49)	0.48 (0.59)	.711	142.05 (6.61)	142.86 (6.58)	0.68 (0.44)	.196	<b>&lt;.0001</b>
Weight, kg	31.79 (9.05)	33.73 (9.71)	2.14 (3.01)	<b>.698</b>	39.35 (9.58)	41.28 (10.24)	2.78 (2.69)	.759	.087
BMI, kg/m <sup>2</sup>	17.28 (3.72)	16.80 (3.76)	-2.35 (2.03)	.816	19.33 (3.82)	20.23 (4.03)	3.46 (1.97)	.701	.078
FM, kg	7.30 (4.59)	8.27 (4.68)	-0.68 (1.58)	.688	11.14 (5.22)	8.78 (5.82)	-2.46 (2.58)	.075	.0534
FFMI, kg/m <sup>2</sup>	13.39 (1.66)	15.29 (3.65)	0.84 (2.57)	<b>.036</b>	13.76 (2.34)	13.59 (3.89)	-0.32 (3.41)	.514	<b>&lt;.0001</b>
BMI percentile, *	58.85 (43.98)	45.71 (34.74)	-6.50 (0.27)	.054	68.38 (32.99)	73.60 (30.59)	5.21 (2.67)	<b>&lt;.0001</b>	<b>.038</b>
<b>Executive functions</b>									
TMT-A, s	94.55 (34.17)	66.24 (23.08)	-24.46 (25.01)	<b>.001</b>	84.88 (31.88)	74.33 (33.87)	-7.19 (43.99)	<b>.032</b>	.0656
TMT-B, s	208.39 (57.09)	159.72 (62.93)	-20.28 (33.29)	.064	175.19 (56.66)	165.17 (64.42)	-2.54 (36.28)	.173	<b>.0109</b>
TMT-Tot, s	302.94 (80.52)	225.97 (79.08)	-22.52 (27.89)	<b>.008</b>	260.07 (79.26)	239.50 (64.42)	-5.58(28.31)	.078	<b>.0084</b>
<b>Physical fitness</b>									
Shuttle-run stage	2.42 (1.50)	3.21 (1.54)	1.03 (1.13)	<b>&lt;.001</b>	1.8(1.5)	3.4 (1.9)	1.18 (1.24)	<b>.012</b>	<b>.0029</b>
MAS, km/h	9.21 (0.75)	9.14 (0.71)	-0.64 (5.51)	.310	8.90 (0.77)	9.19 (0.94)	3.21 (6.03)	.069	<b>.023</b>
Motor skills, CAMSA, 1-24	16.94 (2.70)	20.64 (2.25)	3.64 (3.42)	<b>.001</b>	17.00 (1.68)	22.90 (2.99)	4.5 (1.92)	<b>.001</b>	<b>.001</b>
Handgrip, kg	13.3 (3.0)	15.1 (3.5)	14.7 (15.75)	<b>.032</b>	15.2 (3.55)	17.3 (4.3)	14.65 (18.2)	.202	.865
CMJ, cm	18.37 (3.74)	18.35 (3.64)	0.88 (13.79)	.461	17.42 (4.00)	18.46 (4.23)	6.85 (13.68)	.525	.0907
SBJ, cm	152.76 (24.34)	143.55 (19.24)	-5.22 (9.62)	<b>&lt;.001</b>	125.31 (19.41)	161.12 (25.59)	29.22(10.7)	<b>.033</b>	<b>&lt;.0001</b>
TMB, cm	271.45 (50.93)	228.72 (44.43)	-15.11 (12.7)	.982	228.1 (45.0)	249.4 (46.0)	10.34 (14.91)	.892	<b>&lt;.0001</b>

Abbreviations: BMI, body mass index; CMJ, countermovement jump; ES, effect size; FFM, fat-free mass index; FM, fat mass; MAS, maximal aerobic speed; SBJ, standing broad jump; SES, socioeconomic status; TD, baseline; T1, time 1; TMB, Throw Medicine Ball; TMT-A, Trail Making Test part A; TMT-B, Trail Making Test part B; TMT-Tot, Trail Making Test Total. Note: Boldfaced values:  $P < .05$ .

compared to those in high-SES group, who experienced a decrease in BMI percentile ( $P = .038$ ). FFMI increased over time in the high-SES group ( $P = .036$ ), while FFMI tended to decrease in the low-SES group ( $P = .0514$ ). Children in low-SES group grew more in height during the intervention than the high-SES group ( $P < .0001$ ). There was no SES effect for weight, BMI, or FM.

#### Sex Effect

There were no sex differences in the change in body composition following the intervention (Supplementary Table S1 [available online]).

### Physical Fitness

#### Time Effect

Table 1 presents PF results in 3 components: CRF, motor skills, and muscular strength. Concerning CRF, shuttle run was significantly higher after the cycling desks program (T1) compared to baseline (T0;  $P < .0001$ , both). Motor skills performance was higher at T1 compared with T0 ( $P < .001$ ). Regarding strength of the upper limbs, handgrip strength was higher at T1 compared with T0 ( $P < .0001$ ); however, there was no difference in throwing distance during the TMB assessment ( $P = .196$ ). Concerning lower-limb strength, there was a significant increase in both the jump distance during SBJ ( $P < .0001$ ) and the jump height during countermovement jump ( $P = .0355$ ) between T0 and T1.

#### SES Effect

Delta values between T1 and T0 ( $\Delta T1-T0$ ) for shuttle-run stage ( $P = .0029$ ), maximal aerobic speed ( $P = .023$ ), and motor skills ( $P = .001$ ) were significantly higher for children in low-SES group compared with those in high-SES group (Table 2), suggesting greater improvements among this group. Regarding strength of the upper limbs, children in low-SES group showed an increase in throwing distance during TMB, while this parameter decreased in high-SES group ( $P < .0001$ ). The pattern of response was similar for lower-limb strength, with an increase in jump distance during SBJ in the low-SES group and a decrease in the high-SES group after the intervention ( $P < .0001$ ).

#### Sex Effect

Generally, there were no sex differences in PF results at either time point or over the course of the intervention, with the exception of SBJ at T0 only, such that boys who showed better performance compared with girls ( $P = .0197$ ; Supplementary Table S1 [available online]).

### Executive Function

#### Time Effect

As detailed in Table 1, the total time to perform the TMT total ( $P < .0001$ ), TMT-A ( $P < .0001$ ), and TMT-B ( $P = .0004$ ) was significantly lower (better performance) at T1 compared with T0.

#### SES Effect

Table 2 presents executive function performance in each SES group. The high-SES group showed a significantly greater decrease in TMT-B and TMT total ( $P = .01$ ,  $P = .008$ , respectively), suggesting greater improvement in executive function between T0 and T1 than their peers in the low-SES group.

#### Sex Effect

No sex differences were noted concerning executive function at either time point or over the course of the intervention (Supplementary Table S1 [available online]).

## Discussion

Physical inactivity may contribute to obesity during childhood and have deleterious consequences in children's health, demonstrating a need for creative school-based intervention programs beyond what has previously been tested. Newer strategies like the use of a cycle desk that can promote low-intensity PA during the school day should be promoted during teaching time. The present study shows that the use of cycling desks is associated with an improvement in body composition, PF, and executive function in primary school children. In addition, the positive effects on PF seem to be more pronounced in the low-SES group of children, with no notable sex differences after the use of cycling desks.

After 9 weeks of using the cycling desk, anthropometric parameters were modified with a higher BMI mainly explained by an increase in body weight, and body composition was improved with a decrease in FM. The results we obtained on the whole group regarding body composition suggest that the use of a desk cycle could limit fat gain in growing children. These results contrast with the study of Torbeyns et al (63) who found that after a cycle desk program, there was no change in BMI but FM increased. Many methodological differences make comparison with this previous study difficult. Indeed, our study participants were prepubertal children whereas Torbeyns study included adolescents. In addition, the duration of the program as well as the total volume of use of the cycle desk differed significantly (4 class h/wk over 5 mo vs 1 h and 45 min/wk over 9 wk).

In children and adolescents, PF and muscular strength are associated with cardiometabolic disease risks, adiposity, mental health, and cognition, which can all have downstream effects on all-cause mortality later in life (47,52,56,69). Most of the studies that have investigated effects of a cycle desk program in children have only included one of the dimensions of PF (ie, CRF, muscular strength, or motor skills), but not all. For the first time, we studied PF across the dimensions of CRF, muscular strength, and motor skills. In the current study, components of PF improved after a 9-week program of cycling desk use. These results are in line with a previous study that showed an increase in children's CRF performance after a cycling desk program (63). Our results extended this work to show that the children evaluated have lower-limb muscle strength values that are higher than average European scores. This is not the case for the cardiorespiratory parameters which, although improved with the Desk Cycle program, were still lower than average European scores at the end of the intervention (62). Taken together, improvements in PF are encouraging given documented correlations with academic performance (69). Indeed, Solberg et al (57) emphasized the importance of a school-based intervention that increases aerobic fitness to aiming to increase academic performance. Thus, the use of a cycle desk during school time could be an interesting strategy to optimize both PF and academic achievement. However, additional studies are needed in this regard.

Investigation of executive function remains important in children, as it plays a major role in academic achievement. Concerning executive function, our results show that the 9-week cycle desk program was associated with an improvement in executive function outcomes. In relation to the previous literature, it seems that an improvement of executive function is not systematically

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found after the implementation of active classroom strategies (7). However, our results are consistent with the study by Torbeyns et al (63) which also showed an improvement in executive function after using the cycle desk. Executive function is considered a mediator between PA and academic achievement, and several studies have shown a positive association between PF level (including CRF) and academic achievement score (58,64). In our study, CRF and executive function were not correlated. A possible explanation could be the low volume of cycling desk use per week (1 h and 45 min/wk on average) and the short study duration (9 wk).

Socioeconomic environment has been shown to influence executive function, body composition, and PF of children (6,45,49). We investigated for the first time in this study the effect of SES on body composition, PF, and executive function before and after a 9-week program of cycle desk use during school. At baseline, children in low-SES group had higher level of adiposity than children in high-SES group, which is in line with several previous studies describing lifestyle behaviors and health outcomes (6,19,53). Our results regarding the effects of the cycle desk program show that children in the low-SES group have a higher range of improvement in PF. In some outcomes, these children seem to derive greater benefit from the cycle desk program than children in the high-SES group. While several studies showed that a higher CRF level was associated with higher SES (5,45), results obtained in our study indicate that cycling desk use during school may help lessen in the CRF inequalities between the 2 SES groups.

### Strengths and Limitations

Our project aimed to apply an innovative approach and strategy to increase PA levels and reduce sedentary behavior during the day, as recommended by a recent review (7), the PA strategy for the WHO European Region 2016–2025 (72), and the WHO 2020 global PA guidelines (12). Within the participating schools, parental consent and children assent to participate were obtained for 100% (n=99) of eligible children. Overall, these findings demonstrated the feasibility of recruiting and retaining teachers and children and suggest a strong interest in this type of intervention. This high acceptability was consistent with a previous study where students preferred to sit on a bike compared with sitting in a chair (21). The findings from this study encourage the implementation of active learning and are in line with previous studies that showed better academic outcomes, children's health, and well-being compared with sedentary "traditional" teaching approaches (8,10,33). No pedaling intensity was evaluated during use of the active desks. This represents a real strength of the study, as it makes the use of this strategy consistent, since the child can vary pedaling according to cognitive demand (which is not possible, eg, with a walking desk). The main limitation of our study is the absence of a control group. This limits the interpretation of the results and does not allow us to differentiate the effects that are specific to the program from those of typical maturation. However, previous studies involving children of similar age to that of our study and of longer duration do not show any effect of maturation alone (control group) on the parameters that we measured (2,11,37,61, 63,75). This suggests that at least some of the improvements found for the different parameters in our study reflect the effects of using the cycle desk.

### Conclusions

Promoting active learning with cycling desks at school should be a major goal of school policy given that they have no negative

impacts on both physical health and executive function. Further studies should investigate long-term effects of cycling desks program at school including a follow-up on these outcomes even after the end of the program, as well as downstream effects on long-term academic performance. Finally, innovative strategies to fight physical inactivity in the school environment can promote children's health without jeopardizing academic success.

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## Conclusion de l'étude

Promouvoir l'apprentissage actif à l'aide de vélo-bureaux à l'école devrait être un objectif majeur de la politique scolaire, étant donné qu'ils n'ont pas d'impact négatif sur la santé physique et les fonctions exécutives. Il serait nécessaire de réaliser d'autres études complémentaires portant sur les effets à long terme du programme de vélo-bureaux à l'école, incluant une année scolaire globale et un groupe contrôles, ainsi que d'autres stratégies d'enseignement actif.

Dans tous les cas, notre étude montre que des stratégies innovantes de lutte contre la sédentarité en milieu scolaire peuvent promouvoir la santé des enfants sans compromettre la réussite scolaire.

### AXE III – Evaluation et détection des fragilités des séniors en milieu rural et semi-urbain

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*Publication 5 : Dépistage des fragilités en milieu rural et semi-urbain via la démarche ICOPE*

La part des personnes âgées en France ne cesse de croître et les estimations démographiques tendent vers une population française de plus en plus âgée. Aussi, pour favoriser le bien-vieillir et limiter la dépendance chez les séniors, le dépistage des fragilités est un outil qui a fait ses preuves. Afin d'adopter une vision toujours plus holistique, l'OMS a développé l'outil ICOPE « Integrated Care of Older People » pour identifier les personnes fragiles et proposer un plan de soin adapté aux séniors si nécessaire.

L'objectif de cette étude est d'évaluer la prévalence de la fragilité globale et d'identifier les personnes fragiles parmi les personnes âgées vivant dans la communauté dans deux zones différentes : une zone rurale (bassin de santé de Mauriac) et une zone semi-urbaine (bassin de santé de Vichy). L'étude visait également à étudier la qualité de vie liée à la santé chez les personnes âgées vivant dans des zones rurales et semi-urbaines et son association avec la fragilité. Enfin, nous avons analysé les niveaux d'AP et de comportement sédentaire en fonction de facteurs sociodémographiques et de la zone de résidence.

## Screening for frailty according to rural and suburban health areas in the context of adapted integrated care for older people (ICOPE) approach: the FRAGING study

Camille Chambonnière<sup>1,2</sup>, Marie Blanquet<sup>3,4</sup>, Cassandra Delorme<sup>5</sup>, Laurie Flory<sup>6</sup>, Bruno Pereira<sup>7</sup>, Lore Metz<sup>1</sup>, Martine Duclos<sup>8,9</sup>

<sup>1</sup>Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions, (AME2P), UE3533, Clermont Auvergne University, 63170 Aubiere CEDEX, France;

<sup>2</sup>Auvergne Research Center for Human Nutrition (CRNH), 63000 Clermont-Ferrand, France;

<sup>3</sup>CNRS, Pascal Institute, Clermont Auvergne University, 63000 Clermont-Ferrand, France;

<sup>4</sup>Public Health Unit, Clermont-Ferrand University Hospital, 63000 Clermont-Ferrand, France;

<sup>5</sup>CleRMA, IAE Clermont Auvergne, 63000 Clermont-Ferrand, France;

<sup>6</sup> Accès Santé Nord Cantal territorial professional health community, 15210 Ydes, France ;

<sup>7</sup>Biostatistics Unit, Clermont-Ferrand University Hospital, 63000 Clermont-Ferrand, France;

<sup>8</sup>National Observatory for Physical Activity and Sedentary Behaviour, 63000 Clermont-Ferrand, France;

<sup>9</sup>Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, 63000 Clermont-Ferrand, France.

### Corresponding author:

Camille Chambonnière, Clermont Auvergne University, EA 3533, 63170 Aubiere CEDEX, France

Email: [camille.chambonniere@uca.fr](mailto:camille.chambonniere@uca.fr)

Phone and fax: 0033 4 73 40 76 79

## Highlights

- Frailty is an underestimated syndrome in healthy older adults.
- Screening should adapt to health issues and the local healthcare organization.
- Primary care provider training should include care pathway and integration-of-care paradigms.
- Efforts are needed to inculcate physical activity guidelines for older adults.

## Abstract

*Background:* The Integrated Care for Older People (ICOPE) program, developed by the World Health Organization, serves as a public health initiative to maintain older adults' functional abilities and promote healthier ageing. Here we adapted the ICOPE approach to assess overall prevalence of frailty in rural and semi-urban areas. We also investigated health-related quality of life and physical activity and sedentary behaviour in older people.

*Methods:* The FRAGING multicenter cohort study was performed on screening days dedicated to older adults ( $\geq 65$  years) without chronic disease in a rural area (RU) and in a semi-urban area (SU).

*Results:* The study included a total of 105 participants: 98.4% of participants were frail, with a mean of 4.3 [SD: 2.5] frailties per participant. RU participants had higher number of frailties ( $p=0.02$ ) and a higher percentage of frail participants in the dimensions of health-related quality of life ( $p<0.0001$ ), socioeconomical level ( $p=0.008$ ), colorectal cancer screening ( $p=0.022$ ), and tetanus booster doses ( $p=0.008$ ). Globally, women were less sedentary than men ( $p=0.02$ ) and engaged more in low physical activity (LPA) than men ( $p=0.01$ ). RU participants engaged more in LPA than SU participants ( $p=0.03$ ).

*Conclusions:* The prevalence of frailty is alarmingly underestimated in older adults without chronic disease. This study demonstrated the need to propose appropriate, validated screening tests that consider territorial issues and organization of care delivery. The ICOPE framework, which is designed to be adapted to the territory and the organization of care, serves as a good startpoint for reorganizing person-centered healthcare pathways.

## Keywords

Ageing; Healthy ageing; Quality of life; Frailty; Public health

## Introduction

Populations around the world are ageing rapidly, with global projections pointing to almost 2 billion people aged 60 years or over by 2050 (United Nations Department of Economic and Social Affairs, Population Division, 2017), making ageing a major global public health challenge. In 2023, 21.3% of people in France were aged 65 and over (Papon & INSEE, 2023), which has social, cultural and economic costs for wider society (Grangier, 2018; Grignon, 2003). Ageing is associated with increased probability of falls (Q. Xu, Ou, & Li, 2022), fractures (Kojima, 2016a), disabilities (Kojima, 2017), ill health (Clegg, Young, Iliffe, Rikkert, & Rockwood, 2013), poor quality of life (Nikolova et al., 2020), hospitalizations (Kojima, 2016b), healthcare costs (Kojima, 2019; Pagès et al., 2022) and death (Chang & Lin, 2015; Kojima, Iliffe, & Walters, 2018; Shamliyan, Talley, Ramakrishnan, & Kane, 2013). Specifically, 40% of community-dwelling older adults have at least one functional limitation: 30% are physical limitations, 19% are sensory limitations, and 8% are cognitive limitations (Carcaillon-Bentata et al., 2022). These functional limitations have significant costs associated with lead to loss of autonomy and dependency, which costs France an estimated 34 billion euros a year (DREES, 2022). However, the effects of ageing are highly heterogeneous: the way they appear and the pace and extent of decline vary according to the cells, tissues or organs involved (De Jaeger, 2012), which complexifies efforts to deliver concerted health action.

In 2020, the World Health Organization (WHO) endorsed the proposal for a Decade of Healthy Ageing (2020-30) (WHO, 2020b) plan to promote healthy ageing by providing holistic services that foster capacity and well-being in old age (Weltgesundheitsorganisation, 2015; WHO, 2017c). Functional ability is related to intrinsic capacity (IC), which is *"the composite of all physical and mental capacities of an individual"* (Weltgesundheitsorganisation, 2015). In 2015, the World Report on Ageing and Health defined healthy ageing as the process of developing and maintaining functional ability to improve quality of life and reduce level of frailty in older people (Christensen, Doblhammer, Rau, & Vaupel, 2009; Weltgesundheitsorganisation, 2015).

'Frailty syndrome' has been mobilized to conceptualize the age-related increase in vulnerability at an individual level and to develop action on these limitations (Dent et al., 2019; Rodriguez-Mañas & Fried, 2015). Frailty is a reversible intermediate state between healthy ageing and loss of independence and pathological ageing. Frailty syndrome is associated with severe disability, dependency, hospitalization, institutionalization, and mortality (Collard et al., 2012; Crocker et al., 2019; Linda P. Fried et al., 2004; Frisoli, Chaves, Ingham, & Fried, 2011; Rantanen et al., 1999). Living conditions seem to play a role in frailty, as older adults in rural

area have higher mortality rates, higher levels of frailty, greater disease burden, worse health, more severe depression, and faster decline in physical function (Song et al., 2007). As frailty remains a complex concept, none of the screening tools available are relevant by itself (De Oliveira et al., 2023). To address this issue, the WHO introduced the Integrated Care for Older People (ICOPE) guidelines that are based on screening domains of IC including cognition, locomotion, vitality, vision, hearing, and psychology. The ICOPE approach needs to be adapted to local conditions, both in terms of local issues and local organization. Here we adapted ICOPE by adding assessments of health issues in the area (socioeconomical level, caregiver support needs, alcohol use, cardiovascular risk, cancer screening, vaccination boosters, iatrogenesis) and health-related quality-of-life.

This study set out to assess prevalence of overall frailty and identify frail individuals among community-dwelling older adults in two different areas: a rural area and a suburban area. The study also aimed to investigate health-related quality of life in older adults living in rural and suburban areas and its association with frailty. Finally, we analyzed levels of physical activity and sedentary behaviour according to sociodemographic factors and home area.

## **Material and methods**

### *Study design*

The FRAilty aGING (FRAGING) multicentre cohort study was performed over September–November 2021 and March–May 2022 in a rural area (RU) and over September–November 2022 in a suburban area (SU) in the Auvergne region in south-central France. The study was conducted via 8 screening days with the Accès Nord Santé Cantal territorial professional health community in the RU and via 4 screening days with the Vichy agglomeration community in the SU.

This study analyzed data collected by screening the generic care pathway based on the ICOPE approach (Figure 1). A screening day was organized into several steps: i) explanations around the concept of frailty; ii) recording the participant's identity; iii) completion of the self-report questionnaire by the participant; iv) frailty screening with a nurse; v) analysis of iatrogenesis by the geriatrician and synthesis of the frailty identified (Figure 2). Participants are considered frail if they reach the test's threshold for positivity (Table 1) and if the problem is unknown to the participant or is known to the participant but not being treated.

The questionnaires were created in several steps (see Figure 3). IC screening included assessments of cognition capacity, locomotor capacity, vitality, visual capacity, hearing

capacity, and psychological capacity (WHO, 2017c). Assessment of health issues in the area included socioeconomic status, caregiver support needs, alcohol use, cardiovascular risk, cancer screening (breast, colorectal, skin), and vaccination (tetanus, flu, pneumococcal). In addition, accelerometry tests were performed on the first 10 volunteers at the end of each screening day in order to get a subjective assessment of physical activity and sedentary behaviour.

### *Population*

Health-area residents aged 65 or older came to attend screening days organized in the SU and the RU. Participants with 'chronic disease', living in an institution or living outside the areas were excluded. All participants gave informed consent to be enrolled.

### *Questionnaires*

The questionnaires were divided in two parts: the self-administered questionnaire and the nurse-administered questionnaire. The self-administered questionnaire included 8 items: sociodemographic data (level of education, marital status, home-life situation (e.g. alone), home helpers, presence of a caregiver), locomotor capacity, visual capacity, hearing capacity, psychological capacity, quality of life, socioeconomic status, caregiver help. The nurse-administered questionnaire included 7 items: cognitive capacity, locomotor capacity, vitality, alcohol consumption, cardiovascular risks, cancer screening, and vaccination boosters. All scientific tests and questionnaires proposed were validated and reproducible, and the associated test sensitivity and specificity data is reported in Table 1.

#### *Cognitive capacity*

Cognitive capacity was assessed by preliminary questions on the presence of family history, memory disorders or family complained about the memory and relinquishment of administrative documents. If a disorder is identified with the preliminary questions, the nurse administered the Cognitive Disorders Examination (CODEX) was completed (Belmin et al., 2007).

#### *Locomotor capacity*

Level of physical activity and sedentary behaviour (locomotor capacity) were assessed using the ONAPS Questionnaire (parts B and C) (Marc Charles et al., 2021; WHO, 2020a). The 'Timed

Up and Go' test was performed if the participant had experienced a fall within the last 12 months (Podsiadlo & Richardson, 1991).

#### *Vitality*

Vitality assessment included screens for malnutrition and sarcopenia. Following French guidelines, malnutrition was screened using Global Leadership Initiative on Malnutrition (GLIM) criteria, Mini Nutritional Assessment (MNA), and anthropometric data, i.e. height in cm, weight in kg, weight loss the last 3 months, and body mass index ( $BMI = \text{weight}(\text{kg}) / \text{height}(\text{m}^2)$ ) (Cederholm et al., 2019; HAS, 2007, 2019a). Sarcopenia was assessed by measuring upper-body muscle strength with a handgrip dynamometer (Takei Scientific Instruments Co. Ltd., Niigata, Japan) according to the Southampton protocol (M. Blanquet et al., 2020; Marie Blanquet et al., 2022; Cruz-Jentoft et al., 2019; Roberts et al., 2011). Three measures were performed from each side, and the highest result was kept for analysis (Marie Blanquet et al., 2022)

#### *Visual impairment*

Visual impairment was defined as any problems experienced with the eyes, i.e. difficulties seeing far, difficulty reading, eye disease, or problems currently under medical treatment.

#### *Hearing capacity*

Hearing capacity was screened via a few questions on problems experienced with hearing, ear diseases, or hearing loss currently under medical treatment. If necessary, the 10-question Hearing Handicap Inventory for the Elderly – Screening Version (HHIE-S) was completed (Servidoni et al., 2018).

#### *Psychological capacity*

Psychological capacity (symptoms of depression) was assessed using the 9-question Patient Health questionnaire (PHQ-9) self-questionnaire (Cheng et al., 2010; Kroenke, Spitzer, & Williams, 2001).

