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Contribution à la surveillance et à la mesure de l'activité physique et des comportements sédentaires

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Résumé français

Revue de la littérature

La surveillance est un élément central pour la prise de décision en matière de santé publique. La surveillance de la santé publique est généralement considérée comme étant le recueil systématique et continu de données pertinentes, ainsi que leur consolidation et leur évaluation efficaces, s'accompagnant de la diffusion rapide des résultats aux personnes concernées, en particulier celles en mesure d'agir. La surveillance de la santé et de ses déterminants permet ainsi d'identifier les besoins et de définir les actions de santé prioritaires (Macera et Pratt, 2000, Lee, 2010).

L'activité physique et la sédentarité sont des déterminants majeurs de la santé et de la qualité de vie et, au regard de la prévalence des maladies non transmissibles, associées avec un trop faible niveau d'activité physique et une trop grande sédentarité, la surveillance de ces comportements et des maladies auxquelles ils sont associés paraît indispensable. L'activité physique est un comportement qui implique le mouvement humain et qui résulte en des caractéristiques physiologiques incluant une dépense énergétique (Pettee Gabriel et al., 2012). Un individu est caractérisé comme physiquement actif lorsque celui-ci respecte les recommandations sur l'activité physique. A l'inverse, lorsqu'un individu ne respecte pas ces recommandations, on parle d'individu inactif ou d'insuffisamment actif. Parfois confondu avec l'inactivité physique, le comportement sédentaire se définit « comme une situation d'éveil caractérisée par une dépense énergétique ≤ 1,5 METs en position assise, inclinée ou allongée » (Tremblay et al., 2017).

Récemment, l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses), saisie par la Direction générale de la santé, a proposé de nouvelles recommandations (intégrant de nouveaux repères de pratique), synthétisées dans le tableau ci-dessous (Anses, 2016).

Catégories d'âge	Recommandations			
	Activité physique (AP)		Comportements sédentaires (CS)	
Enfants 0-5 ans	1	Au moins 3 heures d'AP (180 min) dans la journée ou 15 minutes par heure (pour 12 heures d'éveil) ;	3	Limiter la durée des CS et passer moins d'1h en continu dans des activités sédentaires ;
	2	L'AP doit se composer d'activités motrices variées et de préférence ludiques.	4	Eviter l'exposition aux écrans avant 2 ans et limiter l'exposition à moins d'1h/jr entre 2 et 5 ans.
Enfants 6-11 ans	5	Au moins 60 min/jr d'APME ;	7	Limiter la durée des CS ;
	6	Dont au moins 3 séances d'au moins 20 minutes d'une AP d'intensité élevée (jours non consécutifs), et au moins 3 séances d'au moins 20 minutes d'une AP basée sur le travail musculo-squelettique (jours non consécutifs).	8	Passer moins de 2h consécutives dans des CS ;
			9	Limiter le temps de loisir passé devant un écran à 60 min/jr jusqu'à 6 ans et 120 min/jr jusqu'à 11 ans.
Adolescents 12-17 ans	10	Au moins 60 min/jr d'APME ;	12	Limiter les périodes de sédentarité et d'inactivité à moins de 2h consécutives en position assise ou semi-allongée
	11	Dont au moins 3 séances de 20 min/semaine d'AP à intensité élevée (jours non consécutifs) ; et 3 séances de 20 min/semaine d'AP basée sur le travail musculo-squelettique (jours non consécutifs).		
Adultes 18-65 ans	13	Au moins 30 min/jr d'APME cardio-vasculaire. Des bénéfices supplémentaires sur la santé peuvent être obtenus avec une pratique de 45 à 60 min. Les AP peuvent être fractionné en périodes de 10 min minimales. Ces AP devraient être répétées au moins 5 jr/semaine, et si possible tous les jours ;	16	Réduire le temps total quotidien passé en position assise, autant que faire se peut ;
			17	Interrompre les périodes prolongées passées en position assise ou allongée, toutes les 90 à 120 min, par une AP de type marche de quelques minutes (3 à 5), accompagnée de mouvements de mobilisation musculaire.
	14	1 à 2 fois par semaine des AP de renforcement musculaire contre résistance ;		
	15	Les étirements doivent être réalisés régulièrement, au minimum 2 à 3 fois par semaine		
Séniors +65 ans	**1**	Au moins 30 min/jr d'AP cardio-vasculaires d'intensité modérée, au moins 5 fois par semaine ; ou 15 min par jour d'AP cardio-respiratoires d'intensité élevée, au moins 5 fois par semaine ; ou une combinaison d'APME sachant que 1 min d'AP d'intensité élevée équivaut à 2 min d'AP d'intensité modérée ;	**3**	Limiter le temps total quotidien passé assis ou allongé ;
			-	Fractionner le temps passé à des activités sédentaires
	2	APME de renforcement musculaire 2 jr/semaine ou plus, de préférence non consécutifs.		