#### *Health-related quality of life*

Health-related quality of life was assessed using the validated French-language version of the LEIPAD self-questionnaire instrument (De Leo et al., 1998; Isabelle Jalenques et al., 2019) composed of 31 items covering 7 dimensions: physical functioning, self-care, depression and anxiety, cognitive functioning, social functioning, sexual functioning, and life satisfaction. Results were immediately compared to the average of people in a comparable age-sex group using a computer program created by Clermont-Ferrand university hospital public health unit. Participants were considered frail if at least one dimension score was poorer than the comparable age-sex group score.



### *Socioeconomic status*

Social deprivation was assessed with the French 'EPICES' score (Bongue et al., 2016; Labbé et al., 2007; Sass, Moulin, et al., 2006). The EPICES score includes 11 binary items (yes/no) covering dimensions of social and material deprivation.

### *Caregiver support needs*

If the participant was a caregiver, then their caregiver burden was assessed by the mini-Zarit, a simplified version of Zarit Burden Interview (Gort et al., 2005; J. Yu et al., 2019; Zarit & Femia, 2008).

### *Alcohol consumption*

Risk of alcohol dependence was assessed using the Fast Alcohol Consumption Evaluation (FACE) questionnaire (Dewost, Michaud, Arfaoui, Gache, & Lancrenon, 2006).

### *Cardiovascular risk*

Cardiovascular risk factors were analyzed by geriatrician, and a participant was defined as presenting cardiovascular risk-related frailty if they had unmanaged risks factors (Visseren et al., 2021).

### *Global cancer monitoring*

Participants were screened for three cancers, i.e. breast cancer, colorectal cancer, and skin cancer, all according to the governing French guidelines. Screening followed recommended practice for breast cancer and colorectal cancer and used the INCa (national cancer institute) questionnaire to screen for skin cancer (INCa, 2019).

### *Global vaccination*

Vaccination status (tetanus, flu, and pneumococcal vaccine) was verified.

### *Level of physical activity and sedentary behaviour*

On each screening day, the first 10 volunteers were offered an ActiGraph activity monitor (model GT3X ActiGraph Inc., Pensacola, FL) to be worn at the right hip for 7 days after the screening day. The monitors were only taken off when going to bed and when taking a shower or bath or engaged in other water-based activities. The ActiGraph tool objectively measures daily physical activity patterns (Aguilar-Farías et al., 2014). Count data were classified as sedentary behaviour or low physical activity (LPA) or moderate-to-vigorous physical activity (MVPA) using the Freedson and Troiano cut-off points, respectively (Freedson, Melanson, & Sirard, 1998; Troiano et al., 2008). Periods of non-wear time were defined using the algorithm given in Choi et al. (L. Choi et al., 2011). Data was analyzed if the device was worn for at least 10 hours a day on at least 4 days. The total amount of sedentary behaviour, LPA and/or MVPA

during the recording week was divided by the number of valid wearing days for each participant to calculate daily averages.

### **Data analysis**

All statistical analyses were performed using SPSS version 26.0 (IBM Inc., Chicago, IL). Each screening component was analyzed as a qualitative variable, and participants were categorized as 'frail' or 'non-frail'. The participant was considered frail in each questionnaire or test if they had an abnormality that was not already being addressed. Sociodemographic characteristics included age (in years), sex, marital status (married vs. unmarried), and educational attainment (below high school education vs. high school education and above). Continuous variables were expressed as mean and standard deviation [SD], and median (interquartile range) and normative data was expressed as percentage (number). BMI was categorized into four groups: malnutrition (BMI < 18.5 kg.m<sup>2</sup> if participant was < 70 years old and BMI < 22kg.m<sup>2</sup> if participant was ≥ 70 years old), normal (18.5 kg.m<sup>2</sup> ≤ BMI < 25 kg.m<sup>2</sup> if participant was < 70 years old and 22 kg.m<sup>2</sup> ≤ BMI < 25 kg.m<sup>2</sup> if participant was ≥ 70 years old), overweight (25 kg.m<sup>2</sup> ≤ BMI < 30 kg.m<sup>2</sup>), and obese (BMI ≥ 30 kg.m<sup>2</sup>).

The Shapiro-Wilk test was used to test the assumption of normality. A chi-square test or Fisher's exact test were used to test for associations between frailty and health areas (SU vs RU). A Student's t-test was used to test for associations between number of frailties and sociodemographic characteristics or health-related quality of life, and to examine level of physical activity and sedentary behaviour according to sociodemographic characteristics. The relationships between qualitative parameters (frailty × health-related quality of life) for each territory (RU and SU) and gender were assessed using a chi-square test with Cramer's V (V). The results of these relationships were illustrated with a color-coded heatmap, as follows: Cramer's V ≤ 0.2: negligible, 0.2 < Cramer's V ≤ 0.4: weak, 0.4 < Cramer's V ≤ 0.7: moderate, Cramer's V > 0.7: strong.

### ***Ethical issues***

This study was approved by the governing ethical review board (CPP Ouest II) and registered as a clinical trial at [clinicaltrials.gov](https://clinicaltrials.gov) under reference number NCT04992286.

## Results

### *Sociodemographic characteristics of the sample*

Of the 188 properly-completed questionnaires, the FRAGING study included 105 older adults of mean age 74.2 [SD:6.4], with 77.1% women (Figure 4). Across the entire sample, 52.4% of participants had below-high education, 53.3% were not married or cohabiting, 49.5% lived alone, 82.9% had no homecare, and 91.9% had no caregiver (Table 2). A total of 98.4% of all participants were frail, but age was not significantly associated with overall frailty (Table 3). In total, 24.8% (n=26) of participants had cognitive impairment, 20.0% (n=21) had locomotor impairment, 24.8% (n=26) had lacked vitality, 8.6% (n=9) had visual impairment, 27.6% (n=29) had hearing impairment, and 29.5% (n=31) had psychological impairment. Furthermore, 52.4% (n=55) of the participants had not been screened for skin cancer, 43.8% (n=46) had not received a tetanus booster vaccine, and 36.2% (n=38) had cardiovascular frailty. Mean number of frailties was 4.4 [SD: 2.6]. Total number of frailties ranged between 0 and 12 frailties. A total of 17 health components were screened with tests and questionnaires (Table 4): of the screened participants, 15.2% had 3 frailties, 26.7% had 4 frailties, and 12.4% had 5 frailties.

### *Differences between health-area settings*

We ran comparative analysis between the RU (50.5% (n=53) of included participants) and the SU (49.5% (n=52) of included participants (see Figure 4). In total, 96.2% of RU participants were frail, versus 88.5% of SU participants, but the difference was not statistically significant (Table 3). However, RU participants presented a significantly higher number of frailties than SU participants ( $p=0.02$ ) (Table 4). Compared to the SU, the RU had a significantly higher percentage of participants who were frail on health-related quality of life ( $p<0.0001$ ), socioeconomic status ( $p=0.008$ ), colorectal cancer screening ( $p=0.022$ ) and tetanus booster vaccine status ( $p=0.008$ ). Conversely, pneumococcal vaccine frailty was higher in the SU than in the RU ( $p<0.0001$ ).

### *Association between frailty and health-related quality of life according to health-area setting and gender*

Figure 5 shows the association between health-related quality of life and frailty stratified by RU and SU health area. In the RU, vitality frailty was associated with cognitive functioning ( $V=0.42$ ,  $p=0.015$ ), alcohol misuse was significantly associated with physical function

( $V=0.36$ ,  $p=0.04$ ), and psychological functioning was significantly associated with self-care ( $V=0.31$ ,  $p=0.001$ ) and life satisfaction ( $V=0.37$ ,  $p=0.03$ ). In the SU, cognitive capacity frailty was significantly associated with depression and anxiety ( $V=0.33$ ,  $p=0.018$ ), locomotor capacity frailty was significantly associated with self-care ( $V=0.56$ ,  $p<0.001$ ), and vitality frailty was significantly associated with physical function ( $V=0.35$ ,  $p=0.012$ ), self-care ( $V=0.31$ ,  $p=0.024$ ) and depression and anxiety ( $V=0.29$ ,  $p=0.038$ ), and socioeconomic level was significantly associated with depression and anxiety ( $V=0.31$ ,  $p=0.025$ ) and social functioning ( $V=0.30$ ,  $p=0.029$ ).

We also analyzed the association between health-related quality of life and frailty according to gender. Globally, we founded more association between frailty and women than men (Figure 6). In men, only vitality frailty ( $V=0.50$ ,  $p=0.034$ ) and social deprivation ( $V=0.50$ ,  $p=0.034$ ) were significantly associated with physical function. In women, caregiver support needs were significantly associated with social functioning ( $V=0.27$ ,  $p=0.03$ ). In women, psychological impairment was significantly associated with physical function ( $V=0.33$ ,  $p=0.008$ ), depression and anxiety ( $V=0.23$ ,  $p<0.001$ ) and cognitive functioning ( $V=0.60$ ,  $p=0.009$ ).

### ***Level of physical activity and sedentary behaviour***

Table 5 shows level of physical activity and sedentary behaviour expressed in time terms. Women were less sedentary than men ( $p=0.02$ ) and engaged in more LPA than men ( $p=0.01$ ). Participants who were living with someone and had no homecarers were significantly more sedentary ( $p=0.03$ ). Globally, MVPA was lower in participants who had no homecarers ( $p=0.04$ ). RU participants engaged in more LPA than SU participants ( $p=0.03$ ).

## **Discussion**

We are currently in the 2020–2030 Decade of Healthy Ageing promoted by the WHO (WHO, 2020b), and screening for frailty is still a major public health issue. This study borrowed the ICOPE approach to assess prevalence of overall frailty and health-related quality of life among community-dwelling older adults in rural *versus* suburban health areas. We also analyzed the level of physical activity and sedentary behaviour according to sociodemographic characteristics and home living area. This study found that more than nine out of ten adults (95.2%) aged 65 and over without chronic disease were frail. This percentage is higher than in other studies using the ICOPE approach or other tools such as Fried's phenotype (L. P. Fried

et al., 2001) and the frailty index (Mitnitski et al., 2001). This higher figure could be explained by: i) the fact that the Fried phenotype considered frailty as an underlying biological syndrome with only 5 criteria while the frailty index describes frailty as an accumulation of age-related deficits with 70 criteria; ii) the ICOPE approach includes 6 IC, which has been completed by screening local-area-specific issues identified in a previous epidemiologic analysis; iii) we screened frailty using a different set of tests to the ICOPE approach that have better sensitivity and specificity ((De Oliveira et al., 2023)). Note too that the older adults included here were without chronic disease and therefore hypothetically in “good health”, and yet the prevalence of the number of frail older adults was still dramatically high.

Screening for decreased IC in primary care, as promoted by the ICOPE approach, is a relevant intervention because declining IC has been associated with increased risk of death, high-incidence disability and dependence (independent of other health problems) in up to 5-year follow-up (B. Chen et al., 2022; Locquet et al., 2022). Here, 24.8% of participants had poor nutritional status, which is a higher proportion than other studies that have reported a prevalence in the community ranging from 7% to 17% in the same age-group (Johansson, Bachrach-Lindström, Carstensen, & Ek, 2009; Torres et al., 2014). Another alarming finding is that 29.5% of participants had psychological impairment. These results warrant some degree of perspective given the recent COVID-19 pandemic (a few months before our measures) that negatively impacted the mental health of older adults (who were particularly at risk) (Schäfer, Lindner, Kunzler, Meerpohl, & Lieb, 2023). Furthermore, the various different health conditions associated with losses in IC interact at several levels, which makes it necessary to adopt an integrated approach in order to screen, assess and manage age-related decline in IC. However, in our study, skin cancer check-ups (52.4%), tetanus vaccination (43.8%) and cardiovascular risks (36.2%) were not integrated into the ICOPE approach but were nevertheless the most common frailties identified. These results are significant, as older people are particularly vulnerable to these issues which have a direct impact on their autonomy (INCa, 2023; Isono et al., 2016; Rodgers et al., 2019). We find it important to complete the ICOPE approach with a global ageing assessment.

This study also highlighted disparities between rural and suburban areas, which is an important finding as the proportion of older adults in the population is higher in rural areas (Sabau, Blasquet-Revol, & Lenain, 2010). To our knowledge, this is the first study to compare the prevalence of frailty according to home areas (rural vs suburban) based on the ICOPE approach. Our data showed that the RU had a higher prevalence of socio-economic deprivation frailty, colorectal cancer screening frailty, and tetanus vaccine frailty. These results are in line with previous work concluding that poverty and social exclusion tend to be more

prevalent in thinly-populated areas (Bonerandi-Richard & Boulineau, 2016). Colorectal cancer screening also varies according to geographic distribution, level of education, income, and marital status (Hester et al., 2015; Pernet, Dejardin, Morlais, Bouvier, & Launoy, 2010). Conversely, our data showed that the SU had a higher prevalence of pneumococcal vaccine (50.0%) than in the RU. This prevalence rate is alarming but nevertheless in line with the results of a national study that reported a low rate of up-to-date pneumococcal vaccines (5.8%) and that 15% of participants did not know that this vaccine existed (Guthmann, 2011). Efforts are needed to train and educate health professionals to promote vaccine monitoring and cancer screening.

Our study also emerged geographic disparities concerning the association between frailty and health-related quality of life. Specifically, in the SU, socioeconomic deprivation was associated with depression and poor social functioning. This result is in line with previous studies that have identified socioeconomic status as a predictor of depression (Freeman et al., 2016) and a factor that has an indirect effect on social functioning and depressive symptoms (Bielderma, de Greef, Krijnen, & van der Schans, 2015). However, our results concerning the association between socioeconomic status and health-related quality of life were only significant in the SU, whereas the prevalence of socioeconomic deprivation was significantly higher in the RU. It is now well established that a decline in IC is associated with a decline in quality of life (Ma et al., 2020). Our results highlight the need to identify local area-specific health issues in order to organize appropriate screening.

It has been proven that retirement induces a decrease in the proportion of time spent in active behaviours, especially time spent in MVPA (Suorsa et al., 2022). However, increasing physical activity or minimizing sedentary time prevents frailty (D. Scott Kehler et al., 2018; Dustin Scott Kehler & Theou, 2019). The use of a wearable accelerometer has been validated as a way to assess body-movement-based behaviours in older people (Migueles et al., 2017). Here, analysis of accelerometer data showed that the older adults in our French sample spent more than 7 hours per day (52.6% of their waking time) in sedentary behaviour. This sedentary time is lower than in research in the United Kingdom which reported that older people spend more than 60% of their waking day engaged in sedentary behaviour (Gale, Čukić, et al., 2018). The WHO recommends that older adults should complete 150 minutes of MVPA each week (WHO, 2020a), but the participants in this study were found to complete only 61.3 minutes of MVPA per week. SU-area older adults spent significantly less time in LPA (37.6% vs. 43.7%) and spent more time sedentary (55.32% vs. 47.0%) than RU-area older adults. These results confirm the importance of the built environment as a factor for physical mobility (D. W. Barnett et al., 2017; Zhou, Grady, & Chen, 2017). We also found that women are less likely than men to be sedentary and they spent more time in LPA, which contrasts with findings from other studies (Martins,

Lopes, Diniz, & Guedes, 2021). Previous studies have clearly shown that the COVID-19 pandemic had a negative impact on physical activity and sedentary behaviour, especially among women and older adults in urban areas (Oliveira et al., 2022). Physical inactivity and sedentary behaviour have been linked to diabetes, decline in ADL (activities of daily living) and IADL (Instrumental ADM), obesity, mortality, morbidity, and cardiovascular disease (Amaral Gomes, Ramsey, Rojer, Reijnierse, & Maier, 2021; Garcia et al., 2023; Harvey, Chastin, & Skelton, 2013; Katzmarzyk et al., 2021). The social cost of physical inactivity in France has been estimated at 140 billion euros per year, which equates to 38 000 deaths and 62 000 pathologies caused each year (France stratégie & Ministre de la transition écologique, 2022).

This study has some weaknesses. First, the sample size was small, which is explained by the fact that the FRAGING study took place in the wake of the COVID-19 pandemic, which made older adults reluctant to participate, despite the health measures taken to organize them. Second, the effects of COVID-19 may have had an impact on the level of frailty among the older population. Third, participation was dependent on local dynamics and geographic isolation in rural areas, but note that we set up 8 screening days in rural areas (compared with 4 in suburban areas) to counteract this problem.

However, this study also has a number of strengths. First, the screening included not only IC but also local area-specific health issues as part of a more holistic approach. Second, the high quality of screening, which mobilized trained professionals, enabled a comprehensive screening exercise with very little missing data. Third, this is one of the few studies that includes an analysis of the sensitivity and specificity of each scientific test used to identify the most appropriate instruments for detecting frailty-related issues. Fourth, the fact that the study enlisted territorial professional health communities serves as a great opportunity to develop the project on a larger scale and integrate it into territorial programming policies. Finally, the comparison of frailty between rural and suburban areas is novel and original and one of the strongest assets of this work.

## **Conclusion**

This study showed that frailty is an underestimated clinical condition in older adults healthy older adults. In addition, we demonstrated the need to offer suitably appropriate validated tests while factoring in territorial issues and the organization of care. Government-backed prevention consultations at key stages of life should serve as a solid foundation for public health screening. The ICOPE framework promotes a change in the way we manage and provide health services, and advocates adopting an integrated and focused approach to the individual person. However, a paradigm shift is needed to enculturate this new care framework

among the healthcare professionals community. Further investigations should analyze the impact of the global ICOPE approach, including the personalized care plan, and to identify any allied barriers and drivers to realize the health-care pathway.

#### **Author contributions statement**

Camille Chambonnière – conceptualization, data curation, investigation, formal analysis, methodology, writing – Original draft, review & editing.

Marie Blanquet – conceptualization, data curation, investigation, formal analysis, methodology, writing – review & editing.

Lore Metz – conceptualization, data curation, formal analysis, writing – review & editing.

Cassandra Delorme – conceptualization, investigation, methodology.

Laurie Flory – conceptualization, investigation, methodology.

Bruno Pereira – conceptualization, data curation, formal analysis, methodology.

Martine Duclos – conceptualization, methodology, writing – review & editing.

All authors gave final approval of the submitted manuscript.

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#### **Conflict of interest**

The authors have no conflicts of interest to disclose.

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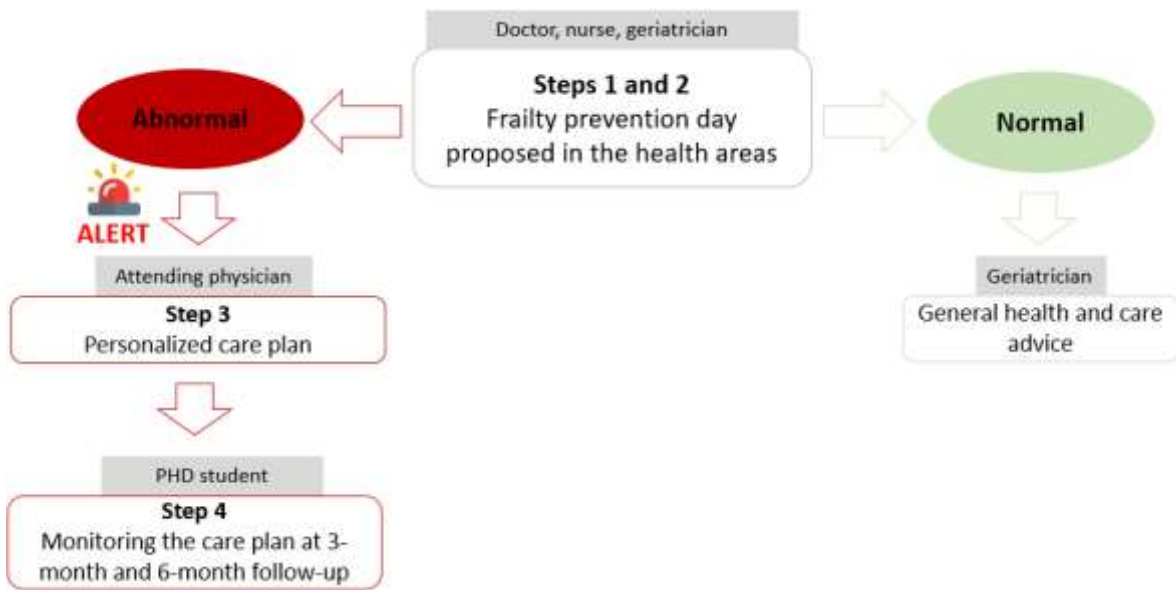


Figure 1: The ICOPE approach

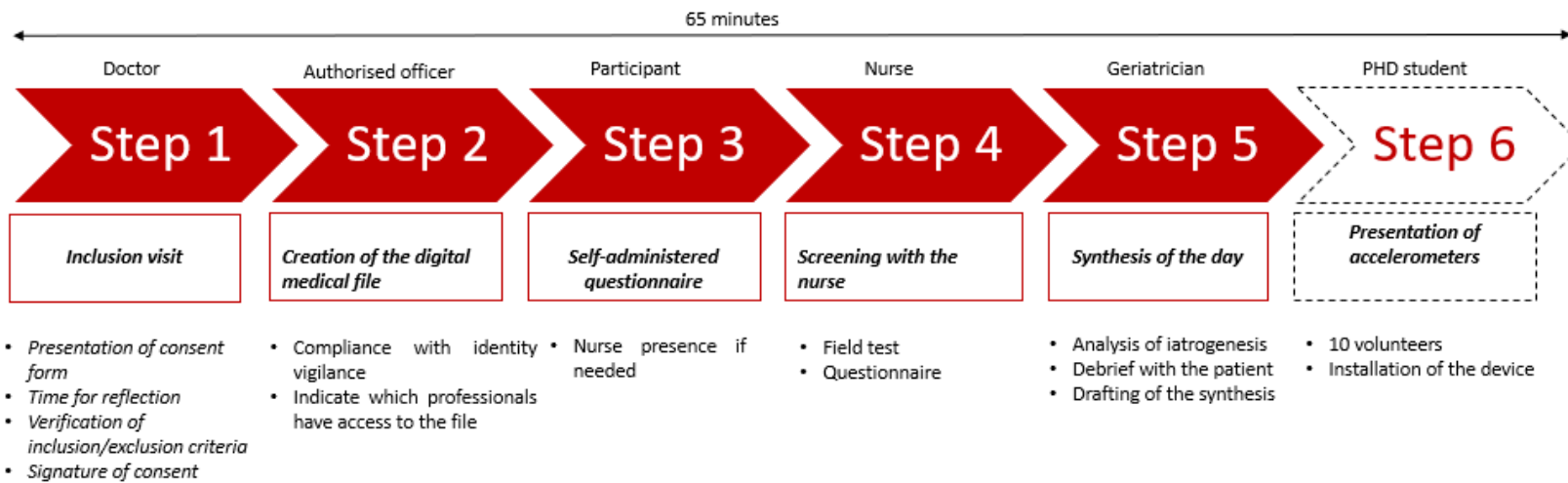


Figure 2: Steps followed during each screening day



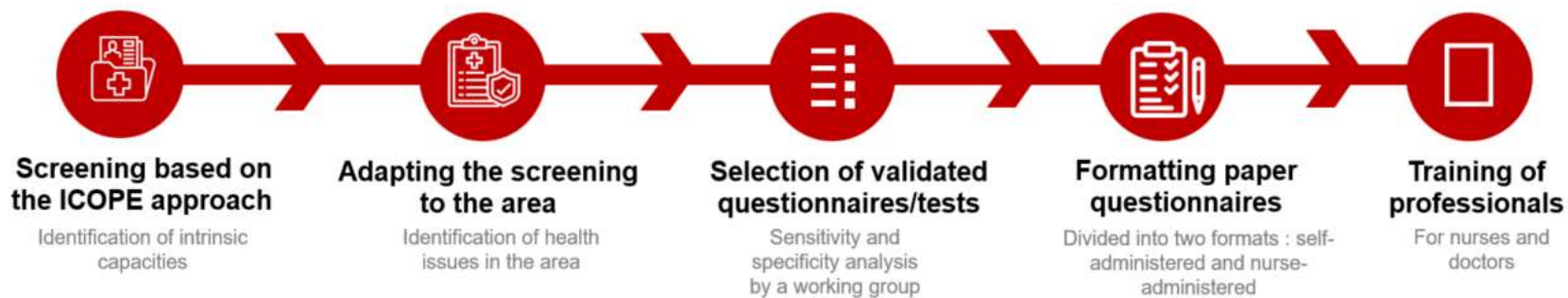


Figure 3: Steps involved in creating the screening process

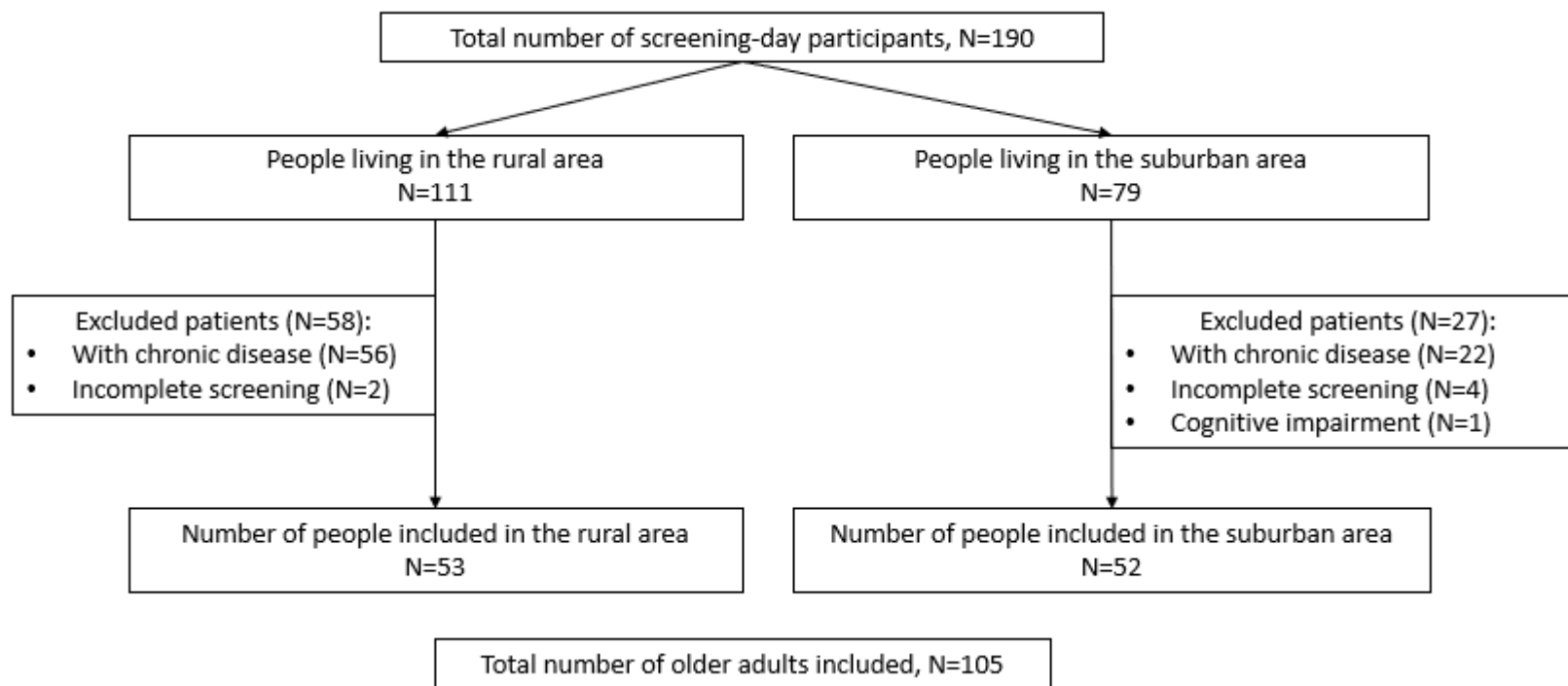


Figure 4: Participant inclusion flowchart

**Table 1: Screening domains and screening criteria used**

Domain	ICOPE	FRAGING study		
		Tests and questionnaires	Performance	Frailty
Cognitive capacity	Remember three words, orientation in time and space, recall the three words	CODEX	se=92.0%, spe=85.0% (Belmin et al., 2007)	Cognitive frailty < 3
Locomotor capacity	Chair rise test	ONAPS questionnaire Frequency of falls and TUG	reliability ICC= 0.71–0.98 (M Charles et al., 2021) se=93.3% , spe=80.0% (Shumway-Cook, Brauer, & Woollacott, 2000)	Inactivity: PA < 150 min/week Sedentary behaviour ≥ 7h/day If fall(s), TUG ≥ 14s
Vitality	Weight loss Appetite loss	Body composition (height, weight, BMI), MMI if needed MNA Handgrip test	MMI: se=81.0% , spe=61.0% (Rubenstein, Harker, Salvà, Guigoz, & Vellas, 2001) se=80.0%, spe=53.6% (men); se=94.4%, spe=56.8% (women) (M. Blanquet et al., 2020)	BMI < 22 kg.m <sup>2</sup> , MMI < 17 kg.m <sup>2</sup> (men) or < 15 kg.m <sup>2</sup> (women) (HAS, 2019a, 2021) MNA score ≤ 11 Handgrip score < 27kg (men) or < 16kg (women) (Cruz-Jentoft et al., 2019) Answer "yes"
Visual capacity	Ask patients if they have any problems with their eyes, such as problems seeing far away, reading, or disease of the eyes, or under medical treatment (diabetes mellitus, hypertension)	Ask patients if they have any problems with their eyes, such as problems seeing far away, reading, or disease of the eyes, or under medical treatment (diabetes mellitus, hypertension)		
Hearing capacity	Whisper test or audiometry	Ask patients if they have any problems with their hearing, and if necessary administer the HHIE-S	se=89.1% , spe=75.0% (Servidoni et al., 2018)	Hearing frailty ≥ 10
Psychological capacity	Ask patients if they are feeling down, depressed	PHQ-9	se=88.0%, spe=88.0% (Kroenke et al., 2001)	Psychological frailty ≥ 10
Quality of life	Not applicable	LEIPAD	internal reliability=0.68 et 0.87, test-retest reliability > 0.7 (I. Jalenques et al., 2013b; Isabelle Jalenques et al., 2019)	Above-average score by age
Socioeconomic status	Not applicable	EPICES score	se=88%, spe=71% (Demény, 2017)	Social deprivation ≥ 30
Help for caregivers	Not applicable	Mini-Zarit	se=80.7% , spe=79.4%	Caregiver support needed ≥ 1
Cardiovascular risk factors	Not applicable	Cardiovascular risks factors		Presence of cardiovascular risks
Alcohol consumption	Not applicable	FACE questionnaire	se=87.8%, spe=74.0% (men); se=84.4%, spe=84.0% (women) (Dewost et al., 2006)	Alcohol risk ≥5 (men) or ≥8 (women)
Cancer screening follow-up	Not applicable	INCa questionnaire		INCa references
Vaccination	Not applicable	Update of vaccinations		Vaccination references
Iatrogenesis	Not applicable	Analysis of drug prescriptions		

*Se: Sensitivity; Spe: Specificity; PA: Physical activity ; SB: Sedentary behavior; BMI: Body Mass Index; MMI: Muscular Mass Index; CODEX: Cognitive Disorders Examination; EPICES: Evaluation de la précarité et des inégalités de santé dans les Centres d'examen de santé; FACE: Fast Alcohol Consumption Evaluation; GLIM: Global Leadership Initiative on Malnutrition; HHIE-S: Hearing Handicap Inventory for the Elderly; MNA: Mini Nutritional Assessment; ONAPS questionnaire: Observatoire National de l'Activité Physique et de la Sédentarité questionnaire; PHQ-9: Patient Health Questionnaire-9; TUG : Timed Up and Go;*

Table 2 Characteristics of the participants

	Mauriac (n=53)		Vichy (n=52)		p-value
	m <sup>a</sup> [sd] <sup>b</sup> % <sup>c</sup> (n) <sup>d</sup>	Median (Iq1-Iq3)	m <sup>a</sup> [sd] <sup>b</sup> % <sup>c</sup> (n) <sup>d</sup>	Median (Iq1-Iq3)	
Age (years)	74.6 [6.6]	72 [69-80]	74.6 [6.4]	73 [70-77]	0.98
Educational attainment (low)	58.2 (32)		41.8 (23)		0.09
Marital status (not married or with a partner)	50.9 (29)		49.1 (28)		0.91
Lifestyle (alone)	49.1 (26)		50.9 (27)		0.77
Homecarers (yes)	50.0 (9)		50.0 (9)		0.97
Caregivers (yes)	50.0 (9)		47.1 (8)		0.76
Number of visits to doctor in the last 12 months	3 [2]	3 [1-4]	3 [2]	2 [2-4]	<b>0.04</b>
Weight (kg)	69.1 [14.6]	67.0 [87-104]	66.8 [16.2]	86 [55-80]	0.42
BMI (kg.m <sup>2</sup> )	26.3 [4.8]	26.3 [24-30]	24.8 [5.0]	25 [21-28]	0.88
BMI categories (n, %)					0.10
Underweight	9.4 (5)		27.5 (15)		
Normal weight	22.6 (12)		19.2 (10)		
Overweight	39.6 (21)		32.7 (17)		
Obese	28.3 (15)		19.2 (10)		

<sup>a</sup>m: mean; <sup>b</sup>sd: standard derivation; <sup>c</sup>%: percentage; <sup>d</sup>n: number; BMI: Body Mass Index. Data are presented as mean (standard derivation) or median (interquartile range) in each area, with p-values. Boldfaced values: p < 0.05

Table 3: Frequency of frailty in the RU (n=53) and the SU (n=52) according to screening and reference criteria.

	RU (n=53)		SU (n=52)		Frailty × health area p-value
	Non-Frail % <sup>a</sup> (n) <sup>b</sup>	Frail % <sup>a</sup> (n) <sup>b</sup>	Non-Frail % <sup>a</sup> (n) <sup>b</sup>	Frail % <sup>a</sup> (n) <sup>b</sup>	
Cognitive capacity	75.5 (40)	24.5 (13)	75.0 (39)	25.0 (13)	0.995
Locomotor capacity	81.1 (43)	18.9 (10)	78.8 (41)	21.2 (11)	0.770
Vitality	77.4 (41)	22.6 (12)	73.1 (38)	26.9 (14)	0.611
Visual capacity	86.8 (46)	13.2 (7)	96.2 (50)	3.8 (2)	0.087
Hearing capacity	71.7 (38)	28.3 (15)	73.1 (38)	26.9 (14)	0.874
Psychological capacity	62.3 (33)	37.7 (20)	78.8 (41)	21.2 (11)	0.063
Health-related quality of life	45.3 (24)	54.7 (29)	86.5 (45)	13.5 (7)	<b>&lt;0.0001</b>
Socioeconomic status	69.8 (37)	30.2 (16)	90.4 (47)	9.6 (5)	<b>0.008</b>
Caregiver support needs	90.6 (48)	9.4 (5)	90.4 (47)	9.6 (5)	0.975
Alcohol consumption	86.8 (46)	13.2 (7)	92.3 (48)	7.7 (4)	0.356
Cardiovascular risk factors	60.4 (32)	39.4 (21)	67.3 (35)	32.7 (17)	0.460
Global cancer screening					
<i>Breast cancer</i>	83.0 (44)	17.0 (9)	90.4 (47)	9.6 (5)	0.267
<i>Colorectal cancer</i>	60.4 (32)	39.6 (21)	80.8 (42)	19.2 (10)	<b>0.022</b>
<i>Skin cancer</i>	41.5 (22)	58.5 (31)	53.8 (28)	46.2 (24)	0.206
Global vaccination					
<i>Tetanus</i>	43.4 (23)	56.6 (30)	69.2 (36)	30.8 (16)	<b>0.008</b>
<i>Flu</i>	69.8 (37)	30.2 (16)	73.1 (38)	26.9 (14)	0.711
<i>Pneumococcal</i>	88.7 (47)	11.3 (6)	50.0 (26)	50.0 (26)	<b>&lt;0.0001</b>

<sup>a</sup>%; <sup>b</sup>n: number; IC: Intrinsic capacity. Data are presented as percentage (number) with p-value. Boldfaced values:  $p < 0.05$

Table 4: Frequency of frailty in the RU (n=53) and the SU (n=52) according to sociodemographic characteristics.

Characteristics	Total number of frailties						
	Mean [SD]	RU (n=53) Median [IQ-IQ3]	p-value	Mean [SD]	SU (n=52) Median [IQ-IQ3]	P-value	p-value total
<b>General</b>	5.1 [2.3]	5.0 [4.0-7.0]		3.6 [2.3]	3.5 [2.0-5.0]		<b>0.02</b>
<b>Gender</b>			0.26			0.13	
Female	5.0 [2.5]	5.0 [3.0-6.0]		4.2 [2.4]	4.5 [3.0-6.0]		<b>0.03</b>
Mal	5.0 [3.2]	4.0 [3.0-7.0]		2.1 [1.5]	2.0 [1.0-3.0]		
<b>Educational attainment;</b>			0.45			0.2	0.15
High-school or higher education;	4.0 [2.6]	4.0 [2.0-6.0]		3.2 [2.0]	3.0 [2.0-5.0]		
Pre-high school;	5.7 [2.6]	5.0 [4.0-8.0]		4.6 [2.6]	5.0 [2.0-7.0]		
<b>Marital status</b>			0.57			0.05	0.07
Married or with a partner	4.2 [2.1]	4.0 [3.0-5.0]		3.5 [2.5]	3.0 [1.5-5.0]		
Never-married, divorced, widower	5.9 [3.0]	5.0 [4.0-8.5]		4.0 [2.3]	4.0 [2.5-5.5]		
<b>Physical function</b>			0.92			0.06	0.12
Normal score	4.3 [2.1]	4.0 [3.0-6.0]		4.1 [2.3]	4.0 [3.0-5.5]		
Abnormal score	4.4 [2.7]	4.0 [3.5-5.0]		2.7 [1.9]	2.5 [1.0-5.0]		
<b>Self-care</b>			0.082			0.90	0.92
Normal score	4.4 [2.6]	4.0 [3.0-6.0]		3.7 [2.3]	3.5 [2.0-5.0]		
Abnormal score	4.1 [1.5]	4.0 [4.0-4.0]		2.8 [2.1]	2.5 [1.0-4.5]		
<b>Depression &amp; anxiety</b>			0.34			0.29	0.39
Normal score	4.7 [2.5]	4.0 [4.0-6.0]		3.8 [2.5]	4.0 [2.0-5.0]		
Abnormal score	3.8 [2.0]	4.0 [2.0-5.0]		3.3 [1.9]	3.0 [2.0-5.0]		
<b>Cognitive functioning</b>			0.87			0.26	0.56
Normal score	4.5 [2.6]	4.0 [3.0-6.0]		3.6 [2.0]	4.0 [2.0-5.0]		
Abnormal score	4.1 [2.1]	4.0 [3.0-5.0]		3.7 [2.6]	3.0 [2.0-5.0]		
<b>Social functioning</b>			0.22			0.47	0.40
Normal score	3.8 [1.8]	4.0 [2.5-4.0]		3.6 [2.2]	3.0 [2.0-5.0]		
Abnormal score	4.9 [2.7]	4.0 [4.0-7.0]		3.6 [2.4]	4.0 [1.5-5.0]		
<b>Sexual functioning</b>			0.13			0.85	0.21
Normal score	3.2 [1.7]	4.0 [2.0-4.0]		3.6 [2.2]	3.0 [2.0-5.0]		
Abnormal score	4.8 [2.5]	4.0 [3.5-6.5]		3.6 [2.4]	4.0 [1.0-5.0]		
<b>Life satisfaction</b>			0.96			0.93	0.39
Normal score	4.4 [2.5]	4.0 [3.0-6.0]		3.3 [2.3]	3.0 [2.0-5.0]		
Abnormal score	4.2 [2.2]	4.0 [3.0-5.5]		4.1 [2.3]	4.5 [3.0-5.0]		

IC: Intrinsic capacity; SD: Standard Derivation; IQ: InterQuartile range. Data are presented as mean (standard derivation) and median (interquartile range) with p-value. Boldfaced values:  $p < 0.05$

Figure 5: Heatmap of relationships between the health-related quality-of-life component and frailty stratified by health-area setting (RU : n=53; SU: n=52)

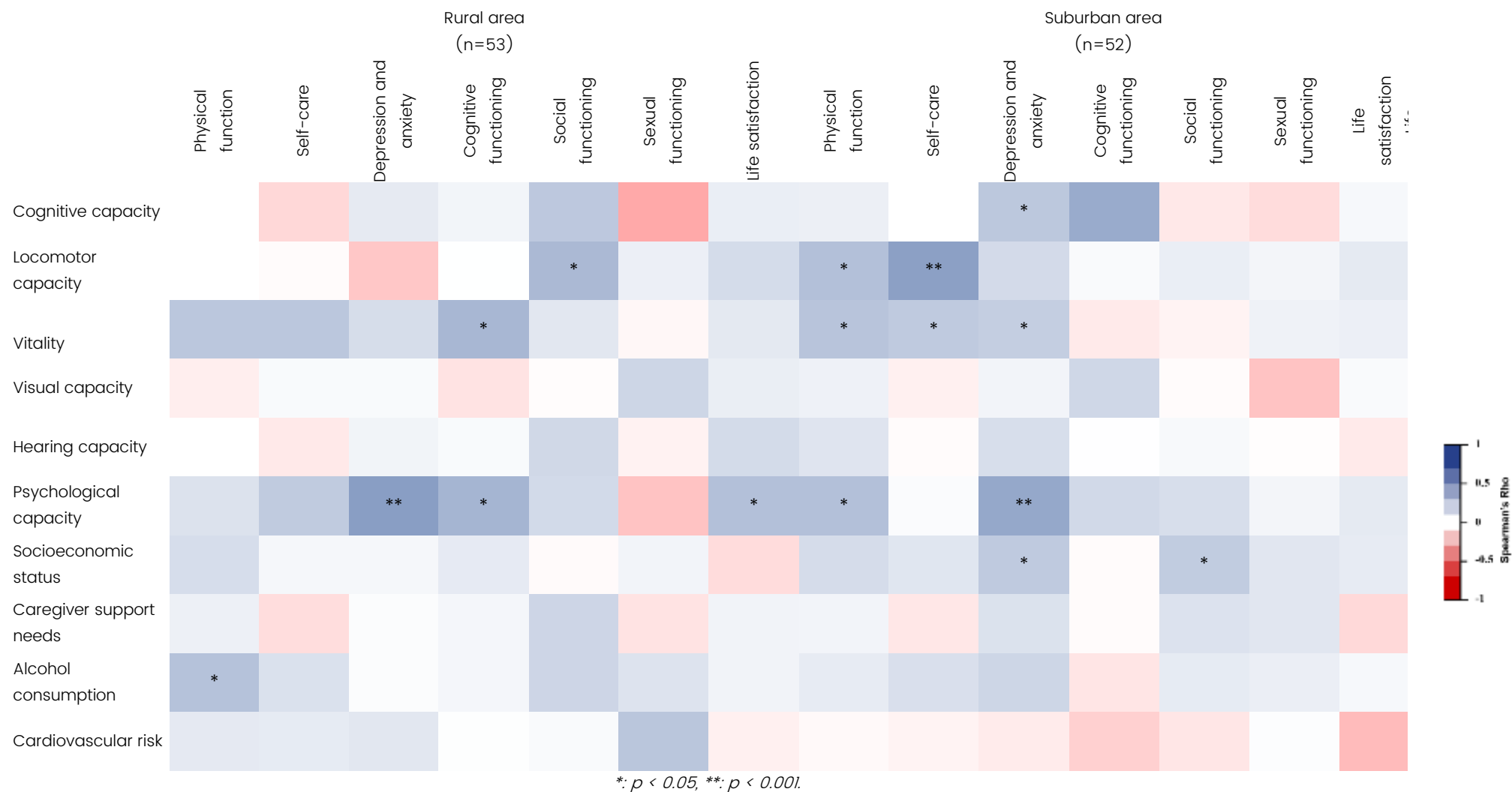


Figure 6: Heatmap of relationships between the health-related quality of life component and frailty stratified by gender (men: n=24; women: n=81).

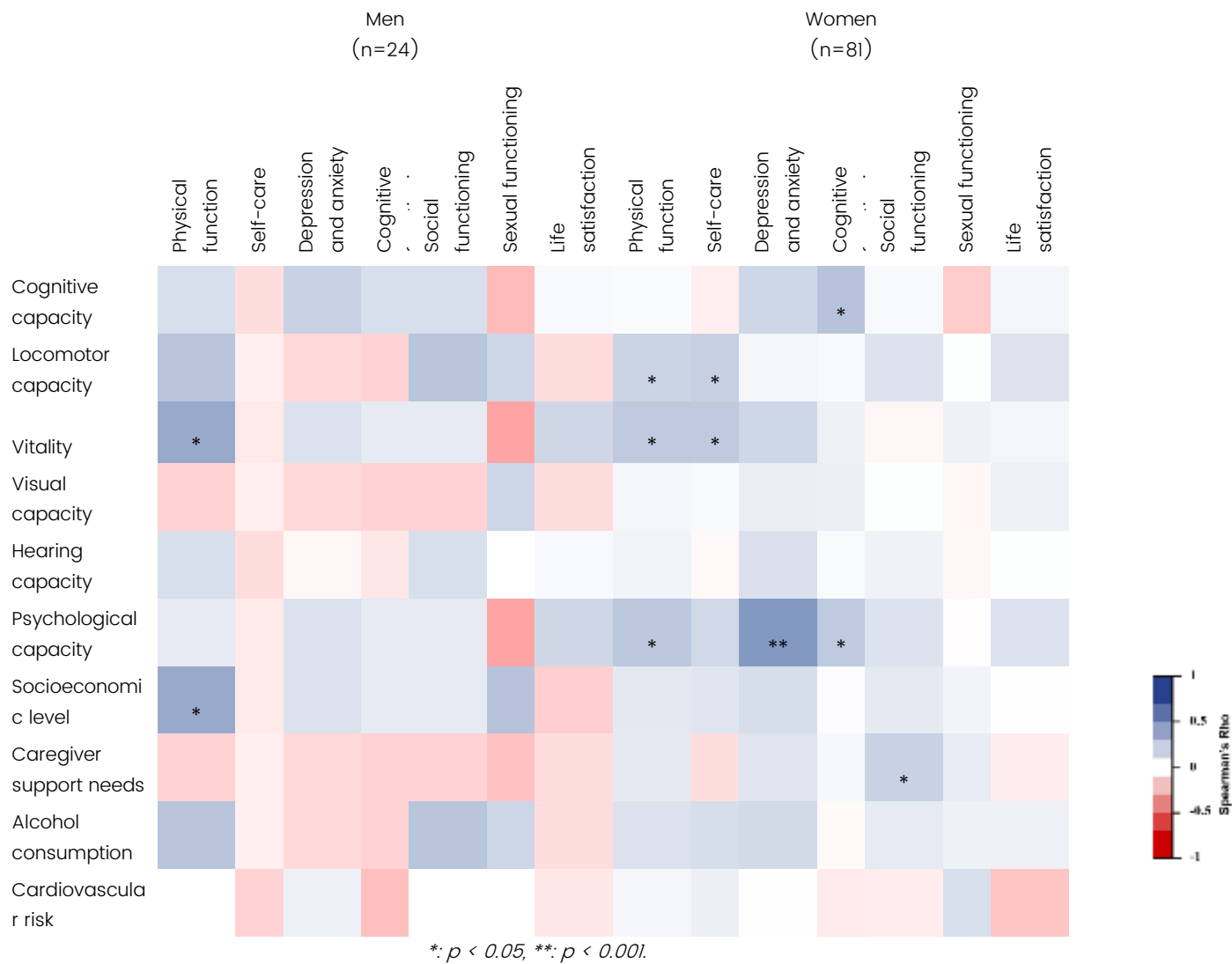




Table 5: Demographic characteristics and accelerometer-measured level of physical activity and sedentary behaviour in time and in percentage of wear time (n=44).

	Sedentary time (h/day)		Low physical activity (min/week)		Moderate physical activity (min/week)	
	Mean [SD]	p-value	Mean [SD]	p-value	Mean [SD]	p-value
<b>Territorial setting</b>		<b>0.06</b>		<b>0.03</b>		0.61
<i>Rural</i>	6.8 [1.9]		373.5 [111.2]		68.6 [47.1]	
<i>Suburban</i>	7.8 [1.7]		312.1 [73.4]		57.5 [30.7]	
<b>Gender</b>		<b>0.02</b>		<b>0.01</b>		0.27
<i>Men</i>	8.9 [2.1]		259.6 [11.6]		46.9 [26.1]	
<i>Women</i>	7.0 [1.6]		357.9 [84.0]		66.0 [40.8]	
<b>Educational attainment;</b>		0.70		0.94		0.28
<i>High-school or higher education</i>	7.4 [1.9]		339.3 [90.9]		69.7 [41.7]	
<i>Pre-high school</i>	7.2 [1.8]		341.0 [105.9]		53.1 [33.8]	
<b>Marital status</b>		0.07		0.13		0.40
<i>Married or with a partner</i>	8.0 [2.0]		313.9 [107.0]		69.7 [41.7]	
<i>Never married, divorced, widower</i>	6.8 [1.5]		361.8 [82.8]		53.1 [33.8]	
<b>Living arrangements</b>		<b>0.03</b>		0.14		0.80
<i>Living alone</i>	8.1 [2.0]		315.3 [107.9]		66.4 [38.3]	
<i>Living with someone</i>	6.8 [1.5]		360.6 [82.5]		59.3 [40.0]	
<b>Homecarers</b>		0.13		0.33		<b>0.04</b>
<i>No</i>	7.1 [1.7]		346.2 [97.5]		67.2 [39.8]	
<i>Yes</i>	8.4 [2.0]		307.4 [90.6]		37.7 [23.1]	
<b>Caregivers</b>		0.89		0.35		0.11
<i>No</i>	7.4 [1.9]		348.4 [90.8]		66.7 [40.5]	
<i>Yes</i>	7.3 [1.8]		302.3 [118.2]		43.6 [24.7]	

SD: standard derivation; h: hours; min: minutes. Boldfaced values:  $p < 0.05$

## Conclusion de l'étude

Cette étude a montré que la fragilité est un état clinique sous-estimé chez les personnes âgées en bonne santé. Aussi, les femmes étaient moins sédentaires que les hommes et pratiquaient plus d'AP de faible intensité que les hommes. Les personnes vivant en milieu rural pratiquaient également plus d'AP de faible intensité que celles résidant en milieu semi-urbain. De plus, nous avons démontré la nécessité de proposer des tests validés adaptés tout en tenant compte des enjeux territoriaux et de l'organisation des soins. Les consultations de prévention soutenues par les pouvoirs publics aux étapes clés de la vie devraient constituer une base solide pour le dépistage en santé publique.

Le cadre ICOPE encourage un changement dans la manière dont les états gèrent et fournissent les services de santé. Ce cadre préconise également l'adoption d'une approche intégrée et centrée sur l'individu. Toutefois, un changement de paradigme est nécessaire pour inculquer ce nouveau cadre de soins au sein de la communauté des professionnels de la santé. D'autres études devraient analyser l'impact de l'approche globale ICOPE, y compris le plan de soins personnalisé, et identifier les obstacles et les moteurs connexes pour réaliser le parcours de soins.