Tableau 1. Synthèse des recommandations de l'Anses en matière d'activité physique et de comportements sédentaires.

La surveillance des comportements sédentaires et de l'activité physique en population générale est primordiale, notamment pour en évaluer la prévalence, la comparer aux repères de pratique conseillés, et la confronter aux données de santé. Les études de surveillance sont par ailleurs essentielles à l'élaboration des politiques nationales, ainsi qu'à l'évaluation des stratégies de promotion de l'activité physique et de prévention des comportements sédentaires. Toutefois, la mise en place d'études de surveillance fait face à certaines difficultés. Une difficulté majeure réside dans la capacité à obtenir une mesure précise de l'activité physique et des comportements sédentaires. Différents outils existent pour mesurer ces comportements, présentant différents avantages et inconvénients, et dont la qualité est essentielle pour obtenir des données pertinentes.

La fiabilité, la validité et la sensibilité des instruments sont des éléments à prendre en considération lors du choix de l'outil (Terwee et al., 2012). La fiabilité correspond à la reproductibilité d'une méthode c'est à dire à sa capacité à fourni un résultats identiques lorsque la méthode est utilisée à plusieurs reprises dans un même contexte, par la même personne ou par des personnes différentes. La validité réfère à la capacité de l'instrument à mesure ce qu'il est sensé mesurer. La sensibilité représente la capacité de l'instrument à détecter un changement au cours du temps. Parce que l'activité physique et les comportements sédentaires sont des comportements complexes et ubiquitaires, aucun instrument ne peut mesurer toutes leurs dimensions.

De ce fait, l'objectif de cette thèse était d'étudier l'état de la surveillance de l'activité physique et des comportements sédentaires, en particulier dans le contexte Français, et de contribuer à enrichir les connaissances concernant la mesure de l'activité physique et des comportements sédentaires.

Contributions personnelles

Pour contribuer à la surveillance et la mesure de l'activité physique et des comportements sédentaires cette thèse repose sur 4 articles, répartis dans l'un des deux axes de recherche ci-dessous. A ce jour, 2 articles ont été publiés dans des revues internationales à comité de lecture, et 2 ont été soumis à des revues pour publication.

Axis 1. Surveillance de l'activité physique et des comportements sédentaires

- Etude 1. **Rivière F.**, Escalon H., Duché P., Drouillet-Pinard P., Vuillemin A. **National surveillance of physical and sedentary behaviors in France.** (Submitted)
- Etude 2. Aucouturier J., Ganière C., Aubert S., **Riviere F.**, Praznoczy, C., Vuillemin A., Tremblay M.S., Duclos M., Thivel D. **Results from the first French Report Card on Physical Activity for Children and Adolescents (2016).** Journal of Physical Activity and Health. In press.

Axis 2. Mesure de l'activité physique et des comportements sédentaires

- Etude 3. **Rivière F.**, Aubert S., Yacoubou Omorou A., Ainsworth B.E., Vuillemin A. **Content comparison of sedentary behavior questionnaires: a systematic review.** (Submitted).
- Etude 4. **Rivière, F.**, Widad, F. Z., Speyer, E., Erpelding, M. L., Escalon, H., Vuillemin, A. (2016). **Reliability and validity of the French version of the global physical activity questionnaire.** Journal of Sport and Health Science. In Press.

Axe 1. Surveillance de l'activité physique et des comportements sédentaires.

Etude 1. Surveillance française de l'activité physique et des comportements sédentaires.

Position du problème : Les études de surveillance sont essentielles à l'élaboration des politiques nationales et à l'évaluation des stratégies de promotion de l'activité physique et de prévention des comportements sédentaires. Ce travail a pour objectif de présenter les études nationales françaises disposant de données sur l'activité physique et la sédentarité ainsi que les principaux résultats.