**PARTIE III – DISCUSSION  
GENERALE ET CONCLUSION**

## DISCUSSION

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En raison de leur sensibilité à l'AP, tant sur le plan du développement physique et cognitif que sur celui de la vulnérabilité aux problèmes de santé associés, les enfants et les personnes âgées se trouvent particulièrement exposés aux risques liés à l'insuffisance d'AP et la sédentarité. Aussi, l'évolution de notre mode de vie a engendré une augmentation de l'inactivité physique et de la sédentarité avec des effets délétères sur la santé, que ce soit de manière indépendante ou conjointement (Carson et al., 2016; Ekelund et al., 2020; Garcia et al., 2023; Gibbs et al., 2015; Katzmarzyk et al., 2019; LeBlanc et al., 2017). La pandémie mondiale de COVID-19 et ses restrictions sanitaires ont conduit à une limitation de la mobilité de la population. C'est dans ce contexte que ce travail de doctorat visait à questionner de l'intérêt et des stratégies mises en place afin de favoriser la pratique d'une AP et de la limitation du temps sédentaire, et ce aux âges extrêmes de la vie.

La pandémie de COVID-19 a été une crise sans précédent, rendant impossible toute estimation préalable de ses conséquences. En 2020 en France, quelques semaines après l'annonce des premières restrictions sanitaires et notamment du premier confinement, l'ONAPS a publié de nouvelles recommandations d'AP et préconisait (Onaps, 2020) : i) la pratique d'activités simples comme la marche ; ii) de garder à l'esprit que l'exercice ne doit pas nécessairement être douloureux et que nous devons écouter nos propres sentiments et nos capacités à nous améliorer progressivement ; iii) de favoriser tout mouvement quotidien, quelle que soit son intensité et sa durée ou encore iv) de minimiser les comportements sédentaires dès les premiers jours de confinement afin d'éviter la léthargie et d'adopter des comportements et des habitudes de mouvement sains. Par la suite, des études françaises et internationales ont rapidement confirmé les effets délétères du confinement sur les comportements de mouvements de la population générale (Cheval et al., 2021; Deschasaux-Tanguy et al., 2021; Genin et al., 2021; Stockwell et al., 2021), des enfants et adolescents (Do et al., 2022; Kharel et al., 2022; Neville et al., 2022; Pang et al., 2023; Rossi et al., 2021; Trott et al., 2022), et des seniors (Charreire et al., 2022; Oliveira et al., 2022).

Alors que la vulnérabilité des seniors au virus du COVID-19 est encore plus élevée que le reste de la population, la plupart des études mesurant les effets du COVID-19 sur le type d'AP pratiquée se sont majoritairement intéressées aux adultes (70,5 %), mais peu aux enfants (13,1 %) et encore moins aux seniors (3,3 %) (König et al., 2023; Park et al., 2022). Pourtant, les seniors ont encore plus limité leur AP collective et/ou en plein air afin de limiter le risque

d'infection . Cet isolement a également limité les contacts sociaux, ce qui a des répercussions sur la fragilité physique et probablement psychologique (Gale et al., 2018). Il est donc essentiel de surveiller et de soutenir en permanence les activités sociales des personnes âgées sensibles dans des circonstances extraordinaires, comme l'est celle du COVID-19 (Otaki et al., 2022). Ces résultats montrent à quel point il est primordial de favoriser l'AP au travers d'interventions communautaires visant à aider les personnes âgées à exploiter des stratégies d'adaptation positives telles que l'exercice, des routines modifiées et des stratégies sociales afin d'améliorer la santé physique et mentale, de favoriser le soutien social en période de stress et de traumatisme (Finlay et al., 2021).

Cette pandémie a permis à la population d'avoir une réelle prise de conscience sur l'importance de l'accès aux extérieurs et aux espaces verts (Park et al., 2022), qui semblaient limiter les effets des restrictions sanitaires en population générale. En effet, tout comme un faible niveau socio-économique (Rossi et al., 2021; S. Sasaki et al., 2021; Suzuki et al., 2020), vivre en milieu urbain a négativement été associé à la pratique d'une AP pendant la pandémie en France (Charreire et al., 2022; Pouget et al., 2022), en Europe (Lohmöller et al., 2023; Zenic et al., 2020) et au Canada (Mitra et al., 2020). Le type de confinement (strict ou partiel) semble avoir impacté les comportements de mouvements pendant la pandémie. Ainsi, dans les pays avec un confinement strict comme la France (Chambonniere et al., 2021a, 2021b), et plus largement en Europe (Constandt et al., 2020; Giustino et al., 2020), les personnes actives ont encore plus réduit leur AP quotidienne. Au contraire chez les enfants au Brésil, où un confinement partiel a été en place, il a été observé que le confinement n'a pas eu d'impact sur le NAP (Siegle et al., 2022). Même si les écoles et les parcs étaient fermés, les activités individuelles comme le vélo et la course à pied étaient autorisées, ce qui a contribué à maintenir un certain niveau d'AP chez les enfants pendant cette période. Dans certaines régions du Canada également, les enfants pouvaient toujours participer à des activités en extérieur (Mitra et al., 2020). Aussi, les politiques de promotion de l'AP, notamment celles pour les enfants, devraient se focaliser sur l'accès aux installations de loisirs, sur les programmes scolaires et les loisirs afin de favoriser la mobilité des enfants (Fabre et al., 2023; Sallis et al., 2008) (Figure 31).

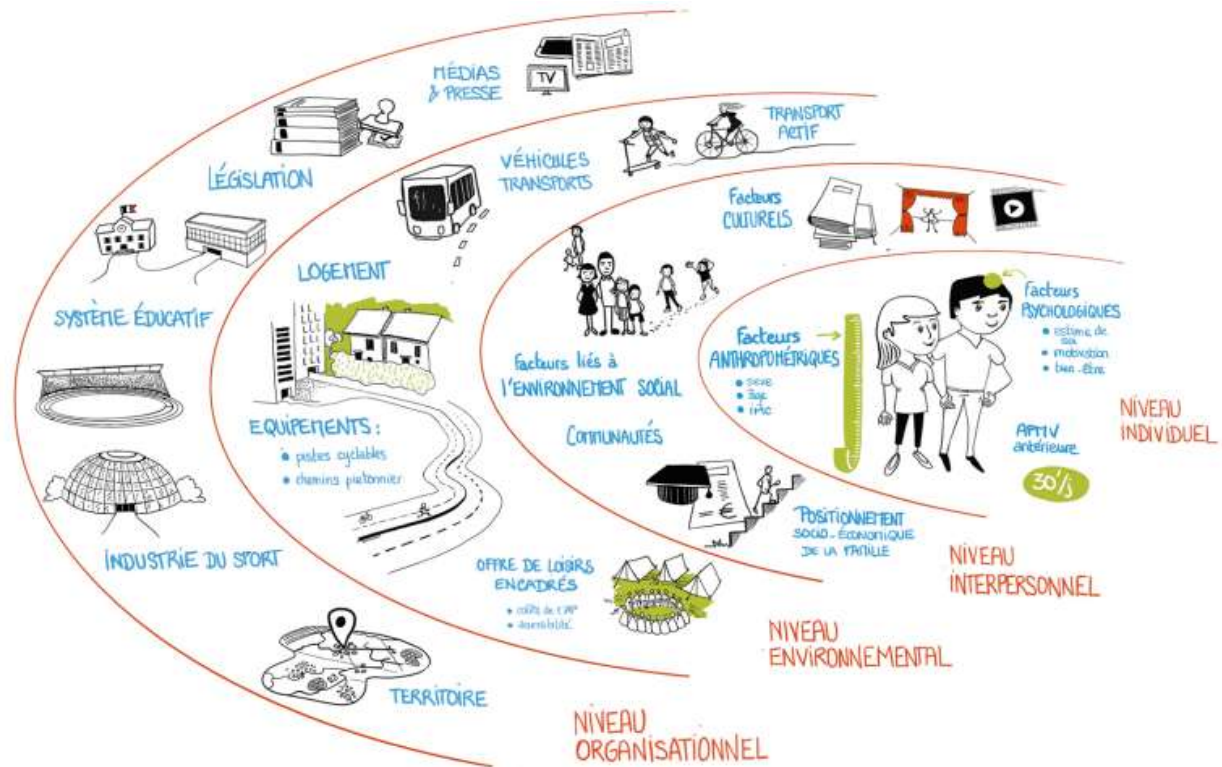


Figure 31 : Modèle socio-écologique des différents facteurs d'influence sur le comportement d'activité physique des adolescents

Source : Fabre *et al.* (2023) inspirée de Sallis *et al.* (2015)

En lien avec une altération de la mobilité, les restrictions associées à la pandémie ont induit une diminution significative des capacités physiques des enfants de primaire en France (Béghin *et al.*, 2022; Chambonnière *et al.*, 2021c), ce qui a été confirmé en Europe (López-Bueno *et al.*, 2021; Rúa-Alonso *et al.*, 2022; Sunda *et al.*, 2021) aux Etats-Unis (Wahl-Alexander & Camic, 2021) et en Australie (Tsoukos & Bogdanis, 2021). Les effets du COVID-19 et des restrictions sanitaires sur le long terme ont également été questionnés (Teich *et al.*, 2023), avec des effets toujours visibles deux ans après le début des restrictions sanitaires, ce qui renforce le besoin d'identifier des stratégies efficaces et pérennes pour favoriser les comportements de mouvements sains chez les jeunes générations.

Les enfants sont confrontés à la nécessité de concilier des activités essentielles telles que la réussite scolaire et l'accomplissement de leurs devoirs, avec le risque inhérent d'accroître leur sédentarité (Carson *et al.*, 2016). Les écrans, dont on connaît les effets néfastes lors d'une exposition prolongée, ont été largement utilisés pendant le confinement et ont permis le maintien des cours à distance. L'école favorise les longues périodes ininterrompues de temps passé assis (Bailey *et al.*, 2012; Janssen *et al.*, 2016), ce qui en fait un lieu privilégié pour

l'innovation en termes de nouvelles stratégies de fonctionnement (incluant le mouvement) en classe. Aussi, les vélo-bureaux ont été identifiés comme efficaces pour limiter la sédentarité, augmenter l'AP de faible intensité, l'APMV (Fedewa et al., 2017) et la stratégie la plus efficace pour augmenter la dépense énergétique pendant le temps scolaire (Guirado et al., 2021).

C'est dans ce contexte que le projet BICLASS, après avoir montré les effets délétères du COVID-19 sur les capacités physiques et cognitives des enfants, a mesuré les effets de l'utilisation de vélo-bureaux à l'école primaire pendant les temps de classe sur ces mêmes paramètres (Chambonnière et al., 2023). Nos résultats sont prometteurs et montrent pour la première fois les effets non délétères de l'utilisation de vélo-bureaux sur l'ensemble de nos paramètres étudiés. Aussi, l'analyse du niveau socio-économique nous a permis de montrer l'efficacité d'un tel dispositif chez tous les enfants. Le niveau socio-économique des enfants est associé à une inactivité physique et une sédentarité accrue en Europe (Musić Milanović et al., 2021), ce qui a été confirmé pendant la pandémie de COVID-19 (Deoni et al., 2021; Engzell et al., 2021). Pour la première fois, notre étude a montré une diminution significative des disparités en termes de résultats aux capacités physiques et cognitives entre les deux niveaux socio-économiques lors de l'utilisation de vélo-bureaux.

Actuellement, seulement 3 études se sont intéressées aux effets de l'utilisation des vélo-bureaux pendant le temps scolaire sur la santé des enfants, dont deux ont été réalisées en Europe (Ruiter et al., 2019; Torbeyns et al., 2017), et une aux Etats-Unis (Fedewa et al., 2017). Parmi elles, seulement une est réalisée en école primaire (Ruiter et al., 2019). La littérature scientifique a mis en avant des effets bénéfiques de l'utilisation de vélo-bureaux sur les capacités cardiorespiratoires (Torbeyns et al., 2017) et des effets mixtes sur les capacités cognitives (Ruiter et al., 2019; Torbeyns et al., 2017). Dans notre étude, nous n'avions pas de groupe contrôle, ce qui représente la principale limite. Cependant au vu de la littérature il semble peu probable qu'il y ait eu un effet de maturation sur l'ensemble de nos paramètres lors d'une intervention si courte (Alesi et al., 2020; Bonnema et al., 2022; Li et al., 2022; Thomas et al., 2020; Torbeyns et al., 2017; Zhao et al., 2022). Notre étude a complété ceux de la littérature scientifique en montrant des effets non délétères de l'utilisation de vélo-bureaux en primaire sur les capacités physiques, cognitives et de composition corporelle. En outre, notre étude renforce la faisabilité d'intégrer des vélo-bureaux en école primaire, bien qu'une étude réalisée sur une année scolaire complète permettrait plus précisément de mesurer la relation entre capacités physiques et cognitives lors de l'utilisation des vélo-bureaux (Barbosa et al., 2020; Esteban-Cornejo et al., 2020).

Bien que ces paramètres n'aient pas été inclus dans une des publications du projet BICLASS, ce travail a également montré des résultats prometteurs quant à la faisabilité d'utilisation d'un tel dispositif à l'école. Dans notre étude tous les enfants ont signé le consentement (n=99 enfants), et aucun n'a quitté l'étude. Parmi les 4 enseignants, tous ont été satisfaits de la cohésion de groupe, du respect des règles, de la rotation sur les vélo-bureaux, de l'atmosphère de classe, ce qui rejoint les résultats ayant reporté une bonne acceptabilité des enfants et des enseignants sur des dispositifs similaires (Fedewa et al., 2017; Dornhecker et al., 2015; Koepp et al., 2012; Mehta et al., 2015).

Si les enfants représentent une population en devenir dont la santé à l'âge adulte et aussi les habitudes dépendent, en outre du mode de vie dans l'enfance, une autre population mérite également une attention particulière au vu du risque de fragilité dont elle fait l'objet. Bien que ces deux groupes semblent très éloignés en termes d'âge, ce projet de thèse cherche à établir des liens importants entre l'AP tout au long de la vie et les avantages pour la santé qu'elle peut offrir, quels que soient l'âge et le contexte. À mesure que la proportion de personnes âgées augmente en France, et plus globalement dans le monde, il devient essentiel de promouvoir leur autonomie, notamment agissant sur les fragilités. Les études réalisées en France (Tavassoli et al., 2022, 2022), en Europe (Luque et al., 2023) et dans le monde (Ma et al., 2020; Won et al., 2021) selon le modèle ICOPE montrent globalement une forte hétérogénéité de prévalence de la fragilité chez les séniors située entre 3,2 % 92,6 % (Sum et al., 2022).

Si nous avons déjà évoqué plus haut les effets néfastes de la crise du COVID-19 sur le NAP et les comportements sédentaires chez les séniors, signalons simplement ici que cette crise a également accéléré le passage d'un certain nombre de séniors de l'état non-fragile à l'état fragile (Hirose et al., 2023; Kojima et al., 2018; Ferrara et al., 2023) (Figure 32). Ce constat souligne d'autant plus la nécessité de favoriser la mise en place de dépistage de la fragilité dans cette population en vue d'une meilleure prise en charge et prévention de cet état.



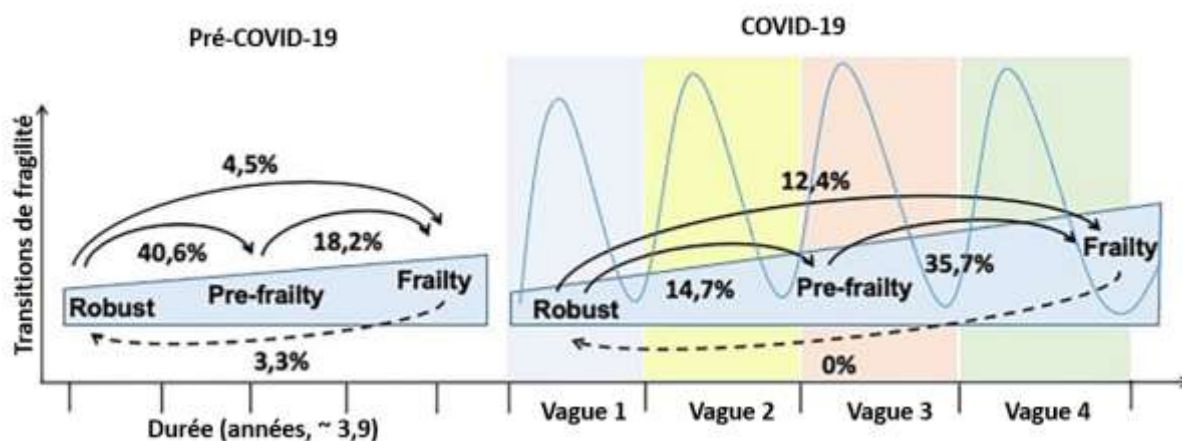


Figure 32 : Evolution du statut de fragilité

Robust : robuste ; pre-frailty : pré-fragilité ; frailty : fragilité

Source : König *et al.* (2023)

Au travers de l'étude FRAGING ce travail de thèse a permis d'agrémenter la littérature scientifique en réalisant i) une analyse multicentrique sur deux territoires avec des caractéristiques distinctes (rural vs semi-urbain) ; ii) un dépistage des fragilités avec une vision holistique de la santé pour les séniors sans affection longue durée ; iii) un suivi téléphonique individuel réalisé à +3 et +6 mois. Ainsi, ce travail met pour la première fois en lumière un plus grand nombre de fragilités chez les séniors du milieu rural en comparaison du milieu semi-urbain. Ce vieillissement de la population, encore plus marqué en population rurale en Europe engendre des défis d'ordre sociaux, économiques et politiques et technologiques en termes de pauvreté, d'exclusion numérique et de télémédecine, d'isolement social ou encore de santé physique et mentale (European Parliament. Directorate General for Parliamentary Research Services., 2020), que le dépistage des fragilités pourrait éviter.

L'accessibilité semble être un facteur majeur expliquant les disparités milieu rural/milieu semi-urbain. En milieu rural, l'accès aux services de transport est limité voire inexistant, ce qui entrave l'accès aux services de santé, en particulier pour les séniors qui ne peuvent pas conduire (Findholt N., 2021). De plus, la littératie en santé et l'accès aux informations de santé sont moindres en milieu rural par rapport aux zones urbaines qu'il s'agisse de l'Europe (Chen et al., 2019) ou des Etats Unis (Aljassim & Ostini, 2020). Enfin, l'accessibilité au numérique restreinte en milieu rural peut être un frein à la e-santé. (Maillot et al., 2018; Meredith et al., 2023). Pourtant, le numérique peut être une vraie ressource pour réaliser le dépistage et le suivi des fragilités mais également pour favoriser l'AP chez les séniors. Ainsi, en France une étude a expérimenté l'utilisation du numérique pour le dépistage comme proposé dans l'approche ICOPE, ce qui a permis d'inclure plus de 10000 personnes (Tavassoli et al., 2021;

2022), ce qui n'aurait pas été possible sans l'utilisation du numérique. Cette utilisation paraît complexe dans le milieu rural où le face-à-face est souvent favorisé, pour éviter les difficultés d'accessibilité à la e-santé (Reiners et al., 2019).

Quel que soit le lieu de vie, il a maintenant été largement démontré que l'isolement social, la solitude et les problèmes de santé mentale qui en découlent (subis pendant les confinements), ainsi que l'inactivité physique, sont des facteurs de risque majeurs de fragilité, de déclin fonctionnel et même de mortalité chez les personnes âgées (Ammar et al., 2020; Hoogendijk et al., 2019). Aussi, une association a maintenant été largement démontrée entre une plus faible APMV, une plus grande sédentarité et la fragilité chez les seniors (Chen et al., 2020). Notre étude a également répertorié les niveaux d'AP et de sédentarité des seniors lors du dépistage des fragilités avec une démarche subjective (n=79) et objective (n=44). Les données d'accéléromètre présentes dans notre étude ont révélé que les personnes vivant en milieu rural pratiquent significativement plus d'AP de faible intensité que ceux vivant en milieu semi-urbain. Pourtant, en milieu rural, les équipements sportifs sont moins nombreux (27 % des équipements sportifs en France), peuvent se situer à plus d'une demi-heure, des équipements plus vétustes et avec un moindre confort (Hurtis & Sauvageot, 2018). En effet, une barrière majeure de la pratique d'AP chez les seniors est le manque de motivation quel que soit le lieu de vie (Marcen et al., 2022).

Une des motivations de pratique d'AP des personnes vivant en milieu rural est de limiter l'isolement et la solitude (Hussain et al., 2023). Pour ce faire, l'AP peut être favorisée par l'accès à un extérieur, les propositions communautaires pour favoriser l'AP, une meilleure connaissance des efforts de l'AP et des ressources disponibles (Gansefort et al., 2018). Il ne s'agit donc pas de proposer une stratégie spécifique au lieu de vie, mais plutôt de proposer des interventions communautaires adaptées et incluant un contact personnel, facteur de motivation à l'AP chez les seniors (Bock et al., 2014; Meredith et al., 2023). Aussi, afin d'instaurer un mode de vie actif au long terme, il s'agit de favoriser l'autodétermination centrée sur la santé par l'AP plaisir, en associant par exemple l'AP et le jeu dans une activité attrayante.

Notre étude FRAGING a, pour la première fois dans la littérature, proposé un suivi téléphonique des fragilités, avec une approche holistique. Bien que cette étude n'ait pas encore fait l'objet d'une publication, nous sommes en mesure d'en discuter. Notre étude a démontré la faisabilité de cette approche avec l'inclusion de 87,7 % de l'échantillon initial inclus dans l'analyse du suivi. Il est intéressant de noter que la seule autre étude réalisant un suivi a inclus 9,3 % de l'échantillon initial, ce qui est largement inférieur à notre étude (Tavassoli et al., 2022), en raison de contraintes financières. Notre suivi a révélé que 23,0 % des participants n'ont pas

bénéficié d'une prise en charge en raison du fait qu'ils n'ont « *pas été orienté par le médecin traitant* ». Cette observation soulève la question de l'orientation spécifique nécessaire pour les individus fragiles, qui requiert une expertise approfondie et parfois une prescription médicale, ce qui peut être le cas pour la locomotion. Pourtant, parmi les personnes présentant une fragilité de locomotion, seulement 38,5 % des personnes ont réalisé une prise en charge, et aucune n'a eu de prescription de « *sport-santé* » ou de « *sport sur ordonnance* ». Cette constatation soulève des interrogations quant à la perception de la prévention par l'AP chez les personnes âgées, ainsi que sur la formation des professionnels de la santé, en particulier des médecins traitants.

Cette situation peut s'expliquer par le manque de médecin traitant, de temps dédié aux consultations de prévention, ainsi que par un manque de formation dans ce domaine. De plus en France, 47 % des médecins ont 55 ans ou plus et 30 % ont 60 ans ou plus (DREES, 2019), ce qui peut influencer leur sensibilisation et leur compétence en matière de prescription d'AP et sportive pour les personnes âgées. Par conséquent, il semble essentiel que les médecins, étant au cœur de la réalisation du plan de soin des séniors, aient une connaissance approfondie des recommandations de la Haute Autorité de Santé concernant la prescription d'APS chez les personnes âgées (HAS, 2019b). Aussi, l'analyse des prises en charge réalisées en termes de locomotion montre qu'elles sont exclusivement axées sur de l'AP, alors que des interventions efficaces mobilisant les capacités locomotrices sont en réalité des interventions multifactorielles englobant des aspects tels que la nutrition et le contexte socioculturel (Ashikali et al., 2023) (Tableau 7).

	Type de prise en charge	Orientation	Reste à charge	Justification	Problématique identifiée	Gêne actuelle
Territoire rural	Activité physique à domicile	Elle-même	N.A.	N.A.	Besoin de marcher	Oui
	Ateliers en APAS	Médecin traitant	N.A.	N.A.	Isolement, rhumatismes	Oui
	Club de gymnastique	Elle-même	55 € / an	Adhésion	Sédentarité	Non
	Groupe séniors (gym, aquagym, marche)	Elle-même	4,30€ / séance	Adhésion	Sédentarité	Non
Territoire semi-urbain	Ateliers en APAS	Journées fragilités	3€ / séance	Séance	Douleurs aux genoux Manque d'équilibre +	Non
	Ateliers en APAS	Cardiologue	4€ / séance	Séance	renforcement musculaire	Non
	Ateliers en APAS	CCAS	20 € / an	Adhésion	Manque d'équilibre	Non
	Acuponcteur	Médecin traitant	Ne sait pas		Maladie de Lyme suspectée	Oui
	Kinésithérapie	Médecin traitant	N.A.	N.A.	Manque d'équilibre	Oui
	Kinésithérapie + radio	Médecin traitant	N.A.	N.A.	Rhizarthrose	Oui

**Tableau 7 : Types de prises en charge réalisées pour la locomotion**

N.A. : Non Applicable ; APAS : Activité Physique Adaptée et Santé ; CCAS : Centre Communal d'Action Sociale

## PERSPECTIVES

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Les différents travaux réalisés pendant ce doctorat ont certes permis d'agréments la littérature, mais ont également ouvert des perspectives quant à l'implémentation de nouvelles stratégies de santé au sein de différents espaces auprès de différentes populations.

Concernant les stratégies pour rendre plus actifs et moins sédentaires les enfants, il semble tout d'abord indispensable d'évaluer la faisabilité des classes plus « actives » et moins sédentaires sur une année scolaire complète. Il paraît par ailleurs important d'évaluer les possibilités d'implémentation à grande échelle (toute l'école, plusieurs écoles). Ainsi, la mise en place de vélo-bureaux apparaît comme intéressante pour limiter la sédentarité des enfants tout en les mettant en mouvement. Toutefois, son coût (entre 200 et 800 euros) (Guirado et al., 2021) peut être un frein à leur acquisition par les écoles.

Aussi, bien que l'utilisation d'un vélo-bureaux ne soit qu'une AP de faible intensité, elle montre une bonne acceptabilité par les enfants, ce qui pourrait induire à un attrait de l'AP. Aussi, la littérature scientifique a considéré que 50 % des recommandations d'AP devraient être réalisées à l'école (van Sluijs et al., 2021) afin d'atteindre les 60 minutes d'APMV par jour (Tassitano et al., 2020). De ce fait, il est primordial de trouver d'autres stratégies pour favoriser toujours plus l'AP et limiter la sédentarité chez les enfants pour : i) limiter les effets délétères de la pandémie sur les plans linguistique, moteur et cognitif, (Deoni et al., 2021), ii) limiter la diminution des capacités physiques présentes depuis des années chez les enfants. Aussi, tout comme l'école, le milieu de vie et notamment le logement doit être un lieu propice aux bons comportements de mouvements (Sheldrick et al., 2019), d'autant que l'influence de la famille sur l'AP a largement été démontrée (Flynn et al., 2023; Nader et al., 1996). Aussi, il serait intéressant de développer la promotion des interventions familiales, reconnues comme des approches prometteuses, telles que celles proposées dans le projet ProxOb en France, destiné aux enfants atteints d'obésité (Miolanne et al., 2022). Cette démarche, mise en œuvre au domicile des familles, englobe des composantes telles que l'éducation à l'AP, l'éducation nutritionnelle, ainsi que le soutien psychologique et parental pour les familles confrontées à l'obésité pédiatrique.

Chez les seniors, dans l'étude FRAGING réalisant un dépistage et un suivi des fragilités, nous avons montré l'importance non seulement d'identifier la fragilité, mais également le besoin

d'orienter les participants afin d'accompagner les seniors dans une prise en charge adaptée. Les disparités notamment en termes d'accessibilité entre milieu rural et milieu semi-urbain ont été mises en évidence. Ainsi, des perspectives s'offrent à nous pour le projet en lui-même mais également pour la promotion de l'AP et la limitation de la sédentarité chez les seniors. Afin de lutter contre cette problématique d'accessibilité au dépistage des fragilités, l'utilisation des « *bus santé mobile* » pourraient permettre « *d'aller vers* » les populations les plus fragiles et/ou vivant dans des déserts médicaux tout en proposant un dépistage en face-à-face, ce qui serait une grande aide pour aider à gérer les problématiques d'accès physique et numérique de la fragilité. Aussi, l'identification et l'évaluation de la fragilité par des infirmiers en pratique avancée sont réalisables (Safari et al., 2023) et permettrait d'accompagner les médecins traitant pour un suivi personnalisé et adapté aux problématiques identifiées. Pour identifier les structures favorisant l'AP et la sédentarité, il nous semble indispensable de s'appuyer sur les Communautés Professionnelles de Santé Territoriales (CPTS), qui connaissent leur territoire et leurs spécificités.

Enfin, pour favoriser l'AP chez les seniors, l'enjeu majeur est de favoriser la motivation et l'adhérence par le plaisir et le côté ludique. L'émergence de nouvelles stratégies telles que les jeux vidéo (comme la Nintendo Wii et la Microsoft Xbox 360 Kinect) qui combine des exigences cognitives et physiques (Maillot et al., 2012) ont montré leurs effets positifs avec une amélioration des capacités cognitives (Spence & Feng, 2010). Plus récemment la pratique immersive, qui consiste à immerger l'apprenant dans un univers virtuel pour lui faire vivre des situations réalistes (Béraud-Peigné et al., 2023; Drazich et al., 2023) semble également ouvrir le champ des possibles pour limiter le déclin physique et cognitif des seniors.

## CONCLUSION GENERALE

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Les travaux de recherche conduits durant ce projet de thèse ont permis i) de mettre en exergue les effets du confinement sur les niveaux d'activité physique et de sédentarité des enfants et des séniors (axe 1) ; ii) d'explorer les répercussions du COVID-19 sur les capacités physiques et cognitives des enfants, tout en examinant les effets de l'utilisation de vélo-bureaux chez les élèves de primaire (axe 2) ; et iii) d'éclairer la fragilité des personnes âgées vivant en milieu rural et semi-urbain (axe 3).

Ce travail de doctorat s'est ainsi concrétisé par :

- L'identification de critères d'influence des comportements de mouvements délétères pendant le confinement tels que le milieu de vie urbain et ne pas avoir accès à un extérieur et l'effet non protecteur du niveau initial de mobilité, chez les enfants et les séniors
- La validation des effets non délétères de l'utilisation d'un vélo-bureau en école primaire, et donc de sa faisabilité
- La caractérisation de la fragilité chez les séniors en milieu rural et semi-urbain basée sur le modèle ICOPE, avec une analyse et un suivi de la locomotion .

Cette thèse a scientifiquement contribué à la compréhension des effets néfastes du COVID-19 sur les habitudes de mobilité, notamment chez les enfants et les personnes âgées, Elle a également identifié des approches de détection et de promotion de l'AP à destination des enfants et des personnes âgées, dans le but ultime de proposer des prises en charges adaptées à ces groupes de population.

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# ANNEXES





# Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children



Quella (Université), Akou (Université), Lévy (Université), Pacher (Université), Akou (Université), Aubry (Université), Lévy (Université), Millaire (Université), Allard (Université), Terry (Université), Bruns (Université), David (Université) and Marnier (Université)  
 \*Laboratory of Metabolic Adaptations to Exercise under Physiological and Pathological conditions (MADAP) UPR 3030, Clermont Auvergne University, France  
 †Clinical Science Division, Pennington Biomedical Research Center, Baton Rouge, LA, USA  
 ‡National Observatory for Physical Activity and Sedentary Behaviors (OMAPS), Clermont-Ferrand, France  
 §Clermont-Ferrand University Hospital, Sorbonne and CHU, Clermont-Ferrand, France  
 ¶University Clermont 1, IIR Medicine, Clermont-Ferrand, France  
 ¶INSISE, UMR 1075, Clermont-Ferrand, France  
 ††Department of Sport Medicine and Functional Ergonomics, Clermont-Ferrand University Hospital, D. Maignier Hospital, Clermont-Ferrand, France  
 †††National Research Chair Health & Mobility, Clermont Auvergne University Clermont-Ferrand, Clermont-Ferrand, France

## BACKGROUND

The COVID-19 pandemic has resulted in a lockdown on 17 March 2020, for a total of 55 days with all primary and secondary schools closed and all teaching activities conducted online. As a direct consequence, an alarming decline in physical activity levels and an increase in sedentary behaviors have been showed in youth. Besides, children made little or no progress while learning from home during the confinement compared to a normal academic year. We hypothesize that a decline in physical fitness (PF) could also be involved, of the association between fitness and academic achievement in children. The aim of the present study is to evaluate whether the COVID-19-related confinement and social restrictions affected the levels of PF and academic achievement in primary school French children.

## METHODS

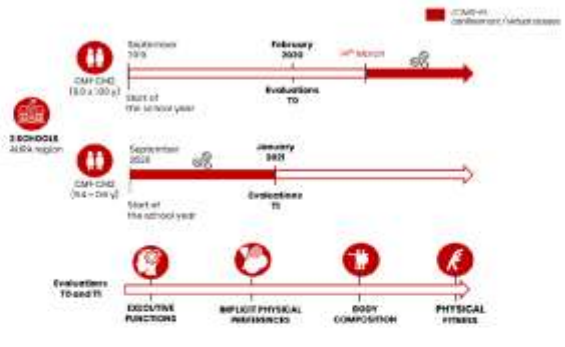


Figure 1: study design and details of evaluations

## RESULTS

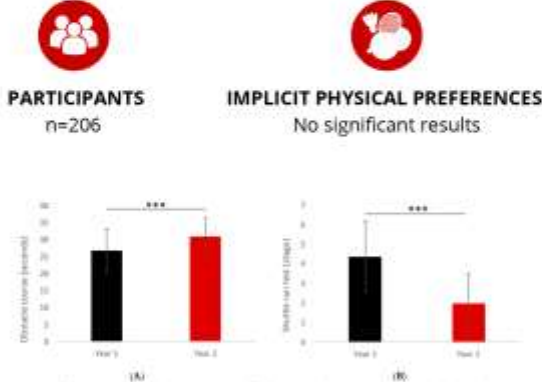


Figure 1. Performances at the Motor Skills Obstacle Course (A) and shuttle-run test (B) between T0 (year 1) and T1 (year 2). p < 0.0001.

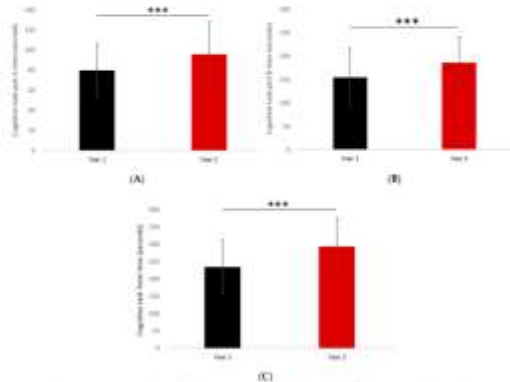


Figure 2. Results of the parts A and B (A,B) of the Trail Making Test and total score (C) at T0 (year 1) and T1 (year 2). p < 0.0001.

## CONCLUSION

↓ of executive functions could explain by the lower intellectual stimulation induced by

- ↓ in school time
- the use of virtual classes

The effects of the lockdown on movement behaviors and physical health might not be irreversible, children might be willing to re-engage in active behaviors

Body composition did not differ after 1-year confinement in youth

↓ in PF by about 25% over the last 40 years in children (Tomkinson et al., 2007). COVID-19 pandemic induced even more a ↓ in PF

We must work to encourage a healthy, active lifestyle in children in order to preserve their physical, mental, and social health during this continued public health crisis.

Reference: Tomkinson, G.R.; Olds, T.S. Secular changes in pediatric aerobic fitness test performance: The global picture. *Med. Sport Sci.* 2007,50, 46-66.



# The effects of using a cycling desk at school on executive functions, physical fitness and body composition in primary school children: a pilot within-subject study (BICLASS)

Camille Chambonnière, Pauline Demonteix, Méline Bailly, Audrey Boscato, Léna Pelissier, Terry Guirado, Alicia Fillon, Line Bonjean, Ludvine Paris, Julie Siroux Bruno Pereira, David Thivel, Lore Metz and Martine Duclos

## BACKGROUND

Physical activity decreases and sedentary behaviours increase during childhood and adolescence. In order to limit the time spent in sedentary activities at school and to promote low-intensity exercise, innovative strategies have emerged in recent years, such as active desks.

The purpose of this study was to investigate the effects of a program using a Cycle Desk during school time in primary school French children on body composition, physical fitness (PF) and executive functions (EF).

## METHODS

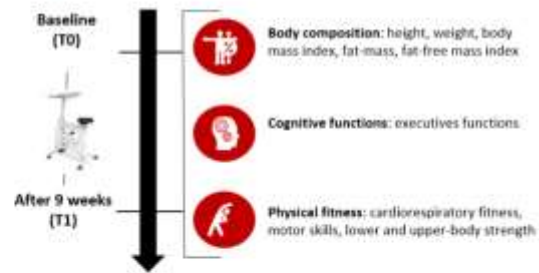


Figure 1: study design and details of evaluations.

## RESULTS



**PARTICIPANTS**  
CM1/CM2 (n=75)



**SOCIO ECONOMICAL LEVEL**  
High (n=33) & low (n=42)

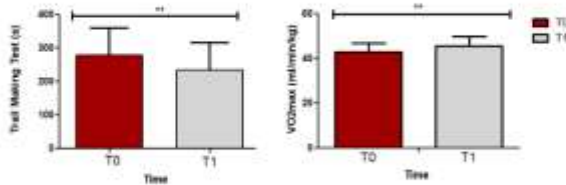


Figure 2. Results of the Trail Making Test and VO<sub>2</sub>max scores at baseline (T0) and after 9 weeks (T1) to use cycling desks

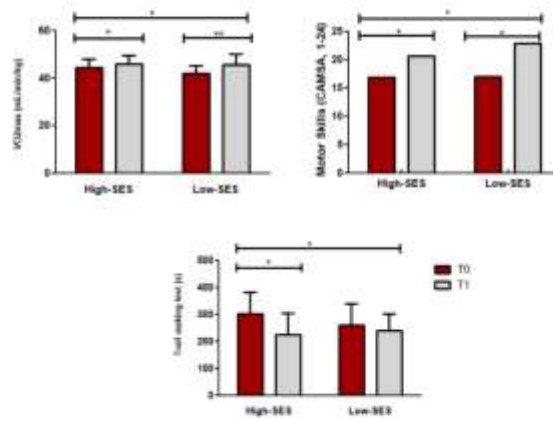


Figure 3. Comparison of EF, motor skills and cardiorespiratory performances according to socioeconomical statut (SES) at baseline (T0) and after 9 weeks (T1) to use cycling desks.

## CONCLUSION

Promoting active learning with cycling desks at school should be a major goal of school policy for main reasons:



↓ the negative effects of children's SES on body composition, PF and EF



Not negatively interfere the modifications of body composition, PF and EF



Good feasibility of implementing cycling desks at schools





## Review

# Effects of Classroom Active Desks on Children and Adolescents' Physical Activity, Sedentary Behavior, Academic Achievements and Overall Health: A Systematic Review

Terry Guirado <sup>1,2,3,\*</sup>, Camille Chambonnière <sup>1,2,3</sup>, Jean-Philippe Chaput <sup>4</sup>, Lore Metz <sup>1,2</sup>, David Thivel <sup>1,2</sup> and Martine Duclos <sup>2,3,5,6</sup>

- <sup>1</sup> Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions, (AME2P), UE3533, Clermont Auvergne University, 63170 Aubiere, France; Camille.CHAMBONNIERE@uca.fr (C.C.); lore.metz@uca.fr (L.M.); david.thivel@uca.fr (D.T.)
- <sup>2</sup> Auvergne Research Center for Human Nutrition (CRNH), 63000 Clermont-Ferrand, France; mduclos@chu-clermontferrand.fr
- <sup>3</sup> National Research Institute for Agriculture, Food and Environment (INRAE), 63000 Clermont-Ferrand, France
- <sup>4</sup> Healthy Active Living and Obesity Research Group, Children's Hospital of Eastern Ontario Research Institute, Ottawa, ON K1H 8L1, Canada; jpchaput@cheo.on.ca
- <sup>5</sup> Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, 63000 Clermont-Ferrand, France
- <sup>6</sup> UFR Médecine, Clermont Auvergne University, BP 10448, 63000 Clermont-Ferrand, France
- \* Correspondence: terry.guirado@uca.fr; Tel./Fax: +33-473405488



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**Abstract:** The purpose of this systematic review was to examine the effects of active desks in the school setting on sedentary behavior, physical activity, academic achievements and overall health among children and adolescents aged 5–17 years. A systematic literature search was conducted using five databases until October 2020. Twenty-three studies were included. Studies reported an increase of around 36% in energy expenditure for cycling desks and between 15% and 27.7% for upright active desks. Children increased inhibitory control and selective attention capacity while using cycling desks. A heterogeneous quality of design and of results were observed limiting comparisons and conclusions for each active desk. Despite the lack of strong methodology for the included studies, active desks appear to be a promising intervention in classrooms to improve health-related outcomes in children aged 5–17 years. Due to weak methodology, future studies with stronger study designs and methodology are needed to better inform policy and practice about the role of classroom active desks on health-related outcomes in children and adolescents.

**Keywords:** academic achievements; active desks; adolescent; children; physical activity; sedentary behavior

## 1. Introduction

Concerns and research regarding the effects of sedentary behaviors and physical inactivity on overall health have been growing for the last decades, leading nowadays to a better identification of their independent and joint implications [1,2]. While sedentary behaviors is defined as any waking behavior characterized by an energy expenditure  $\leq 1.5$  metabolic equivalents, while in a sitting, reclining or lying posture [3,4], physical inactivity is typically defined as “the non-achievement of physical activity guidelines” [5]. Both sedentary behaviors and physical inactivity have substantially increased in our societies, with physical inactivity being identified as the main cause for about 1.6 million deaths worldwide [6] and leading to a public health cost of \$53.8 billion per year [7]. Due to their important implication in the risks of all-cause mortality and cardio-metabolic morbidity as well as in some cancer occurrence [8], both sedentary behaviors [9,10] and physical inactivity [11,12] are of public health concern today.

In children and adolescents, it has been found with device-based measurements that daily sitting time takes over 50% of the waking day at 7 years and 75% at 15 years [13]. This high level of sedentariness, combined with the fact that about 80% of children and adolescents are inactive (i.e., not reaching the physical activity recommendations) [14,15], led some scientists to propose the existence of what they called a “Sedentary & Inactive” profile [16]. Not only physical inactivity and sedentary behaviors have been found to be associated with early metabolic and cardiovascular risk in children and adolescents [17–21], they have also been found to be related to a decrease in cognitive performance and academic achievements [22–24].

Knowledge and behaviors developed during childhood have been shown to influence their future behaviors as adults [25]. In particular, children’s physical activity and sedentary behaviors have been shown to not only determine their actual health but also their adolescent and adult behaviors and health [26]. Since children spend at least one third of their waking time in class [27], school appears as an ideal setting to promote health and induce behavioral change [28]. Targeting school time and the school place to promote healthy active behaviors necessitates however to face the highly sedentary nature of the children’s class time. In that context, the literature shows a growing number of experiments trying to implement interventions aimed at breaking and reducing this sedentary time during class [29,30]. The use of active desks in the classroom (e.g., standing desks, sit-to-stand desks, cycling desks, stability balls) has been especially studied [31–34], with studies showing for instance that sit-to-stand desks seem to reduce sedentary time in the classroom [31] or increase energy expenditure with the use of bike desks [34]. These studies are providing some promising results and our aim is to conduct a systematic analysis of these works to have a better understanding of their effects.

Previous reviews have examined the effects of standing desks on children and adolescents [35,36]. Regarding, active desks, while some already systematically reviewed their effects on academic achievement [37] or questioned their use among specific groups (e.g., overweight and obese) [38], no review has specifically studied the impact of classroom active desks on cognitive, academic and overall health-related (physical, metabolic and mental health) outcomes among children and adolescents. Having a global picture on the role of classroom active desks on improving health-related outcomes of children and adolescents is needed to inform policy and practice.

Thus, the objective of the present systematic review was to analyze the existing literature on the implementation of active desk in the school environment and examine their effects on physical activity, sedentary behavior, academic achievements and overall health in children and adolescents aged 5–17 years.

## 2. Methods

This research is registered in PROSPERO as CRD42020196096. This review was completed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to identify and collate studies [39].

### 2.1. Search Strategy

A literature search was conducted for studies from year 1990 to October 2020 using the following electronic bibliographic databases: PubMed, ScienceDirect, ResearchGate, Google Scholar and Medline (Cochrane Library). The search terms included the key words “desk\* or workstation\* or work station” AND “treadmill OR pedaling OR cycling OR bicycl\* OR bik\* OR active OR exercise ball\* OR swiss ball\* OR stability ball\* OR dynamic seating OR active sitting OR standing OR stepping OR stand up OR position, standing OR standing position\* OR sit-to-stand OR sit stand OR stand/sit OR stand biased OR adjustable furniture OR height adjustable” AND “school\* OR class\* OR child\* OR student\* OR academic institution”. To identify articles potentially missed during the literature search, reference lists of candidate articles were reviewed.

## 2.2. Eligibility Criteria

### 2.2.1. Inclusion Criteria

Our selection criteria were specified in advance and included the following: published in English peer-reviewed journal and available in full text [1]; randomized controlled design, non-randomized controlled design, non-randomized design, randomized design, cross-over design [2]; included children and adolescents aged 5–17 years, normal-weight, overweight or obese [3]; included active desks in comparison with traditional desks or within-subject [4]; and experiments were conducted in the school classroom [5]. The following outcomes were reported if they were assessed at least at baseline and follow-up: body composition, sedentary behaviors and physical activity, energy expenditure, cognitive and academic performance, fatigue and musculoskeletal pain symptoms, process evaluation, cardiometabolic health and physical fitness. All intervention durations were included.

### 2.2.2. Exclusion Criteria

Studies were excluded for: (1) non-school-aged participants or mixed groups (e.g., school-aged children and adults); (2) study with mixed intervention (e.g., active desks coupled with active breaks); (3) study where participants already experimented active desks before the study; (4) specific population with health issues; and (5) studies where authors did not reply to our requests for more complete data or full-text.

## 2.3. Synthesis of Results

Authors have collectively elaborated the structure of the tables based on the different active desks (as described in Table 1). Table 2 presents the included studies as follows: article, study design, school description, sample description, type of active desk, intervention description and outcomes. Tables 3 and 4 report the different outcomes studied.

**Table 1.** Active desks characteristics and range of price.


Active Desk Type	Description	Range of Price (USD)	Pictures
Upright active desk	Corresponds to standing desk, sit-to-stand desk or stand-biased desk.	150–900	

Table 1. Cont.


Active Desk Type	Description	Range of Price (USD)	Pictures
Cycling desk	Is a stationary bike with a desk enabling individuals to work while cycling	200–900	
Stability ball	Replace the traditional chair with a stability ball on individual desk	10–100	

Table 2. Participants’ characteristics of included studies for the systematic review.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Upright active desk:						
Benden et al. (2011) (Texas, USA) [40]	RCT *	1 E	N = 58 Age: NR Sex: NR Grade: 1 BMI: NR Race/ethnic: NR Total study groups: 4 classrooms (2 IG and 2 CG) IG (N = 31) CG (N = 27)	Upright active desks + stools	Treatment length: 9 months (2009–2010 school year) Active desks: individuals Active desks usage time per week: all the school day	EE Body composition (body mass, BMI, body fat percentage) Method: BodyBugg Armband
Benden et al. (2012) (Texas, USA) [41]	NRT	1 E	N = 9 Age range: 6–8 y Grade: 1st grade Sex: girls 33% BMI: 19.5 ± 4.3 kg·m <sup>2</sup> Race/ethnic: NR	Upright active desks + stools	Treatment length: 5 months Active desks: individuals They used traditional desk on fall semester before swapping stand-biased for spring semester Active desks usage time per week: own volition	Body composition (weight, BMI) EE Step count Methods: Bodybugg Armband A digital scale
Benden et al. (2014) (Texas, USA) [42]	RCT	1 E	N = 326 Mean age: 8.5 y Sex: girls 51.23% Grade: 2, 3, 4 Race/ethnic: White (70.55%), Black (10.12%), Hispanic (10.74%), Asian (7.98%), Native American (0.61%) Total study groups: 8 classrooms (4 IG and 4 CG) Interventional group (N = 202) BMI IG: 17.44 ± 3.26 kg·m <sup>2</sup> Overweight and obesity IG: 16% overweight and 13% obesity Control group (N = 124) BMI CG: 17.73 ± 3 kg·m <sup>2</sup> Overweight and obesity CG: 5% with overweight and 16% with obesity	Upright active desks + stools	Treatment length: 9 months (2012–2013 school year) Active desks: individuals Active desks usage time per week: all the school day	Body composition (BMI, body mass) Step count EE Method: Sensewear armband

Table 2. Cont.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Blake et al. (2012) (Texas, USA) [43]	NRCT *	1 E	N = NR Age range: 6–7 y Grade: 1 <sup>st</sup> Sex: NR BMI: NR Race/ethnicity: NR Total study groups: 5 groups (2 IG, 2 CG, 1 within-group comparisons)	Upright active desks + stools	Treatment length: 1 year Active desks: individuals Active desks usage per week: own volition	Sitting and standing time EE On-task behavior (concentration, engagement) Process evaluation Methods: BodyBugg armband Interviews
Clemes et al. (2016) (Melbourne, Australia **) [31]	RCT *	1 E	N = 44 Mean age: 11.6 ± 0.5 y Grade: 6 Sex: girls 56.8% BMI: 19.4 ± 3.3 kg·m <sup>2</sup> Race/ethnicity: NR Total study groups: 2 classrooms (1IG and 1CG) IG (N = 24) CG (N = 20)	Upright active desks	Treatment length: 10 weeks (September–November 2013) Active desks: individuals Active desks usage time per week: children were encouraged to stand at least one 30-min class per day	Sitting, standing and stepping time Step counts Method: Accelerometers (activPAL)
Clemes et al. (2016) (Bradford, England **) [31]	NRCT *	E	N = 54 Mean age: 10.0 ± 0.3 y Age range: 9–10 y Grade: 5 Sex: NR BMI: 18.3 ± 3.2 kg/m <sup>2</sup> Race/ethnicity: NR Total study groups: IG (N = 27) CG (N = 27)	Upright active desks	Treatment length: 9 weeks (January–April 2014) Active desks: 6 sit-to-stand desks Active desks usage time per week: once a day for at least 1 h	Sitting, standing and stepping time Step counts Method: Accelerometers (activPAL)
Clemes et al. (2020) (Bradford, England) [44]	RCT *	8 E	N = 176 Mean age: 9.3 ± 0.5 y Age range: 9–10 y Sex: girls 44.3% Grade: 4–5 Race/ethnicity: White British (35.8%), South Asian (48.3%), Other (15.9%) Total study groups: 8 classrooms (4 IG and 4 CG) Interventional group (N = 86) mean age: 9.3 ± 0.4 y BMI: 18.2 ± 3.3 kg·m <sup>2</sup> Control group (N = 90) mean age: 9.3 ± 0.5 y BMI: 18.2 ± 4.0 kg·m <sup>2</sup>	Upright active desks + stools	Treatment length: 4–5 months (February–July 2017) Active desks: 6 active desks replaced 3 standard desks in IG Active desks usage time per week: at least 1 h/day	Process evaluation PA (MVPA, LPA) Sitting, standing and stepping time Blood pressure Body composition (BMI, body mass) On-task behavior (concentration, engagement) Musculoskeletal discomfort Methods: Inclinometer (ActivPAL3) Bio-impedance (Tanita DC-360S) Accelerometer (ActiGraph GT3x + ) Interview, focus groups Questionnaires Semi-automated recorder (Omron HEM-907)
Dornhecker et al. (2015) [45]	NRCT	3 E	N = 282 Age range: 7–10 y Grade: 2, 3, 4 Sex: girls 53.18% BMI: NR Race/ethnicity: Black (12.68%), Hispanic (10.49%), Asian (7.62%), White (69.22%) Total study groups: 2 groups (1 IG and 1 CG) Interventional group (N = 158) Grade 2 (35.44%), Grade 3 (45.57%), Grade 4 (18.99%) Control group (N = 124) Grade 2 (43.55%), Grade 3 (33.87%), Grade 4 (22.58%)	Upright active desks + stools	Treatment length: 5 months Active desks: NR Active desks usage per week: NR	On-task behavior (concentration, engagement) Method: Behavioral Observations of Students in Schools (BOSS)