Méthode : Les enquêtes nationales sur l'activité physique et la sédentarité ont été identifiées à partir des revues existantes sur le sujet et des sites informatiques des organismes de santé publique français. Les rapports des études ont été analysés et complétés par les informations recueillies auprès des porteurs des études. Les caractéristiques suivantes ont été discutées : la méthode d'échantillonnage, le déroulement de l'étude, les outils de mesure, les niveaux d'activité physique, et les comportements sédentaires.

Résultats : 6 enquêtes réalisées entre 2005 et 2016 ont permis de comparer les comportements de la population au regard des recommandations, parmi lesquelles 4 incluaient des enfants et adolescents âgés de 3 à 17 ans, et toutes des adultes âgés de 18 à 79 ans. Selon les études, entre 63 et 79% des adultes, et entre 30 et 43% des adolescents âgés de 15 à 17 ans atteignaient les recommandations françaises en matière d'activité physique. Les adultes ont reporté une durée moyenne du temps passé assis de l'ordre de 4h40 par jour. Les plus jeunes ont reporté un temps moyen passé devant un écran (télévision, ordinateur, et jeux vidéo) allant de 2h12 (3-10 ans) à 3h50 par jour (15-17 ans). De nombreuses différences ont été observées quant au nombre d'items, la période de rappel, et les caractéristiques mesurées avec les différents questionnaires. Les questionnaires utilisés auprès des enfants ne permettent pas de comparer les résultats obtenus avec les niveaux recommandés. Les enquêtes n'étant pas reproduites dans le temps ou les questionnaires utilisés étant différents, la comparaison des résultats au cours du temps est difficile.

Conclusion : Un système de surveillance constitué de mesures répétées identiques doit être mis en place pour permettre d'observer l'évolution de l'activité physique et la sédentarité et d'évaluer l'efficacité des stratégies de santé publique.

Etude 2. Résultats de la première Report Card française sur l'activité physique des enfants et des adolescents.

Position du problème: De nombreux pays publient périodiquement une Report Card sur l'activité physique des enfants et adolescents. Ce papier présente les résultats de la 1ère Report Card Française et permet d'évaluer les politiques et les actions mises en œuvre pour faciliter la pratique d'activité physique chez les jeunes.

Méthode: Une recherche à été effectuée pour identifier les bases de données nationales permettant de renseigner sur les 8 indicateurs de la Report Card. Chacun des indicateurs s'est ensuite vu attribuer une note après concertation du collectif d'experts. Cette évaluation repose sur l'examen des statistiques et données disponibles, et permet d'attribuer un score au regard du système utilisé par l'ensemble des pays, allant de A (81-100 % des enfants et adolescents) à F (0-20 % des enfants et adolescents), ainsi que NC (pour désigner le manque de données).

Resultats: Le groupe d'expert a attribué les scores suivants: Niveau d'activité physique: INC; Rôle des fédérations sportives: D; Transports actifs: D; Comportements sédentaires: D; L'environnement familial et social: INC; Place de l'école et de l'éducation physique: B; Les espaces de jeu et l'urbanisation: INC; Implcation gouvernementale et institutionnelle : INC.

Conclusions: Les résultats de ce travail révèlent que peut d'enfants et adolescents atteignent le niveau d'activité physique recommandé, et que les efforts doivent être poursuivis pour augmenter l'activité physique des jeunes. Différents indicateurs n'ont pu être évaluer par manque de données, davantage de source de données sont donc nécessaires et peuvent nécessiter la mise en place de nouvelles études.

Axe 2. Mesure de l'activité physique et des comportements sédentaires

Etude 3. Comparaison du contenu des questionnaires portant sur les comportements sédentaires : une revue systématique.

Position du problème: Les comportements sédentaires ont des effets sur la santé pouvant varier en fonction de leurs caractéristiques (ex: le type de comportement, leur durée, le contexte). Au cours des 10 dernières années, un nombre croissant de questionnaires mesurant les comportements sédentaires a été développé; entrainant de la confusion et un manque de clareté quant aux caractéristiques des comportements sédentaires qu'ils mesurent. De ce fait, l'objectif de ce travail était d'examiner le contenu des questionnaires portant sur les comportements sédentaires.

Méthode: Quatre bases de données ont été interrogées pour identifier les questionnaires publiés avant le 1er janvier 2016. En respectant les critères d'inclusion, 82 articles (sur 1369 identifiés) ont été inclus, pour un total de 60 questionnaires. Pour chaque questionnaire, les caractéristiques des comportements sédentaires étaient identifiés et analysés.