Table 2. Cont.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Ec et al. (2018) (Perth, Australia) [32]	Cross-over	1 E	N = 47 Age range: 10–11 y Grade: 4 Sex: boys 100% BMI: NR Race/ethnic: NR	Upright active desks	Treatment length: Academic year (2016–2017) Active desks: individuals They used 21 school day a standing desk, then they swapped during 21 school day with traditional desk. This swapping continued throughout the school year Active desks usage time per week: all the school day.	Standing and sitting time Sedentary time PA (MVPA, LPA) Musculoskeletal discomfort Methods: Accelerometers (ActiGraph GT9X Link) Nordic Musculoskeletal Questionnaire
Kidokoro et al. (2019) (Nagano, Japan) [46]	NRCT	1E	N = 38 Mean age: 11.3 ± 0.5 y Age range: 11–12 y Grade: 6 Sex: girls 42% BMI: IG: 18.3 ± 3.1 CG: 17.4 ± 3.3 Race/ethnic: NR Total study groups: 2 groups (1 IG and 1 CG) Interventional group (N = 18) Mean age: 11.3 ± 0.5 y BMI: 18.3 ± 3 kg·m <sup>2</sup> Control group (N = 20) Mean age: 11.3 ± 0.5 y BMI: 17.4 ± 3.3 kg·m <sup>2</sup>	Upright active desk	Treatment length: 6 months (July–December 2018) Active desks: individuals Active desks usage per week: own volition	PA (LPA, MVPA) Sedentary time Process evaluation Methods: Accelerometers (ActiGraph) Questionnaire (Likert-type scale)
Koepp et al. (2012) (Idaho, USA) [47]	NRT	1 E	N = 8 Mean Age: 11.3 ± 0.5 y Grade: 6 Sex: girls 37.5% BMI: 19.4 ± 5.3 kg·m <sup>2</sup> Race/ethnic: NR	Upright active desk + stools	Treatment length: 5 months (January–June 2010) Active desks: individuals Active desk usage time week: own volition	Step count Body composition (BMI, weight) Musculoskeletal discomfort On-task behavior (concentration, engagement) Methods: Podometers Observations
Mehta et al. (2015) (Texas, USA) [48]	NRT*	1 S	N = 27 Mean age: 14.30 ± 0.61 y Grade: NR Sex: girls 70.6% BMI: 23.27 ± 4.44 kg·m <sup>2</sup> Race/ethnic: White (41%), Hispanic (52%), Black (4%), Asian (4%)	Upright active desks	Treatment length: academic year, 27 weeks of continued exposure Active desks: individuals Active desks usage time per week: own volition	Neurocognitive function Prefrontal Cortex (PFC) Activity Methods: The Psychology Experiment Building Language Wisconsin Card Sorting Task (WCST) Flanker Task (FT) Memory Span Task (MST) Trail-Making Task (TMT) Stroop Color Word Task (SCWT) Functional near infrared spectroscopy (fNIRS)
Parry et al. (2019) (Perth, Western Australia) [49]	Cross-over	E	N = 23 Age range: 9–11 y Grade: 4 Sex: boys 100% BMI: NR Race/ethnic: NR	Upright active desk	Treatment length: academic year (2017) Active desks: individuals They used 21 school day a standing desk, then they swapped during 21 school day with traditional desk. This swapping continued throughout the school year Active desks usage time per week: all the school day	Sitting and standing time Sedentary time and PA (MVPA, LPA) Musculoskeletal discomfort Methods: Accelerometers (Actigraph GT9X Link) Modified version of the Nordic Musculoskeletal Questionnaire Focus groups, interview
Pickens et al. (2016) (Texas, USA) [50]	RT	1 S	N = 18 Age: NR Grade: NR Sex: girls 72% BMI: NR Race/ethnic: Hispanic (66%), White (30%)	Upright active desks + stools	Treatment length: 3 months Active desks: individuals Active desks usage time per week: NR	Step count Sitting, standing time Method: Inclinometer (ActivPal3™)



Table 2. Cont.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Sherry et al. (2020) (Bradford, UK) [51]	CT*	2 E	N = 49 Age range: 9–10 y Grade: 5 Sex: 53.8% BMI: IG: underweight (9.1%), normal (63.6%), overweight (13.6%), obese (18.2%) CG: underweight (3.9%), normal (61.5%), overweight (11.5%), obese (23.1) Race/ethnicity: South Asian (69.4%), White British (26.5%), Other (4%) Total study groups: 2 groups (1 IG and 1 CG) IG (N = 27) CG (N = 22)	Upright active desks + stools	Treatment length: 8 months (November 2015 to July 2016) Active desks: individuals Active desks usage time per week: at least 20 min per classroom day	Musculoskeletal discomfort Cognitive function Process evaluation Sitting, standing, stepping time Methods: Inclinometer (ActivPAL) Questionnaires Stroop test Corsi Block Tapping test Interviews, Observations
Sprengeler et al. (2020) (Ludwigsburg, Germany) [52]	Cross-over	1 E	N = 52 Mean age: 8.4 ± 0.7 y Age range: 8–10 y Grade: 3 Sex: 61.5% BMI: normal weight (78.9%), overweight/obese (21.1%) Race/ethnicity: NR	Upright active desks + stools	Treatment length: 3 months (January–March 2018) Active desks: individuals. 32 desks were equally distributed among the three classes Active desks usage time per week: the group 1 used active desks during 3 weeks (February, T1) and after were assigned to the traditional working desks until March (T2). The group 2 begin to use traditional desks until February (T1) and after used active desks (T2). A washout period of 2 weeks is present between T1 and T2	Standing, and sitting time Methods: Inclinometer (ActivPAL)
Sudholz et al. (2016) (Melbourne, Australia) [53]	NRCT*	1 S	N = 41 Mean age: 13.7 ± 1.4 y Age range: 12–16 y Grade: 7, 9, 10 Sex: girls 49% BMI: NR Race/ethnicity: NR Total study groups: 2 groups (1 IG and 1 CG) IG (N = 27) CG (N = 14)	Upright active desks + stools	Treatment length: 7 weeks (August to October 2014) Active desks: individuals Active desks usage time per week: own volition	Sitting and standing time/bouts Sedentary time PA (LPA) Feasibility/process evaluation Musculoskeletal discomfort Methods: Accelerometer (ActiGraph3X) Inclinometer (ActivPAL3C) Questionnaire
Swartz et al. (2019) (USA) [54]	Cross-over	1 E	N = 99 Mean age: 10.2 ± 1.4 y Grade: 3, 4, 6 Grade 3 (N = 22) Grade 4 (N = 36) Grade 6 (N = 41) Sex: girls 42.9% BMI: Grade 3: 55th BMI percentile Grade 4: 43rd BMI percentile Grade 6: 61st BMI percentile Race/ethnicity: White (69%), black (3%), Asian (8%), mixed race (7%), Hispanic (8%)	Upright active desks + stools	Treatment length: 9 weeks. Active desks: individuals. Half of the students used a stand-biased desk and half used a sitting desk. The Stand-Sit group used a stand-biased desk for 9 weeks (September to December) and sitting desk for 9 weeks (January to April). The Sit-Stand group used a sitting desk for 9 weeks (September to December) and stand-biased for 9 weeks (January to April). Active desks usage time per week: NR	Sedentary time PA (LPA, MVPA) Method: Accelerometer (ActigraphGT3X+ or wGT3X-BT)
Verloigne et al. (2018) (Flanders, Belgium) [55]	RCT	10 E and 9 S	N = 343 Age range: 10–16 y Grade: 5, 10 Sex: girls 54.5% BMI: NR Race/ethnicity: NR Total study groups: IG: 5 primary, 5 secondary CG: 5 primary 4 secondary	Upright active desks	Treatment length: 6 months (January–June 2017) Active desks: 3 standing desks were placed in each intervention class Recommendations of active desks usage time per week: rotations every half lesson hour (25 min)	Process evaluation Sitting, standing and stepping time Methods: Inclinometer (ActivPAL) Focus groups (children) and interviews (teachers) The Paediatric Quality of Life Inventory (PEDS-QL) EuroQol 5dimension Youth (EQ-5D-Y)

Table 2. Cont.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Wendel et al. (2016) (Texas, USA) [36]	RCT	3 E	N = 193 Mean age: 8.8 y Grade: 3, 4 Sex: girls 50.3% BMI: normal (79.3%), overweight (11.9%), obese (8.8%) Race/ethnicity: White (74.6%), Asian (10.4%), Hispanic (7.8%), Afro-American (7.3%) Total study groups: 4 groups (IG, CG, CG-IG, IG-CG) IG (N = 62) CG (N = 49) IG-CG (N = 59) CG-IG (N = 23)	Upright active desks + stools	Treatment length: 2 years (2011–2013) Active desks: individuals Active desks usage time per week: NR	Body composition (BMI)
Wick et al. (2018) (Swiss) [57]	NRCT*	2 E	N = 38 Age range: 10–12 y Grade: NR Sex: girls 42% Race/ethnicity: NR Total study group: 2 groups (1 IG and 1 CG) Interventional group (N = 19) Mean age: 10.8 ± 0.6 y BMI: 18.0 ± 2.8 kg·m <sup>2</sup> Control group (N = 19) Mean age: 10.8 ± 0.8 BMI: 18.8 ± 4.3 kg·m <sup>2</sup>	Upright active desks	Treatment length: 11 weeks (August–December 2014) Active desks: individuals Active desks usage per week: teachers encouraged students to work for about 60 min a day at the active desk	Sitting, standing and walking time Cognitive function Methods: Accelerometers (ActiGraph) Observations Self-reporting Digit span task test Eriksen flanker test
Cycling desk						
Fedewa et al. (2017) (South-eastern region, USA) [30]	RCT*	1 S	N = 17 Age range: 14–18 y Grade: 8–12 Sex: NR BMI: NR Race/ethnicity: NR Total study groups: 6 classrooms (3 IG and 3 CG) IG (N = 11) CG (N = 6)	Bike desks	Treatment length: academic year Active desks: 4 FitDesks per IG classroom. Active desks usage time per week: access to FitDesks for the entire day with the exception of lunch, and extracurricular courses including physical education, computer lab, and art.	Sedentary time PA (MVPA, LPA, vector magnitude) Process evaluation EE Methods: Accelerometers (ActiGraph GT3X) Interviews Questionnaire
Ruiter et al. (2019) (Germany) [58]	NRT	2 E	N = 38 Age: 12.50 ± 0.62 y Grade: 8 Sex: girls 57% BMI: NR Race/ethnicity: NR	Bike desks	Treatment length: 2 weeks Active desks: individuals. Active desks usage time per week: they used bike desks only for the cognitive function's assessment. All 2 sessions (week 1, week 2) occurred at the same time on separate days with a 7-day interval between tests.	Cognitive capacities Methods: Eriksen Flanker Task Digit Span Task Visual pattern Task Questionnaire
Torbeyns et al. (2017) (Ninove, Belgium) [34]	RCT	1 S	N = 44 Mean age: 14.3 ± 0.6 y Grade: 9–10 Sex: girls 34% Race/ethnicity: NR Total study groups: 2 classroom (1 IG and 1 CG) Interventional group (N = 21) BMI: 19.7 ± 3.5 kg·m <sup>2</sup> Control group (N = 23) BMI CG: 20.1 ± 3.7 kg·m <sup>2</sup>	Bike desks	Treatment length: 22 weeks, 5 months (October–February 2015) Active desks: individuals; students adjust the cycling intensity to their preference Active desks usage time per week: IG used a bike desk for 4 class hours/week	PA Body composition (BMI, body mass, body fat percentage, waist circumference) EE Physical fitness Cognitive capacities On-task behavior (concentration, engagement) Methods: SenseWear mini armband The Dutch (Native speech of the participants) version of the Rey Auditory Verbal Learning Test (RAVLT) The Stroop test The Rosvold Continuous Performance Test (RCPT) Continuous electroencephalography (EEG) LOSO attention questionnaire 'Dutch' and mathematics test

Table 2. Cont.

Author (Country)	Study Design	School Description	Sample Description	Type of Active Desk	Intervention Description	Outcomes
Stability ball						
Erwin et al. (2016) (USA) [33]	RCT	1 E	N = 43 Age: NR Grade: 4 Sex: girls 32.6% BMI: NR Race/ethnicity: White (76%), African American (11%), Asian (7%), Hispanic (3%), other (3%) Total study groups: 2 classrooms (1 IG and 1 CG) IG (N = 23) CG (N = 21)	Stability balls	Treatment length: 12 weeks Active desks: individuals Active desks usage time per week: all the school day	On-task behavior (concentration, engagement) PA (step count, horizontal et vertical accelerometers count) Methods: Accelerometer (ActiGraph) Momentary Time Sampling (MTS)
Fedewa et al. (2015) (USA) [59]	RCT	1 E	N = 67 Age: NR Grade: 2 Sex: girls 48% BMI: NR Race/ethnicity: NR Total study groups: 4 classrooms (2 IG and 2 CG) IG (N = 36) CG (N = 31)	Stability balls	Treatment length: 9 months Active desks: individuals Active desks usage time per week: all the school day	Academic performance Discipline referral levels On-task behavior (concentration, engagement) Methods: Measures of Academic Progress "clip downs" (a school wide disciplinary system) Momentary Time Sampling (MTS)

NR: Not Reported; USA: United States of America; RCT: Randomized Controlled Trial; RT: Randomized Trial; NRCT: Non-Randomized Controlled Trial; NRT: Non-Randomized Trial; \*: Pilot Study; \*\* Studies in the same published article; E: Elementary; S: Secondary; IG: Intervention Group; CG: Control Group; CG-IG: switch from a control to an intervention condition; IG-CG: switch from an intervention to a control condition; EE: Energy Expenditure; PA: Physical Activity; BMI: Body Mass Index; LPA: Light Physical Activity; MVPA: Moderate-to-Vigorous Physical Activity.

Table 3. Results of body composition, sedentary behaviors, physical activity, energy expenditure, physical capacity and cardiometabolic health in the included studies for the systematic review.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Upright active desk				
Benden et al. (2011) [40]	NR	N/A	EE: IG > CG: +0.182 ± 0.080 kcal·min <sup>-1</sup> (p = 0.022) Students in the intervention group IG burned 17% more calories than did those in the control group Overweight/obese EE: IG > CG (IG: 1.56 kcal·min <sup>-1</sup> ; CG: 1.18 kcal·min <sup>-1</sup> )	N/A
Benden et al. (2012) [41]	Weight: fall < spring fall vs. spring: fall: 27 ± 7.9 kg vs. spring: 29.5 ± 8.9 kg BMI: fall < spring fall vs. spring: fall: 19.5 ± 4.3 kg·m <sup>2</sup> vs. spring: 19.8 ± 4.3 kg·m <sup>2</sup>	Steps: Steps within-subjects spring > fall: +17.6% Mean number of steps spring > fall: +836 steps	Spring: >fall: +25.7% +0.29 kcal·min <sup>-1</sup> (p < 0.0001) Day-to-day variation: Lower EE day 3 and 4 (p < 0.0001)	N/A
Benden et al. (2014) [42]	BMI: no significant	Step counts: Fall semester: IG > CG: +1.61 steps/min (p = 0.0002) Spring semester: IG > CG (+0.12 steps/min): no significant (p = 0.8193) Normal vs. overweight and obese: overweight: 0.78 steps/min (p < 0.001); obese: 0.62 steps/min (p = 0.0059)	EE: Fall semester: increase IG > CG: +0.16 kcal·min <sup>-1</sup> (p < 0.001) Spring semester: increase IG > CG: +0.08 kcal·min <sup>-1</sup> (p = 0.0092) Normal vs. overweight and obese: overweight: 0.24 kcal·min <sup>-1</sup> (p < 0.001); obese: 0.40 kcal·min <sup>-1</sup> (p < 0.001)	N/A

Table 3. Cont.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Blake et al. (2012) [43]	N/A	Standing and sitting time: IG: 66% standing at their desks as opposed to sitting	EE: IG > CG: +17% burned calories	N/A
Clemes et al. (2016) (Melbourne, Australia) [31]	N/A	During class: Sitting time: IG pre > post: pre vs. post: pre: 67.9 ± 8.4% vs. post: 58.5 ± 8.4% ( $p < 0.001$ ) Standing time: IG pre < post: pre vs. post: pre: 18.1 ± 4.5 vs. post: 26.4 ± 7.5% ( $p < 0.001$ ) Stepping time: no significant Step counts: no significant Sitting time (%) IG < CG ( $p = 0.03$ ) Standing time (%) IG > CG ( $p < 0.01$ ) Whole weekday: Standing time IG pre < post: pre vs. post: pre: 21.3 ± 6.1% vs. post: 25.5 ± 5.5% ( $p < 0.01$ ) Sitting time: no significant Stepping time: no significant	N/A	N/A
Clemes et al. (2016) (Bradford, England*) [31]	N/A	During class: Sitting time IG pre > post: IG pre vs. post: pre: 71.8 ± 10.6% vs. post: 62 ± 15.8% ( $p = 0.03$ ) Standing time: no significant Stepping time IG pre < post: IG pre vs. post: pre: 8.2 ± 2.8% vs. post: 14.5 ± 7.9% ( $p = 0.002$ ) Step counts IG pre < post: IG pre vs. post: pre: 1654 ± 528.9 vs. post: 3024 ± 2195 ( $p = 0.013$ ) Difference IG and CG: no significant Whole weekday: Sitting, standing and stepping time: no significant	N/A	N/A
Clemes et al. (2020) [44]	Body mass: IG < CG IG vs. CG: IG: 37.7 ± 8.7 kg vs. CG: 39.2 ± 10.6 kg Percent body fat: Girls: IG > CG IG vs. CG: IG: 25 ± 8.3% vs. CG: 23.7 ± 9.1% Boys: IG < CG IG vs. CG: IG: 19 ± 6.6% vs. CG: 20.7 ± 8.9% BMI: IG > CG IG vs. CG: IG: 18.8 ± 3.5 kg/m <sup>2</sup> vs. CG: 18.7 ± 4.1 kg/m <sup>2</sup>	↓ Sitting time IG (−30.6 min/day) Sitting time: IG < CG IG vs. CG: IG: 472 ± 73.5 min/day vs. CG: 504.4 ± 94 min/day Standing time: IG > CG IG vs. CG: IG: 197.1 ± 49.4 min/day vs. CG: 176.5 ± 45.7 min/day Stepping time: IG > CG IG vs. CG: IG: 166.4 ± 41.9 min/day vs. CG: 150 ± 42.1 min/day LPA: IG post > pre post vs. pre: post: 392.7 ± 70.8 min/day vs. pre: 383.5 ± 68.6 min/day MVPA: IG post > pre post vs. pre: post: 45.7 ± 24.7 min/day vs. pre: 37.4 ± 17.9 min/day	N/A	Systolic blood pressure: IG > CG IG vs. CG: IG: 110.5 ± 11.2 mmHg vs. CG: 107.3 ± 11.7 mmHg Diastolic blood pressure: IG > CG IG vs. CG: IG: 68.4 ± 9.7 mmHg vs. CG: 66.3 ± 9.5 mmHg
Ee et al. (2018) [32]	N/A	School standing and sitting: IG and CG: sitting time (61%) > standing time (19%) Standing time: IG > CG IG vs. CG: IG: 84 ± 4 min/day vs. CG: 63 ± 3 min/day ( $p < 0.001$ ) Sitting time: IG < CG IG vs. CG: IG: 208 ± 6 min/day vs. CG: 231 ± 5 min/day ( $p = 0.003$ ) Whole Day Physical Activity and Sedentary Time Sedentary time: no significant: IG vs. CG: IG: 674 ± 23 min/day vs. CG: 686 ± 26 min/day LPA: no significant IG vs. CG: IG: 241 ± 7 min/day vs. CG: 256 ± 6 min/day MVPA: no significant Moderate: IG vs. CG: IG: 39 ± 2 min/day vs. CG: 42 ± 2 min/day Vigorous: IG vs. CG: IG: 18 ± 1 min/day vs. CG: 20 ± 1 min/day	N/A	N/A

Table 3. Cont.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Kidokoro et al. (2019) [46]	N/A	During classroom Sedentary behaviors: IG < CG IG vs. CG: IG: 59% vs. CG: 67% ( $p = 0.035$ ) SB: IG post < pre: $-18.3$ min/day LPA: no significant MVPA: IG > CG IG vs. CG: IG: 12.5% vs. CG: 8.3% ( $p = 0.005$ ) MVPA: IG pre < post: $+19.9$ min/day	N/A	N/A
Koepp et al. (2012) [47]	Weight: pre < post: pre vs. post: pre: $41.4$ kg vs. $44.5$ kg ( $p = 0.0007$ ) BMI: pre and post: no significant pre vs. post: pre: $19.4 \pm 5.3$ kg/m <sup>2</sup> vs. post: $19.3 \pm 5.2$ kg/m <sup>2</sup> ( $p < 0.3416$ )	Step counts: no significant pre vs. post: pre $1886 \pm 809$ steps vs. post: $2248 \pm 990$ steps ( $p > 0.1127$ )	N/A	N/A
Parry et al. (2019) [49]	N/A	For IG vs. CG: Standing time: > at the start of the school year ( $+17$ min/school day) and at the end ( $+26$ min/school day) Sitting time: < at the start of the school year ( $-17$ min/school days) and at the end ( $-40$ min/school day) Standing and sitting time over time: IG and CG: no significant ( $p = 0.062$ ) Physical activity and sedentary time: no significant	N/A	N/A
Pickens et al. (2016) [50]	N/A	Sitting time: pre > post pre vs. post: pre: $1032.4$ min vs. post: $857.6$ min ( $p < 0.0001$ ) Standing time: pre < post pre vs. post: pre: $203.7$ min vs. post: $353$ min ( $p < 0.001$ ) Steps: pre < post pre vs. post: pre: $6611.6$ vs. post: $8898.4$ ( $p = 0.0619$ )	N/A	N/A
Sherry et al. (2020) [51]	N/A	During class time Sitting time: IG < CG IG vs. CG: IG: $52.4 \pm 21.9\%$ vs. CG: $72.1 \pm 6.6\%$ ( $p = 0.001$ ) Standing time: IG > CG IG vs. CG: IG: $35.6 \pm 18.1\%$ vs. CG: $17.6 \pm 9.0\%$ ( $p = 0.001$ ) Stepping time: IG > CG IG vs. CG: IG: $12.0 \pm 4.0\%$ vs. CG: $11.0 \pm 2.7\%$ ( $p = 0.035$ ) Sit-to-stand transitions: IG > CG IG vs. CG: IG: $10.7 \pm 2.3$ p/h vs. CG: $5.6 \pm 2.2$ p/h ( $p < 0.001$ ) Behavior after school: no significant Full weekday Sitting time: IG < CG IG vs. CG: IG: $59.1 \pm 10.3\%$ vs. CG: $63.5 \pm 9.7\%$ ( $p = 0.042$ )	N/A	N/A
Sprengeler et al. (2020) [52]	N/A	During lessons: Sitting time: G1: pre > mid: $-13.1\%$ G2: pre > mid: $-9.78\%$ Standing time: G1: pre < mid: $11.6\%$ G2: pre < mid: $8.63\%$ During school breaks: Sitting: G1: pre > mid: $-10.3\%$ , pre > post: $-11.8\%$ G2: pre > mid: $-11.8\%$ , pre > post: $-8.59\%$ Standing: G1: pre < mid: $6.20\%$ G2: pre < mid: $7.82\%$ , pre < post: $8.08\%$	N/A	N/A

Table 3. Cont.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Swartz et al. (2019) [54]	N/A	<p>During classroom</p> <p>Sedentary and active time post: IG + CG: ↑ sedentary time (<math>p &lt; 0.001</math>) ↓ active (<math>p &lt; 0.001</math>)</p> <p>Sedentary behavior: IG pre-post (+2.4%) &lt; CG pre-post (+6.5%) (<math>p = 0.038</math>)</p> <p>LPA: time I: no significant (<math>p = 0.314</math>)</p> <p>MVPA: during classrooms IG pre-post (−0.7%) &lt; CG pre-post (−5.0%) (<math>p = 0.001</math>)</p> <p>Predictive outcomes</p> <p>Sedentary behavior: students with high sedentary time at baseline have more finals effects (<math>p = 0.029</math>)</p> <p>LPA: IG and CG: no significant (<math>p = 0.773</math>)</p> <p>MVPA: students with high sedentary time at baseline have more finals effects (<math>p &lt; 0.0001</math>)</p>	N/A	N/A
Verloigne et al. (2018) [55]	N/A	<p>(Questionnaire data)</p> <p>Primary school</p> <p>Self-efficacy to break up sitting time: IG pre &lt; mid</p> <p>pre vs. mid: <math>3.2 \pm 0.2</math> vs. <math>3.4 \pm 0.2</math> (beta = 0.188)</p> <p>Habit of breaking up sitting time: CG pre &lt; post</p> <p>pre vs. post: <math>3.6 \pm 0.2</math> vs. <math>3.4 \pm 0.2</math> (beta = 0.467)</p> <p>Secondary school:</p> <p>↓ Sitting time: IG &lt; CG pre-mid test, beta = 0.058</p> <p>IG pre vs. mid: <math>275.8 \pm 11.4</math> min/day vs. <math>366.5 \pm 11.4</math> min/day</p> <p>CG pre vs. mid: <math>362.2 \pm 12.5</math> min/day vs. <math>314.7 \pm 12.5</math> min/day</p> <p>Breaking up sitting time: IG pre &gt; mid</p> <p>pre vs. mid: <math>3.7 \pm 0.1</math> vs. <math>3.5 \pm 0.1</math> (beta = −0.456) (ActivPAL)</p> <p>Primary school</p> <p>Sitting time: during school hours: IG pre &gt; mid</p> <p>pre vs. mid: <math>243.8 \pm 8.9</math> min vs. <math>217.9 \pm 8.9</math> min (beta = −37.404)</p> <p>Standing time: during schools hours/entire school day: IG pre &lt; post</p> <p>school hours: pre vs. mid: <math>105.6 \pm 7.5</math> min vs. <math>131.2 \pm 7.5</math> min, beta = 34.148</p> <p>entire school day: pre vs. mid: <math>195.1 \pm 11.1</math> min vs. <math>220.5 \pm 11.1</math> min (beta = 34.464)</p> <p>Stepping time: during entire school day: IG pre &gt; mid: −7 min</p> <p>pre vs. mid: <math>141.5 \pm 8.3</math> min vs. <math>134.1 \pm 8.3</math> min (beta = −18.796)</p> <p>Sitting time: during school hours: IG ↓ (−26 min) vs. CG ↑ (+12 min)</p> <p>Time spent in sitting bouts during school hours: IG ↓ (−19 min) vs. CG ↑ (+11 min)</p> <p>Time spent in sitting bouts across the whole school day: IG ↓ (−27 min) vs. CG ↑ (+18 min)</p> <p>Standing time: during school hours: ↑ IG (+26 min) vs. CG ↓ (−10 min)</p> <p>Time spent in standing bouts during school hours: ↑ IG (+29 min) vs. CG ↓ (−10 min)</p> <p>Time spent in standing bouts across the whole school day: ↑ IG (+25 min) vs. CG ↓ (−10 min)</p> <p>Secondary school:</p> <p>Number of sit-to-stand transition: IG pre &gt; mid</p> <p>pre vs. mid: <math>24.7 \pm 1.8</math> vs. <math>21.7 \pm 1.9</math> (beta = −5.034)</p>	N/A	N/A

Table 3. Cont.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Wendel et al. (2016) [56]	BMI IG < CG IG vs. CG ( $p = 0.037$ ) BMI IG and CG-IG/IG-CG: no significant	N/A	N/A	N/A
Wick et al. (2018) [57]	N/A	Sitting time: IG < CG IG vs. CG: IG: $172.1 \pm 19.7$ min vs. CG: $184.9 \pm 13.7$ min ( $p = 0.03$ ) Standing time: IG > CG IG vs. CG: IG: $60.5 \pm 15.1$ min vs. CG: $47.1 \pm 11.6$ min ( $p = 0.0004$ ) Walking time: no significant IG vs. CG: IG: $19.9 \pm 6.3$ min vs. CG: $18.9 \pm 4.4$ min ( $p = 0.57$ )	N/A	N/A
Cycling desk				
Fedewa et al. (2017) [30]	N/A	Sedentary time: IG < CG: IG vs. CG time 1: IG: $116.3 \pm 53.9$ min/day; CG: $58.6 \pm 10.8$ min/day IG vs. CG time 2: IG: $79.2 \pm 52.1$ min/day vs. CG: $114.5 \pm 18.7$ min/day LPA: IG > CG IG vs. CG time 1: IG: $19.4 \pm 9.2$ min/day vs. CG: $6.7 \pm 3.0$ min/day IG vs. CG time 3: IG: $24.8$ min/day vs. CG: $10.2 \pm 6.4$ min/day MVPA: IG > CG IG vs. CG time 1: IG: $35.6 \pm 19.1$ min/day; CG: $15.6 \pm 6.8$ min/day IG vs. CG time 3: IG: $43.0$ min/day vs. CG: $30.6 \pm 13.2$ min/day Vector magnitude: IG > CG IG vs. CG time 1: IG: $152,394 \pm 83,288$ ct/min; CG: $65,908 \pm 34,085$ ct/min IG vs. CG time 3: IG: $176,119$ ct/min vs. CG: $111,429 \pm 46,059$ ct/min	EE: IG time 3 < time 1 Time 3 vs. time 1: time 3: $94.9 \pm 29$ kcal vs. time 1: $108.9 \pm 32.1$ kcal	N/A
Torbeyns et al. (2017) [34]	Fat percentage: IG and CG: pre < post pre vs. post: pre: $18.8 \pm 9.9\%$ vs. post: $20.1 \pm 9.3\%$ ( $p < 0.001$ ) Waist circumference: IG and CG: pre < post pre vs. post: pre: $66.9 \pm 6.6$ cm vs. post: $68.0 \pm 6.0$ cm ( $p = 0.017$ ) Body weight: IG and CG pre < post pre vs. post: pre: $56.5 \pm 11.3$ kg vs. post: $58.1 \pm 9.9$ kg ( $p < 0.001$ ) BMI: CG post > pre post vs. pre: pre: $20.1 \pm 3.7$ kg/m <sup>2</sup> ; post: $20.5 \pm 3.5$ kg/m <sup>2</sup> ( $p = 0.005$ ) IG post and pre: no significant pre vs. post: pre: $19.7 \pm 3.5$ kg/m <sup>2</sup> vs. post: $19.9 \pm 3.2$ kg/m <sup>2</sup> ( $p = 0.205$ ) BMI CG and IG at T0 and T1: no significant	Physical activity outside the classroom PA: IG and CG pre > post Pre vs. post: pre: $2.6 \pm 0.7$ vs. post: $2.4 \pm 0.7$ ( $p < 0.001$ )	EE: IG EE access bike desks (+36%) > EE normal hours IG bike desks vs. EE IG normal hours: $128.5 \pm 34.7$ kcal.h <sup>-1</sup> vs. $94.6 \pm 16.7$ kcal.h <sup>-1</sup> ( $p < 0.001$ ) Class hours in which IG had access to the bike desks: EE IG > CG IG vs. CG: $128.5 \pm 34.7$ kcal.h <sup>-1</sup> vs. $100.0 \pm 16.2$ kcal.h <sup>-1</sup> ( $p = 0.002$ )	20 m shuttle run test: performance IG post > pre pre vs. post: pre $6.4 \pm 2.5$ ; post: $7.0 \pm 2.9$ ( $p = 0.021$ ) RPE: post IG < CG IG vs. CG: IG: $5.5 \pm 1.3$ ; CG: $6.4 \pm 1.3$ ( $p = 0.047$ )

Table 3. Cont.

Author (Year)	Body Composition	Sedentary Behaviors and Physical Activity	Energy Expenditure	Physical Capacity and Cardiometabolic Health
Stability ball				
Erwin et al. (2016) [33]	N/A	Difference IG and CG pre and post ( $p < 0.05$ ) Vertical accelerometer counts: (IG and CG) pre > post pre vs. post, pre: $79.56 \pm 46.36$ ; post: $51.26 \pm 38.11$ ( $p < 0.05$ ) Horizontal accelerometer counts: (IG and CG) pre > post pre vs. post, pre: $103.92 \pm 95.76$ ; post: $62.45 \pm 27.41$ ( $p = 0.03$ ) Step counts: (IG and CG) pre > post pre vs. post, pre: $4242.01 \pm 2006.16$ ; post: $2975.82 \pm 1611.20$ ( $p < 0.01$ ) PA: IG and CG, pre- and post-test: no significant	N/A	N/A

N/A: Not Applicable; NS: Not Significant; NR: Not Reported; BMI: Body Mass Index; EE: Energy Expenditure; PA: Physical Activity; IG: Intervention Group; CG: Control Group; LPA Light Physical Activity; MVPA: Moderate-to-Vigorous Physical Activity; ↓ decrease of; ↑ increase of.

Table 4. Results of cognitive and academic performance, fatigue and musculoskeletal pain symptoms and process evaluation in the included studies for the systematic review.

Author (Year)	Cognitive and Academic Performance	Fatigue and Musculoskeletal Pain Symptoms	Process Evaluation
Upright active desk			
Blake et al. (2012) [43]	Attention and focus: IG > CG	N/A	By the fourth week of the intervention, more than two-thirds of the students stopped using the stool completely Teacher's perspective: Good acceptability of children Active desks considering as "cool" Parents' perception: positive impact on child's behavior at school
Clemes et al. (2020) [44]	Learning engagement and disaffection scores: no differences Total difficulties score: IG < CG IG vs. CG: IG: $7.8 \pm 6.6$ vs. CG: $6.9 \pm 6.0$ Disruption to the classroom: no adverse effects	Musculoskeletal discomfort: no adverse effects	Overall recruitment: rate being 33% (95% CI: 16 to 55%) Parental consent: 75% At follow-up, retention of participating children was 97%
Dornhecker et al. (2015) [45]	Academic engagement: Fall semester: IG > CG: $+4.21$ ( $p = 0.003$ ) Spring semester: IG > CG: $+0.72$ ( $p = 0.003$ ) Differences 2nd grade and 3rd grade students: no significant ( $p = 0.39$ ) Difference 4th grade and 3rd grade: no significant ( $p = 0.19$ )	N/A	N/A
Ee et al. (2018) [32]	N/A	Neck discomfort: IG < CG ( $p = 0.005$ ) Other body parts: no significant	N/A
Kidokoro et al. (2019) [46]	N/A	N/A	Children's perception: Enjoying classes using standing desks: 66.7% Expressed willingness to continue using their standing desks: 72.2% Felt that they could express their thoughts more effectively: 66.7% Found it easier to work: 77.7% Felt less sleepy when using standing desk: 97.8% Felt fatigued in the standing classroom: 11.2% Usage of standing desks: $21.4 \pm 5.9$ min/day Changing their posture: $1.8 \pm 0.8$ times during a class



Table 4. Cont.

Author (Year)	Cognitive and Academic Performance	Fatigue and Musculoskeletal Pain Symptoms	Process Evaluation
Koepp et al. (2012) [47]	Classroom management: no significant ( $p < 0.5$ ) Concentration: no significant ( $p < 0.81$ )	Discomfort: no significant ( $p < 0.06$ )	N/A
Mehta et al. (2015) [48]	Cognitive performance: (executive function and working memory tasks) post: +7–14% Neurocognitive assessments: Wisconsin Card Sort: Reaction time pre vs. post: –10% ( $p < 0.0001$ ) Correct responses pre vs. post: +14% ( $p = 0.014$ ) % Correct responses pre vs. post: +13% ( $p = 0.016$ ) Flanker test: Reaction times for congruent pre vs. post: no significant ( $p = 0.112$ ) Reaction times for incongruent pre vs. post: no significant ( $p = 0.079$ ) Percent correct congruent pre vs. post: no significant ( $p = 0.18$ ) Percent correct incongruent responses pre vs. post: no significant ( $p = 0.749$ ) Memory Span test: pre vs. post: no significant ( $p = 0.09$ ) Trail Making Test: pre vs. post: no significant ( $p > 0.205$ ) TMT letters: –7% ( $p = 0.012$ ) TMT number + letter: –14% ( $p > 0.0001$ ) Stroop Color Word: Reaction times: pre > post: –13% ( $p = 0.001$ ) Percent correct responses: pre vs. post: no significant ( $p = 0.239$ ) Prefrontal cortex Activity: nHbO <sub>2</sub> levels across all five tasks: pre vs. post: no significant ( $p > 0.212$ ) Effect of hemisphere: no significant ( $p > 0.194$ ) Time point $\times$ hemisphere interactions: Wisconsin Card Sorting Task ( $p = 0.042$ ) Memory Span Task ( $p = 0.05$ ) Trail-Making Task ( $p = 0.033$ ) Stroop Color Word test: nHbT left hemisphere > right hemisphere: 19.22 ( $p = 0.001$ ) Others test: no significant across hemispheres and interaction with time points ( $p > 0.117$ )	N/A	N/A
Farry et al. (2019) [49]	N/A	Musculoskeletal discomfort: neck and shoulder pre > post Neck: ( $p = 0.004$ ) Shoulder: ( $p < 0.001$ )	N/A
Sherry et al. (2020) [51]	Cognitive function: Corsi Block Tapping: no significant Stroop test: no significant	Musculoskeletal discomfort: Whole body: no significant Upper limb: no significant Neck and back: no significant Lower limb: no significant	Children's perception: Like sit-to-stand transition because sitting can become uncomfortable Improve behavior in class: children stay in the same place One child feels the classroom noisier Teacher's perception: Need lot of place Need to adapt his teaching After the 20-min period standing, 22 out of 27 children immediately chose to sit back down.

Table 4. Cont.

Author (Year)	Cognitive and Academic Performance	Fatigue and Musculoskeletal Pain Symptoms	Process Evaluation
Sudholz et al. (2016) [53]	N/A	Musculoskeletal discomfort: Got pain in legs or back: while standing during lessons: 51%	<p>Children's perceptions:</p> <p>Continue to used actives desks: 70%</p> <p>Worked well during lessons: 69%</p> <p>Enjoying lessons more since the actives desks were introduced: 54%</p> <p>Felt more energetic across the day: 46%</p> <p>Concentrated better on doing my work: 44%</p> <p>Was easily distracted: 36%</p> <p>Was too tired: to be active after school: 18%</p> <p>Teachers' perceptions:</p> <p>Continue teaching with the height adjustable desks: 71%</p> <p>Adolescent standing during lessons: Negatively influenced ability to work effectively: 14%</p> <p>Results in loss of concentration: 14%</p> <p>Increase ability to complete tasks: 29%</p> <p>Were too disruptive: 0%</p>
Verloigne et al. (2018) [55]	N/A	N/A	<p>Primary schools:</p> <p>Frequency of using the standing desks: IG mid &gt; post mid vs. post: <math>2.94 \pm 0.61</math> times/week vs. <math>1.80 \pm 0.61</math> times/week (beta = -0.379)</p> <p>Mean duration at the desks: IG mid &gt; post mid vs. post: <math>84.31 \pm 13.03</math> min.week<sup>-1</sup> vs. <math>57.69 \pm 13</math> min.week<sup>-1</sup> (beta = -0.376)</p> <p>Self-efficacy to use the desk: IG mid &gt; post mid vs. post: <math>4.12 \pm 0.15</math> vs. <math>3.75 \pm 0.15</math> (beta = -0.147)</p> <p>Habit to use the standing desk: IG mid &gt; post mid vs. post: <math>3.59 \pm 0.21</math> vs. <math>3.03 \pm 0.21</math> (beta = -0.224)</p> <p>Subjective norm to use the standing desk: IG mid &lt; post mid vs. post: <math>4.11 \pm 0.11</math> vs. <math>4.32 \pm 0.11</math> (beta = 0.242)</p> <p>Relation with classmate: IG pre &gt; post pre vs. post: <math>4.4 \pm 0.2</math> vs. <math>4.2 \pm 0.2</math> (beta = -0.04)</p> <p>Secondary schools</p> <p>Frequency of using the desks: IG mid &lt; post mid vs. post: <math>1.30 \pm 0.66</math> times/week vs. <math>1.42 \pm 0.66</math> times/week (beta = 0.195)</p> <p>Pupils' attitude towards the desks: IG mid &lt; post mid vs. post: <math>3.71 \pm 0.13</math> vs. <math>3.89 \pm 0.13</math> (beta = 0.057)</p>
Wick et al. (2018) [57]	<p>Eriksen Flanker Task:</p> <p>Reaction time (congruous): IG pre &gt; post pre vs. post: pre: <math>476 \pm 99</math> ms vs. post: <math>451 \pm 119</math> ms (<math>p = 0.04</math>)</p> <p>Accuracy: IG pre &lt; post pre vs. post: pre: <math>0.87 \pm 0.17\%</math> vs. post: <math>0.92 \pm 0.16\%</math> (<math>p = 0.01</math>)</p> <p>Digit span task:</p> <p>Working memory: no significant</p> <p>Number of correct trials: no significant</p> <p>Cognitive function x group: no significant results</p>	N/A	N/A

Table 4. Cont.

Author (Year)	Cognitive and Academic Performance	Fatigue and Musculoskeletal Pain Symptoms	Process Evaluation
Cycling desk			
Fedewa et al. (2017) [30]	N/A	N/A	Mean value for all items: $3.87 \pm 0.23/5$ Preference to sit on the bike compared to sitting in a chair: $4.63 \pm 1.59/5$ Sitting on the bike was fun: $4.13 \pm 1.64/5$
Ruiter et al. (2019) [58]	Digit Span Task: Accuracy and response times: no differences Visual Pattern Task: Accuracy and response times: no differences Eriksen Flanker Task: Responses time during incongruent trials IG < CG ( $p = 0.01$ ) Accuracy and response times: no differences Congruent and neutral stimuli: no differences Subjective task experience: Fatigue Motivation, difficulty, mental effort: no significant	N/A	N/A
Torbeyns et al. (2017) [34]	Rey auditory verbal learning test: no significant results Stroop test: Accuracy: on the word incongruent stimuli: IG post > pre pre vs. post: pre: $86.3 \pm 10.9$ ; post: $90.1 \pm 7.1\%$ ( $p = 0.030$ ) Reaction time: IG and CG: pre > post pre vs. post: pre: $728.1 \pm 105.6$ ms vs. post: $694.2 \pm 98.4$ ms ( $p < 0.001$ ) Immediately repeated words: no significant Rosvold continuous performance test: Amplitude: post < pre post vs. pre: post: $3.2 \pm 1.4$ $\mu$ V vs. pre: $3.9 \pm 1.4$ $\mu$ V ( $p = 0.012$ ) reaction time: no significant Attention during class: no significant Academic performance: no significant Mathematics test IG and CG post < pre post vs. pre: post: $0.39 \pm 0.52$ vs. pre: $0.66 \pm 0.52$ ( $p = 0.004$ )	N/A	N/A
Stability ball			
Erwin et al. (2016) [33]	On-task behaviors: no significant	N/A	N/A
Fedewa et al. (2015) [59]	Effect on-task behavior: On task: CG (87%) > IG (77%) Time working with peers: CG (15%) > IG (13%) Effect between Time and Group: ( $p < 0.01$ ) pre < post ( $p < 0.01$ ) Time doing independent work: CG (39%) > IG (29%) Effect time-group: ( $p = 0.02$ ) pre < post ( $p < 0.01$ ) Interaction time with the teacher: CG (33%) < IG (35%) Effect time-group: ( $p < 0.01$ ) pre < post ( $p < 0.01$ ) Effect on academic performance: Literacy: (IG + CG): post > pre ( $p < 0.01$ ) Mathematics: (IG + CG): post > pre ( $p < 0.01$ )	N/A	N/A

N/A: Not applicable; NS: Not Significant; NR: Not Reported; IG: Interventional Group; CG: Control Group.

#### 2.4. Data Collection

Full texts from the articles were imported from a reference manager software (Zotero software; 5.0.21, CHNM, GMU, USA). After removal of duplicates, a screening was conducted by two independent authors on titles and abstracts to assess study eligibility (CC, TG). Identical procedure was used by the same authors on full text articles (CC, TG). Any disagreement regarding eligibility for inclusion was discussed until consensus emerged as made among the research team members. Each author completed data extraction files for every paper included. The process for trial inclusion is shown in the PRISMA flow chart (Figure 1).

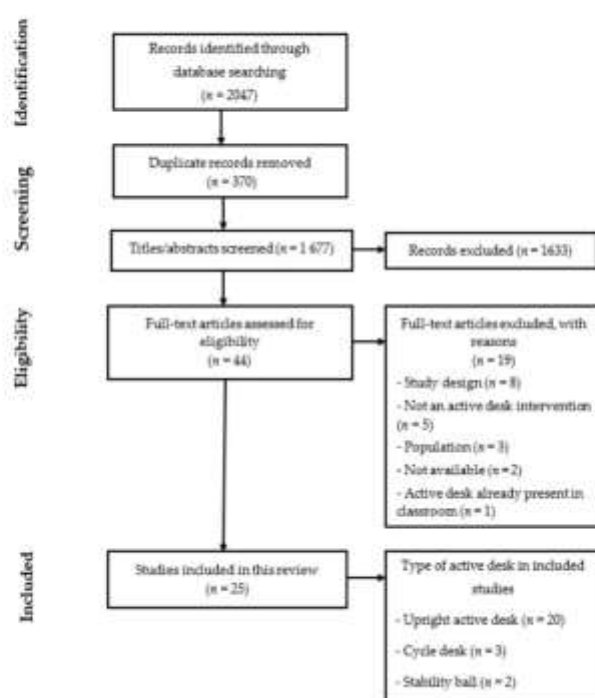


Figure 1. PRISMA flow chart.

#### 2.5. Risk of Bias, Study Quality Assessment and Result Consideration

Risk of bias was independently examined by two authors (CC and TG) using the Cochrane risk of bias tool [60] (Table 5). Selection bias, performance bias, detection bias, attrition bias and reporting bias were assessed. The quality of evidence for each outcome by type of study design was determined using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework [61] (Table 6). Any divergences were reported to the research team (MD, DT, LM). We did not exclude studies on the basis of risk of bias or low quality evidence. Importantly, the results of all the included studies and their directions, have been reported whether or not a statistical analysis was performed and if yes, précising whether the results reached or not the level of significance.

Table 5. Study risks of bias.

Studies	Random Sequence Generation	Allocation Concealment	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Other Bias
Upright active desk							
Benden et al. (2011) [40]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Benden et al. (2012) [41]	High risk	High risk	High risk	High risk	High risk	Low risk	Unclear
Benden et al. (2014) [42]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Low risk
Blake et al. (2012) [43]	High risk	High risk	High risk	High risk	High risk	High risk	Unclear
Clemes et al. (2016) (Bradford, England) [31]	High risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Clemes et al. (2016) (Melbourne, Australia) [31]	Unclear	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Clemes et al. (2020) [44]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk
Dornhecker et al. (2015) [45]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Ee et al. (2018) [32]	N/A	N/A	High risk	High risk	Low risk	Low risk	Low risk
Kidokoro et al. (2019) [46]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk
Koeppe et al. (2012) [47]	High risk	High risk	High risk	High risk	Low risk	Low risk	Unclear
Mehta et al. (2015) [48]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk
Parry et al. (2019) [49]	N/A	N/A	High risk	High risk	Low risk	Low risk	Unclear
Pickens et al. (2016) [50]	High risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Sherry et al. (2020) [51]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk
Sprengeler et al. (2020) [52]	N/A	N/A	High risk	High risk	Low risk	Low risk	Low risk
Sudholz et al. (2016) [53]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk
Swartz et al. (2019) [54]	N/A	N/A	High risk	High risk	Low risk	Low risk	Low risk
Verloigne et al. (2018) [55]	Low risk	Unclear	High risk	High risk	High risk	Low risk	Low risk
Wendel et al. (2016) [56]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk
Wick et al. (2018) [57]	High risk	Unclear	High risk	High risk	Low risk	Low risk	Low risk
Cycling desk							
Fedewa et al. (2017) [30]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Ruiter et al. (2019) [58]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Unclear
Torbeyns et al. (2017) [34]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Low risk
Stability ball							
Erwin et al. (2016) [33]	Low risk	Unclear	High risk	High risk	Low risk	Low risk	Unclear
Fedewa et al. (2015) [59]	Low risk	High risk	High risk	High risk	Low risk	Low risk	Unclear

N/A: not applicable; Other bias included any potential conflict of interest in studies.

**Table 6.** Association between the use of active desks and outcomes of included studies for the systematic review.

Outcome Assessment	No of Studies	Design	Quality Assessment					Quality
			Risk of Bias	Inconsistency	Indirectness	Imprecision	Other	
Body composition	School grade ranged between 1 and 10. Body composition was assessed objectively as body mass index, body mass, body fat percentage (bio-impedance), waist circumference.							
	5	RCT <sup>a</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious imprecision <sup>b</sup>	None	MODERATE
	2	NRT <sup>c</sup>	Serious risk of bias <sup>d</sup>	Serious inconsistency <sup>e</sup>	No serious indirectness	No serious imprecision	None	VERY LOW
Physical activity	School grade ranged between 1 and 12. Physical activity was assessed as light physical activity, MVPA, step counts, standing, stepping and walking time: by devices (accelerometers, inclinometers), self-reported questionnaires and/or external observations.							
	7	RCT <sup>f</sup>	No serious risk of bias	Serious inconsistency <sup>g</sup>	No serious indirectness	Serious imprecision <sup>h</sup>	None	LOW
	6	NRCT <sup>i</sup>	Serious risk of bias <sup>l</sup>	No serious inconsistency	No serious indirectness	Serious imprecision <sup>k</sup>	None	VERY LOW
	2	NRT <sup>j</sup>	Serious risk of bias <sup>m</sup>	No serious inconsistency	No serious indirectness	Serious imprecision <sup>n</sup>	None	VERY LOW
	1	RT <sup>o</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	LOW
	4	Cross-over <sup>p</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	LOW
Sedentary behaviors	School grade ranged between 1 and 10. Sedentary behaviors were assessed by observations and/or self reporting questionnaires.							
	3	RCT <sup>q</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious risk of imprecision <sup>r</sup>	None	MODERATE
	6	NRCT <sup>s</sup>	Serious risk of bias <sup>t</sup>	No serious inconsistency	No serious indirectness	Serious risk of imprecision <sup>u</sup>	None	VERY LOW
	1	RT <sup>v</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	LOW
	4	Cross-over <sup>w</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	LOW
Energy expenditure	School grade ranged between 1 and 10. Energy expenditure was assessed by a portable device (armband) during school days and/or entire days.							
4	RCT <sup>x</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious risk of imprecision <sup>y</sup>	None	MODERATE	

Table 6. Cont.