Résultats: La plupart des questionnaires mesuraient Quand le comportement a lieu (n=55), la Posture associée (n=54), Pourquoi il a lieu (n=46), and le Type (n=45); 20 questionnaires s'intéressaient à l'Environnement, 11 au context Social, et seulement 2 questionnaires prenaient en compte l'Etat de santé physique et mental et les Comportements associés (ex: fumer, manger). Tous les questionnaires, sauf 2, mesuraient le temps passé dans des comportements sédentaires, 17 mesuraient la fréquence de ces comportements, et 6 le nombre d'interruptions. Les caractéristiques qui sont le plus souvent mesurées sont 'être assis', 'TV', et 'ordinateur', identifiés dans 90, 65 et 55% des questionnaires, respectivement. A l'inverse, de nombreuses caractéristiques ne sont souvent pas mesurées.

Conclusions: En apportant un éclairage nouveau sur le contenu des questionnaires mesurant les comportements sédentaires, cette revue aide à sélectionner le questionnaire approprié et permet de guider le développement de nouveaux questionnaires afin de mesurer les caractéristiques qui sont pour l'instant très peu mesurer par les questionnaires.

Etude 4. Fiabilité et validité du questionnaire mondial sur la pratique d'activités physiques.

Position du problème: Le questionnaire mondiale de l'activité physique (GPAQ) a été utilisé pour mesurer l'activité physique et le temps assis en France, mais aucune étude n'a testé ses propriétés psychométriques. L'objectif de cette étude était d'examiner la fiabilité et la validité du GPAQ, en comparaison avec la version française du questionnaire international de l'activité physique (IPAQ) et des accéléromètres, en population générale.

Methode: La population d'étude (n=92) regroupe des étudiants et personnels de l'Université de Lorraine, à Nancy, France. Les participants ont complété le GPAQ et l'IPAQ, à deux reprises, avec 7 jours d'intervalles, et ont porté pendant 7 jours un accéléromètre (Actigraph GT3X). La fiabilité et la validité du GPAQ ont été testés en utilisant les coefficients de corrélations intra-classe (ICC) et de Spearman pour les variables quantitatives, et les coefficients Kappa et Phi pour les variables qualitatives. La validité a également été examinée à l'aide de graphiques de Bland-Altman.

Résultats: Les résultats ont montré une fiabilité (ICC=0.37-0.94; Kappa=0.50-0.62), et validité en comparaison de l'IPAQ (Spearman r=0.41-0.86) faibles à bonnes, mais une faible validité en comparaison des accéléromètres (Spearman r=-0.22-0.42). Les limites de concordance entre le GPAQ et les accéléromètres étaient importantes, avec des différences allant de 286.5 minutes par jour, à 601.3 minutes par jour.

Conclusions: La version française du GPAQ fait preuve de fiabilité et validité limitées, mais acceptables au regard des autres questionnaires actuellement utilisés. Le GPAQ peut être utilisé pour mesurer l'activité physique et le temps assis en population française.

Discussion

Axe 1. Surveillance de l'activité physique et des comportements sédentaires

Cette thèse identifie un certain nombre de besoins et d'opportunités pour améliorer le système de surveillance de l'activité physique et des comportements sédentaires en France. Les études 1 et 2 ont ainsi identifié certaines limites impactant la qualité des données récoltées. Les études de surveillance reposent sur l'utilisation de questionnaire pour mesurer l'activité physique et les comportements sédentaires en population générale. Cependant, différents questionnaires ont été utilisés, et des modifications ont été effectuées pour certains d'entre eux, ce qui limite la comparaison des résultats entre les études et le suivi de l'évolution de ces données. Par ailleurs, les recommandations internationales et françaises préconisent différents types d'activité physique, dont les activités aérobics, de renforcement musculaire, et de souplesse; mais les études françaises ne mesuraient que les activités d'endurance, ne permettant pas d'estimer le pourcentage de la population respectant les valeurs seuils pour les activités de renforcement musculaire et de souplesse. D'autre part, le choix des outils de mesure rendait difficile l'estimation du pourcentage des enfants et adolescents qui respectent les recommandations concernant les activités physiques aérobics, comme le montre le Report Card. Parmi les limites, ces travaux soulignent également que la manière dont les données ont été analysées ne permet pas d'estimer le pourcentage de jeunes ayant un temps assis en deçà des valeurs recommandées. Les différentes méthodes d'analyse utilisées par chaque étude limitent également les comparaisons entre ces études.