Outcome Assessment	No of Studies	Design	Quality Assessment				Quality	
			Risk of Bias	Inconsistency	Indirectness	Imprecision		Other
	1	NRCT <sup>z</sup>	Serious risk of bias <sup>aa</sup>	No serious inconsistency	No serious indirectness	Serious risk of imprecision <sup>ab</sup>	None	VERY LOW
	1	NRT <sup>ac</sup>	Serious risk of bias <sup>ad</sup>	No serious inconsistency	No serious indirectness	Serious risk of imprecision <sup>ae</sup>	None	VERY LOW
Cognitive and academic performance	School grade ranged between 2 and 10. Cognitive performance was assessed by cognitive functions test (working memory, inhibitory control, flexibility, attention) and on-task behaviors (observations, interviews)							
	4	RCT <sup>af</sup>	Serious risk of bias <sup>ag</sup>	No serious inconsistency	No serious indirectness	No serious imprecision	None	MODERATE
	4	NRCT <sup>ah</sup>	Serious risk of bias <sup>ai</sup>	No serious inconsistency	No serious indirectness	No serious imprecision	None	VERY LOW
	3	NRT <sup>aj</sup>	Serious risk of bias <sup>ak</sup>	No serious inconsistency	No serious indirectness	No serious imprecision	None	VERY LOW
Fatigue and musculoskeletal symptoms	School grade ranged between 4 and 10. Fatigue and musculoskeletal symptoms were assessed by questionnaires (Nordic Musculoskeletal Questionnaire, paper questionnaires), teacher observations, focus groups and/or interviews.							
	1	RCT <sup>al</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious imprecision <sup>am</sup>	None	MODERATE
	2	NRCT <sup>an</sup>	Serious risk of bias <sup>ao</sup>	No serious inconsistency	No serious indirectness	Serious imprecision <sup>ap</sup>	None	VERY LOW
	1	NRT <sup>aq</sup>	Serious risk of bias <sup>ar</sup>	No serious inconsistency	No serious indirectness	No serious imprecision	None	VERY LOW
	2	Cross-over <sup>as</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	No serious imprecision	None	LOW
Process evaluation	Mean age ranged between 6 and 17 year. Perceptions and experiences of participants was assessed by questionnaires, self-reporting answers and/or interviews.							
	3	RCT <sup>at</sup>	Serious risk of bias <sup>au</sup>	Serious inconsistency <sup>av</sup>	No serious indirectness	No serious imprecision	None	LOW
	4	NRCT <sup>aw</sup>	Serious risk of bias <sup>ax</sup>	No serious inconsistency	No serious indirectness	No serious imprecision	None	VERY LOW

Table 6. Cont.

Outcome Assessment	No of Studies	Design	Quality Assessment				Quality
			Risk of Bias	Inconsistency	Indirectness	Imprecision	
Physical capacities and cardiometabolic health	School grade ranged between 4 and 10. Physical capacities was assessed by the 20 m shuttle run test. Cardiometabolic health was assessed by blood pressure.						
	2	RCT <sup>ay</sup>	No serious risk of bias	No serious inconsistency	No serious indirectness	Serious imprecision <sup>az</sup>	None

RCT: Randomized Controlled Trial; RT: Randomized Trial; NRCT: Non-Randomized Controlled Trial; NRT: Non-Randomized Trial. <sup>a</sup> Includes five randomized controlled studies [34,40,42,44,56]. <sup>b</sup> One study did not detail the age and sex of participants. Additionally, the results of body composition assessment were incomplete (the quality of evidence was downgraded from “high” to “moderate”). <sup>c</sup> Includes two non-randomized studies [41,47]. <sup>d</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>e</sup> Inconsistencies have been reported in the unit used in the results (the quality of evidence was downgraded from “low” to “very low”). <sup>f</sup> Includes seven randomized controlled studies [30,31,33,34,42,44,55]. <sup>g</sup> Inconsistencies have been reported in the number of participants (the quality of evidence was downgraded from “high” to “moderate”). <sup>h</sup> Several studies did not achieve statistical analyses (the quality of evidence was downgraded from “moderate” to “low”). <sup>i</sup> Includes six non-randomized controlled studies [31,43,46,51,53,57]. <sup>j</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>k</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>l</sup> Includes two non-randomized studies [41,47]. <sup>m</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>n</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>o</sup> Includes one randomized study [50]. <sup>p</sup> Includes four cross-over studies [32,49,52,54]. <sup>q</sup> Includes three randomized controlled studies [31,44,55]. <sup>r</sup> One study did not achieve statistical analyses (the quality of evidence was downgraded from “high” to “moderate”). <sup>s</sup> Includes six non-randomized controlled studies [31,43,46,51,53,57]. <sup>t</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>u</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>v</sup> Includes one randomized study [50]. <sup>w</sup> Includes four cross-over studies [32,49,52,54]. <sup>x</sup> Includes four randomized controlled studies [30,34,40,42]. <sup>y</sup> One study did not achieve statistical analyses (the quality of evidence was downgraded from “high” to “moderate”). <sup>z</sup> Includes one non-randomized non-controlled study [43]. <sup>aa</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>ab</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>ac</sup> Includes one non-randomized study [41]. <sup>ad</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>ae</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>af</sup> Includes four randomized controlled studies [33,34,44,59]. <sup>ag</sup> One study did not achieve statistical analyses (the quality of evidence was downgraded from “high” to “moderate”). <sup>ah</sup> Includes four non-randomized controlled studies [43,45,51,57]. <sup>ai</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>aj</sup> Includes 3 non-randomized studies [47,48,58]. <sup>ak</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>al</sup> Includes one randomized controlled study [44]. <sup>am</sup> One study did not detail the number of participants for this outcome and did not achieve statistical analyses (the quality of evidence was downgraded from “high” to “moderate”). <sup>an</sup> Includes two non-randomized non-controlled study [51,53]. <sup>ao</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>ap</sup> One study did not achieve statistical analyses (the quality of evidence was already at “very low”). <sup>aq</sup> Includes one non-randomized study [47]. <sup>ar</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>as</sup> Includes two cross-over studies [32,49]. <sup>at</sup> Includes three randomized controlled studies [30,44,55]. <sup>au</sup> Studies reported mixed findings (the quality of evidence was downgraded from “high” to “moderate”). <sup>av</sup> Inconsistencies have been reported in the unit used in the results (the quality of evidence was downgraded from “moderate” to “low”). <sup>aw</sup> Includes four non-randomized controlled studies [43,46,51,53]. <sup>ax</sup> Studies reported mixed findings (the quality of evidence was downgraded from “low” to “very low”). <sup>ay</sup> Includes two randomized controlled studies [34,44]. <sup>az</sup> One study did not achieve statistical analyses (the quality of evidence was downgraded from “high” to “moderate”).

### 3. Results

#### 3.1. Description of Studies

The PRISMA flow diagram presented in Figure 1 summarizes the study selection process. The search strategy initially found a total of 1677 references after removing duplicates. A total of 1635 articles were excluded after screening of titles and abstracts. Full text copies were obtained for 44 articles; of which 25 articles matched the inclusion criteria and were thus included in this systematic review. The main reasons for studies exclusion among the remaining were: (1) study design did not meet inclusion criteria ( $n = 8$ ); (2) intervention did not use an active desk ( $n = 5$ ); (3) population was not children without health issues ( $n = 3$ ); (4) full texts were not available ( $n = 2$ ); and (5) active desks were already integrated in classroom ( $n = 1$ ). One article included two different study designs [31].



Ten studies were randomized controlled trials (RCT) [30,31,33,34,40,42,44,55,56,59] with four pilot studies [30,31,42,44]; seven were non-randomized controlled trials [31,43,45,46,51,53,57] with four pilot studies [31,51,53,57]; four were non-randomized trials [41,47,48,58] with two pilot studies [47,48]; one was a randomized trial [50] and four were crossover studies [32,49,52,54].

Among the included studies, 19 were conducted among primary school children aged 6–12 years [31–33,40–47,49,51,52,54,56–59], five took place among secondary level adolescents aged 12–17 years [30,34,52,56,58] and Verloigne et al. [55] enrolled children in both levels aged 10–16 years.

Two studies included boys only [32,49], three did not specify the gender [30,42,48] and the rest of the studies included both boys and girls [31,33,34,41,42,44–48,50–59].

Twenty studies assessed upright active desks (i.e., standing desk, sit-to-stand desk and stand-biased desk) [31,32,40–57]; three cycle desks [30,34,57] and two used stability balls [33,59]. Active desks have been described in Table 1.

In twenty-one studies, active desks were allocated to every individual [31–34,40–43,46–54,56–59]. Verloigne et al. [55] implemented three standing desks per classroom, Clemes et al. [44] provided six active desks in each class and Fedewa et al. [30] provided four active desks in interventional group. One study did not specify the number of implemented active desks [45].

All studies had an intervention duration from two weeks to two years. Verloigne et al. [55] suggested a rotation every half class while Clemes et al. [31] recommended to use active desks at least 30 min per day (Australian study) and one hour per day (English study). Some studies suggested also to practice active desks at least one hour per day [44,57] or for four class hours of 50 min per week [34]. Several studies did not indicate the active desks time and frequency use [47,49,51,58,61]. Some interventions enabled active desks to be free to use [30,40–43,46–48,52,53] or to use it for the entire school day [32,33,45,59]. In one study, active desks were only used for the evaluations [58].

### 3.2. Data Synthesis by Outcome

#### 3.2.1. Body Composition

Six studies assessed body composition when using upright active desks [40–42,44,47,56] and one with cycling desks [34]. However, one study did not detail their results on this outcome [40] (Table 6). Wendel et al. [56] found a significant difference in BMI for interventional group compared to the control group after two years of intervention (−5.24 for BMI percentile) (Table 3). Other studies did not report any change in BMI with the use of an upright active desk.

Torbeyns et al. [34] observed a significant effect of time for height, body weight, fat mass percentage and waist circumference without condition effect. However, traditional desks group reported a significantly higher BMI while cycling desks group did not find any difference.

#### 3.2.2. Sedentary Behaviors

Thirteen articles using upright active desks assessed sedentary behaviors [31,32,43,44,46,49–55,57], while only one used cycling desks [30]. As presented in Table 3, two studies observed that children, when using upright active desks, spent significantly less time sedentary than the control group, using objective measurements [46,54]. Other studies did not find any difference for the interventional group [49,53]. Moreover, Ee et al. [32] observed no significant difference for whole day sedentary time but reported a significant reduction in sitting time during school hours for the intervention group compared to the control group. Similar results have been reported in four other articles [31,44,52,53]. Additionally, four studies reported a reduction of sitting time between T0 and T1 for the intervention group [44,46,51,58]. Similar results have been found in another study but were not statistically significant [49,52].

Fedewa et al. [30] reported a decreased of 9.5% in sedentary time for the intervention group compared to the control group.

### 3.2.3. Physical Activity

Sixteen articles assessed physical activity using upright active desks [31,32,41–44,46,47,49–55,57], two with cycling desks [30,34] and one with stability balls [33]. Studies assessing the upright active desk effects on physical activity reported several different outcomes such as light physical activity, moderate-to-vigorous physical activity (MVPA), step counts, stepping, standing and walking time (Table 3).

For light physical activity, four studies reported no significant changes for interventional group compared to the control group [32,50,52,59,61]. For MVPA, studies found contradictory results while two studies did not find any change [32,49]. Kidokoro et al. [46] observed a significant increase in MVPA for the intervention group between pre- and post-intervention. Another study [54] found that MVPA decreased for the intervention group during school years but less than the control group. Additionally, they reported that the benefit of upright active desk was greater among students initially determined as less active.

Statistically significant increases were reported for the intervention group standing time in height studies [31,32,43,44,50,51,53,55,57]. Similar results have been reported but without reaching significance [49,52].

Regarding step counts, Benden et al. [41] reported an increase of this outcome without statistical analyses (Tables 3 and 6). In another study, they reported similar results at mid intervention but not at the end [42]. No significant effects were observed in two other studies [47,50]. In the article of Clemes et al. [31], the study in Australian school reported no significant effect while the British ones showed an increase for the intervention group in post intervention.

For stepping time a significant decrease was reported for the intervention group [55] or no effect [31,57]. One study [51] observed a significant increase while Clemes et al. [44] found similar results but no statistical analyses have been reported.

Torbeyns et al. [34] assessed the effect of cycling desks on physical activity with a questionnaire. Interventional group and control group decreased their physical activity time between pre- and post-intervention but no condition effect was observed. Despite the lack of statistical analyses (Tables 2 and 4), one study reported, with an objective measurement, an increase of light physical activity and MVPA for the intervention group compared to the control group [30].

One study using stability balls assessed physical activity and missed to observe any difference between the interventional group and the control group after the intervention [33]. Additionally, all groups decreased their physical activity level and their step count between pre- and post-intervention.

### 3.2.4. Energy Expenditure

Four studies assessed energy expenditure with the use of upright active desks [42,43,48,54] and two with cycling desks [30,34]. All upright active desks studies observed an increase between 15% and 25.7% in energy expenditure for interventional groups compared to control groups [42,43,48,54] (Table 2).

Cycling desk studies reported also an increase of energy expenditure. Torbeyns et al. [34] showed a significant increase in energy expenditure (36%) using cycling desks compared to traditional desks. Fedewa et al. [30] reported similar results without any statistical analyses (Tables 3 and 6).

### 3.2.5. Physical Capacities and Cardiometabolic Health

Physical capacities were only evaluated in one study that used cycling desks [34]. The authors reported an increase in the performance during the 20 m shuttle run test in their interventional group compared to the control group (+0.6 interval) (Table 3). Moreover,

there was a significantly lower rate of perceived exertion (RPE) in the interventional group compared to the control group after 22 weeks. For cardiometabolic health, only Clemes et al. [44] assessed blood pressure with the use of an upright active desks. They reported an increase in systolic blood pressure in the interventional group but the authors did not perform statistical analyses (Tables 2 and 4).

### 3.2.6. Cognitive and Academic Performance

Seven studies assessed cognitive and academic performance when using upright active desks [44,48,49,51,53,55,56], two studies with cycling desks [34,58] and two with stability balls [33,59]. Concerning executive functions (working memory, inhibitor control, cognitive flexibility), visual working memory was assessed in two studies using upright active desk and two studies using cycling desks and no change was reported [34,53,56,57]. As detailed in Table 4, inhibitory control has been assessed in three studies, and the use of cycling desks shown to significantly increase the inhibitor control in the intervention group compared to the control group with an higher increase of accuracy for the intervention group (4.21%) [58]. One of the studies that used upright active desk reported an improvement in both reaction time and accuracy [57] while the other reported no significant change [48]. The reaction time for cognitive flexibility decreased after intervention in the study that used upright active desks [57].

Regarding to academic engagement and attention, two studies using upright active desks reported an increase in the intervention group compared to the control group [43,45] without any change in concentration and classroom management [33,44,55]. A study using stability balls reported more interaction time with teachers but the time working with other students or independently were reduced compared to the control group after intervention. Both groups observed improvement in mathematics and literacy but they were not related specifically to the intervention [59]. Mehta et al. [48] assessed several outcomes where they primarily observed a significant increase in cognitive performance with the use of upright active desks compared to traditional ones.

### 3.2.7. Fatigue and Musculoskeletal Pain Symptoms

Six studies, all with upright active desks, assessed fatigue and musculoskeletal pain symptoms [32,44,51,52,55,59]. Three studies reported no difference on those outcomes between upright active desks and traditional desks [44,51,55]. Significant changes have been reported in two studies [32,49] with a decrease of pain symptoms in the neck and shoulder area. Nonetheless, a study observed that 51% of children have experienced pain in legs and back area with the use of upright active desks [53] (Table 4).

### 3.2.8. Process Evaluation

Acceptability and feasibility have been assessed in several studies [30,43,44,46,51,53,55]; one was cycling desks [30] and others were upright active desks. One study reported retention rates of 100% for schools and 97% for children with an overall recruitment rate at 33% [44] (Table 4). Studies have shown a good acceptability of upright active desks in children [48,50,51], with a willingness to use it in the future and a reduction of sleepiness [46]. From teachers' perspective, they have declared a positive influence of upright active desks to complete tasks and are willing to continue teaching with upright active desks [53]. One study reported that parents have felt a positive impact on their children's behavior at school [43]. However, one study [55] reported some negative effects with the use of upright active desks such as a slight deterioration of the relation with classmates. Authors also reported, a decrease of the mean duration and habit to use upright active desks over time. Most of those observations were reported in primary schools; secondary schools observed an improvement of the attitude towards the desk [55].

For cycling desks, authors [30] observed no change in attention and task completion compared to traditional desks. Students also experimented a reduction of fidgeting. Their preference to sit on cycling desks compared to traditional desks was higher despite the lack

of a comfortable seat. Overall, cycling desks have been perceived by teachers and students as a positive tool to improve the environment of school class.

It was determined by the review team that a meta-analysis was not possible due to high levels of heterogeneity across studies; narrative syntheses were employed instead. The overall quality of the included studies was low due to methodological inconsistencies, in addition of the heterogeneity in terms of statistical and clinical characteristics (Tables 5 and 6).

#### 4. Discussion

We are currently at a time where sedentary behaviors are a worldwide concern and classroom active desks have been proposed as a potential solution to counterbalance their adverse effects on health-related outcomes. Several reviews evaluated the effect of some specific types of active desks [35,36] on some specific outcomes such as academic achievement and cognitive outcomes [37]. The present work is the first systematic analysis of the existing literature on active desk implementation in the school environment and their effects on physical activity, sedentary behavior, academic achievements and overall health. According to our results, (i) cycling desk may be a promising active desk to increase physical activity while reducing sedentary behaviors; also, cycling desk is associated with positive cognitive performance and is well-received in the school environment; (ii) studies need to better identify and detail their active desks use; (iii) further studies have to use stronger methodologies to enable comparisons and conclusions regarding the real effects of each active desks.

Among all the included studies that assessed body composition, little or none effect was observed from the use of upright active desks or cycling desks. The only study that found positive changes in body composition was the study that lasted 2 years with upright active desks [56]. This suggests that the time of exposure to active desks can be an important parameter to consider. Additionally, the lack of observed effect on body composition in the reviewed studies can be potentially explained by the low level of energy expenditure generated by active desks. While active desks substantially increase students' energy expenditure compared to traditional desks [30,34,42,43,48,54], the magnitude of responses may not be sufficiently important to induce significant changes in body composition. However, it is important to notice that the range of increase in energy expenditure is not the same across active desks, with cycling desks generating a higher energy expenditure compared with upright active desks. According to our analysis, active desks also seem to positively influence sedentary behaviors. Indeed, by using upright active desks, students spend more time in a standing position and less time seated. Even though "standing" is not included in the definition of sedentary behavior [4], the energetic cost of this passive posture can be under 1.5 METs [62] and this long-term position can be a potential source of musculoskeletal pain [63]. From that perspective, replacing traditional desks by active desks (maybe not only standing), which increase energy expenditure, may be promising due to the replacement of a sitting time to an active behavior. Concerning cognitive and academic performance, all studies reported either no change or an improvement in students, leading to consider the non-deleterious impact of active desks on cognition. This finding is particularly relevant, as the implementation of active desks is clearly dependent on the willingness of the academic actors and parents. Beyond the cognitive aspect, active desks were well received by students and teachers in most studies, suggesting the possibility that active desks can be easily implemented in the school setting.

##### *Methodological Concerns*

The tremendous amount of sitting time spent in classrooms led scientists to examine how active desks for children and adolescents can be used to reduce sedentary behaviors. There has been a constant increase of studies focusing on this target in recent years. However, by systematically reviewing the current literature on the topic, we observed several methodological issues. The lack of strong and reliable results did not allow us to

perform any meta-analysis to avoid misleading errors [64]. Not only the lack of methodological consistency between studies is concerning but also the relatively low quality of the included works (Tables 5 and 6) are certainly the main conclusions emerging from the present systematic review.

Indeed, although there is an increasing number of RCT on the topic in the scientific literature, only 10 of the 23 included studies were RCT in the present analysis. The heterogeneity of designs makes any comparison difficult regarding the potential benefits of active desks on health. Similarly, the variety of methods used to evaluate similar parameters (e.g., evaluation of physical activity and/or sedentary behaviors using accelerometers or inclinometers or questionnaires and expressed as counts, vector of magnitudes, activity or standing/sitting time for instance) prevent any strong collective evidence.

As previously suggested in the literature [65], studies should use parameters indicated in the last available recommendation to evaluate sedentary behaviors, sedentary time and physical activity. Moreover, studies assessing sedentary behaviors and physical activity should also consider the recording time for valid and reliable data. In other words, to observe and understand behavioral changes and compensatory effects, studies should not only record data during class time but rather on overall days, school and non-school day.

Importantly, while the recent years have seen a growing number of studies implementing active desks at school at a time where it was necessary to adopt new solutions and strategies to counteract the adverse effects of sitting time, these studies missed to clearly detail the exact conditions of use of their active desks. Indeed, as underlined in our systematic analysis, most of the included studies do not provide details regarding the time of use of their active desks, the instructions given to the teachers and pupils, which once more, make any practical recommendation hazardous. Characterization of the workload and details regarding the practical instructions should be a priority for investigators to understand at which frequency, intensity and duration active desks are driving benefits or adverse effects. In addition, it appears even difficult to clearly understand which kind of active desk has been used when reading some studies. Indeed, while some studies claim to use standing desks and formulate recommendations and conclusions regarding the use of the standing position at school, it appears that some stools are provided with each desk and that the exact time spent standing is not evaluated or even presented. Literally, it may be possible that users can sit or recline on the stool most of their class time. Considering this information, there is a clear risk of misunderstanding by using the term standing desk when it refers to a stand-biased desk. To avoid any misconception, the following definitions for those three active desks are proposed: (i) standing desk: desk which enables users to be in a standing position, without allowing any support to sit or recline; (ii) sit-to-stand desk: desk enabling users to switch from a sitting to a standing position at their discretion by adjusting the desk height; (iii) stand-biased desk: desk which enables users to be in a standing position while having a support such as a stool to sit or recline at their discretion.

Upright active desks represent a majority of the included study, while cycling desks and stability balls represent only five studies. Regarding results obtained in adults, cycling desk is suggested as the best compromise between all active desks [66] but not enough studies have assessed its effects in children and adolescents. While further studies are needed in the pediatric population, we also encourage future investigations to consider the effects of such active desks on physical discomfort, cognitive performance, physical capacities or physiological components that remain underexplored. Similarly, some ergonomic and process evaluations should be considered, which would benefit for a better use and implementation of these desks. Effectively, whether active desks are showing positive effects on several outcomes, one priority remains to understand if they are well accepted in school class by children, teachers and parents.

Furthermore, studies are essentially focusing on primary schools (17 of the 23 studies included). As previously said, children at 15 years spend on average 75% of their waking day in a sitting position [13]. Then, there is obviously a lack of active desks implementation in secondary school. From this perspective, scientists should also consider secondary

levels. Therefore, to better understand the effect of active desks, further investigations should focus on large sample RCT follow-up in primary and secondary level (long-term follow-up), assessing multicomponent outcomes with valid, reproducible and reliable methods, while quantifying the workload. There is a need for a better description of the active desks use and condition of its use to avoid any misconception and inaccuracies. Additionally, scientists must consider the feasibility and the implementation of active desks in the school environment.

## 5. Conclusions

Active desks appear as a promising tool to reduce sedentary behaviors in school environment. In the present state of knowledge, the effects of all active desks appear not equivalent, mainly due to the difference in body activation and energy expenditure. Regarding the relatively low number of available studies and the high degree of heterogeneity in terms of quality, design and methods, comparisons and conclusions remain difficult at the moment. The present systematic analysis calls for further well-designed studies to better understand the effects of the use of active desks among children and adolescents in order to inform policy and practice.

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## RESUME

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De par l'évolution des modes de vie, la population a progressivement adopté un comportement de sédentarité et d'inactivité de plus en plus prononcé. En raison de leur sensibilité à l'activité physique et à la sédentarité, tant sur le plan du développement physique et cognitif que sur celui de la vulnérabilité aux problèmes de santé associés, les enfants et les personnes âgées se trouvent particulièrement exposés aux risques liés aux comportements de mouvements délétères. Dans le premier axe de cette thèse, nous avons exposé les effets néfastes du premier confinement sur la mobilité de ces deux groupes de population. Le deuxième axe de notre recherche s'est spécifiquement consacré aux enfants, analysant les retombées du COVID-19 sur divers paramètres de santé, puis étudiant les conséquences d'un programme d'intégration de vélo-bureaux au sein de l'environnement scolaire des élèves de primaire sur des paramètres de santé. Le troisième axe de cette thèse, quant à lui, s'est consacré à l'examen de la fragilité des personnes âgées évoluant dans des milieux ruraux et semi-urbains, au moyen d'une approche adaptée au contexte territorial de l'approche ICOPE.

## ABSTRACT

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As a result of changing lifestyles, the population has gradually adopted an increasingly sedentary and inactive lifestyle. Because of their sensitivity to physical activity and sedentary behaviors, both in terms of physical and cognitive development and vulnerability to associated health problems, children and the older people are particularly at risk from unhealthy movement behaviours. In the first part of this thesis, we outlined the adverse effects of initial lockdown on the mobility of these two population groups. The second axis of our research focused specifically on children, analyzing the impact of COVID-19 on various health parameters, then studying the consequences of a program to integrate cycle desks into the school environment of primary school children on health parameters. The third axis of this thesis was devoted to examining the frailty of elderly people living in rural and semi-urban environments, using the ICOPE approach adapted to the territorial context.