Axe 2. Mesure de l'activité physique et des comportements sédentaires

L'étude 3 portant sur l'évaluation des propriétés psychométriques du GPAQ met en évidence une bonne reproductibilité du questionnaire, mais une validité limitée, bien que similaire aux résultats de validité des questionnaires de l'activité physique généralement observées dans la littérature. L'étude 4, évaluant le contenu des questionnaires des comportements sédentaires permet d'observer une grande diversité quant à ce que les questionnaires mesures, avec un nombre négligeable de caractéristiques des comportements sédentaires qui ne sont pas mesurés par les quesitonnaires existant. En conséquence, de nouveaux questionnaires doivent être développés, ou d'autre méthode de mesure doivent être utilisées pour mesurer ces caractéristiques, telles que EMA.

Conclusions

En conclusion, les travaux réalisés durant cette thèse permettent de formuler des recommandations visant à améliorer la surveillance de l'activité physique et des comportements sédentaires en France :

- La surveillance de l'activité physique et des comportements sédentaires doit reposer sur des mesures standardisées et répétées ;
- Les éléments clés des protocoles de collecte données, incluant les questionnaires d'activité physique et des comportements sédentaires, le mode d'administration des enquêtes, la période d'enquête, et les indicateurs utilisés doivent être standardisés ;
- Les propriétés psychométriques des instruments utilisés doivent être testés dans les populations d'intérêts ;
- Le choix de l'instrument de mesure doit être fait en adéquation avec les indicateurs désirés ;
- Le système de surveillance doit non seulement fournir des informations sur l'évolution de l'activité physique et des comportements sédentaires, mais également fournir des informations sur les facteurs influençant l'activité physique et les comportements sédentaires, tels que l'environnement social et physique, et les politiques publiques.

Cette thèse concorde avec la stratégie sur l'activité physique pour la Région européenne de l'OMS 2016-2025 , et avec le plan global d'action sur l'activité physique de l'OMS pour la période 2018-2030. La stratégie et le plan d'action de l'OMS encouragent les états membres à renforcer la surveillance de l'activité physique et des comportements sédentaires à tous âges et dans tous les milieux, pour suivre les évolutions, et évaluer les politiques publiques. Dans le cadre de son plan d'action, l'OMS va soutenir les états membres dans leurs actions, ce qui peut représenter une opportunité pour les institutions de santé publique française d'améliorer le système de surveillance de l'activité physique et des comportements sédentaires en tenant compte des recommandations exprimées au cours de cette thèse.

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Publications

Peer-review publications

Published articles

Rivière, F., Widad, F. Z., Speyer, E., Erpelding, M. L., Escalon, H., & Vuillemin, A. (2016). Reliability and validity of the French version of the global physical activity questionnaire. *Journal of Sport and Health Science*.

Aucouturier, J., Ganière, C., Aubert, S., **Riviere, F.**, Praznoczy, C., Vuillemin, A., Tremblay, M. S., Duclos, M., & Thivel, D. (2017). Results From the First French Report Card on Physical Activity for Children and Adolescents (2016). *Journal of Physical Activity and Health*, 1-14.

Submitted articles

Rivière, F., Aubert, S., Yacoubou Omorou, A., Ainsworth, B.E., & Vuillemin, A. Content comparison of sedentary behavior questionnaires: a systematic review.

Rivière, F., Escalon, H., Duché, P., Drouillet-Pinard, P., & Vuillemin, A. Surveillance of physical activity and sedentary behaviors: case-study using French surveillance data.

Non peer-review publications

Book chapters

Ainsworth, B. E., Pregonero, A. F., & **Rivière, F**. (2017). Assessing sedentary behavior using questionnaires. In W. Zhu & N. Owen (Eds.), Sedentary behavior and health concepts, assessments, and interventions (pp.165-174, 386-388). Champaign, IL: Human Kinetics.

Ainsworth, B. E., **Rivière, F.**, & Florez Pregonero, A. Measurement of sedentary behavior in population studies. In Sedentary Behavior Epidemiology. Upcoming in: Springer.

Report

ONAPS (2017). 2016 – Activité physique et sédentarité de l'enfant et adolescent – Premier état des lieux en France. Available at : http://www.onaps.fr/data/documents/RC2016.pdf

Communications

Oral communications

Rivière, F., & Vuillemin, A. (2016). Analysis of the surveillance system of physical activity and sedentary behavior in France. In: Proceedings of the 6th International Congress on Physical Activity and Public Health. Bangkok, Thailand.

Ainsworth, B. E., & **Rivière F**. (2015). Assessing sedentary behavior using questionnaires. In: Proceedings of the Sedentary Behavior and Health Conference. Urbana Champaign, Illinois, USA.

Rivière, F., Aubert, S., Yacoubou Omorou, A, Ainsworth, B. E., & Vuillemin, A. (2015). Content comparison of sedentary behavior questionnaires: a systematic review. In: Proceedings of the HEPA Europe Conference. Instanbul, Turkey.

Written communications

Rivière, F., & Vuillemin, A. (2016). Analysis of the surveillance system of physical activity and sedentary behavior in France. In: Proceedings of the HEPA Europe Conference. Belfast, Northern Ireland.

Rivière, F., Aubert, S., Omorou, A., Ainsworth, B. E., Vuillemin, A. (2015). Content comparison of sedentary behavior questionnaires: a systematic review. In: Proceedings of the Sedentary Behavior and Health Conference. Urbana Champaign, Illinois, USA.

Abbreviations

ACSM: American College of Sports Medicine
AHS: Australian Health Survey
Anses: French Agency for Food, Environmental and Occupational Health & Safety
BRFSS: United States Behavioral Risk Factor Survey System
CCHS: Canadian Community Health Survey
CDC: Centers for Disease Control and Prevention
CHMS: Canadian Health Measures Survey
EMA: Ecological Momentary Assessment
ENNS: French National and Health Nutrition Study
Eprus: French Preparedness and Sanitary Emergency Response Establishment
GoPA!: Global Observatory for Physical Activity
GPAQ: Global Physical Activity Questionnaire
HCSP: French High Committee on Public Health
HIS: Belgium Health Interview Survey
HRmax: Maximal Heart Rate
Inpes: French National Institue for Prevention and Health Education
InVS: French Institute for Public Health Surveillance
IPAQ: International Physical Activity Questionnaire
ISPAH: International Society for Physical Activity and Health
LOLF: French Organic Law on the Finances Laws
METs: Metabolic Equivalent of Task – multiples of resting energy expenditure
NHANES: United States National Health and Nutrition Examination Survey
NCDs: Non-Communicable Diseases
PAM: Canadian Physical Activity Monitoring
PNNS: French National Nutrition and Health Program
RPAQ: Recent Physical Activity Questionnaire
RPE: Ratings of Perceived Exertion
SAMSS: South Australian Monitoring and Surveillance System
SBRN: Sedentary Behavior Research Network
SDGs: Sustainable Development Goals
VO2max: Maximal Oxygen Consumption
WHO: World Health Organization

Chapter 1

Introduction

Context

Health impacts of physical activity have been increasingly studied since the 1950s and are now well-established (Morris et al., 1953a; Erlichman et al., 2002; Powell et al., 2011; Garber et al., 2011; Ekelund et al., 2016; Lear et al., 2017). Physical activity is associated with a number of health outcomes, including reduced risks of breast cancer, colon cancer, coronary heart disease, depression, fractures, osteoporosis, type 2 diabetes, and improvement in cognitive function, physical function and weight management (Powell et al., 2011; Garber et al., 2011). Despite these health benefits, nearly one third of the world population does not engage in physical activity at recommended levels (Hallal et al., 2012). The World Health Organization (WHO) has identified the lack of physical activity as the fourth global risk factor for mortality (WHO, 2009), and it is estimated to be responsible for 6 to 9 percent of worldwide premature deaths (WHO, 2009; Lee et al., 2012). As a consequence, the economic burden attributable to the lack of physical activity is estimated to be at least 67.5 billion international dollars worldwide, and 15.5 billion international dollars in Europe (Ding et al., 2016).

In 2010, WHO published global recommendations for physical activity for health (WHO, 2010). According to these recommendations, adults aged 18-64 years should engage in at least 150 minutes of moderate intensity physical activity per week, or 75 minutes of vigorous intensity physical activity, or an equivalent combination. This activity should occur in bouts of at least 10 minutes or longer. In addition, muscle-strengthening activities should be done at least 2 times per week. In France, the French Ministry of Health, as part of the National Nutrition and Health Program (PNNS), recommended that adults engage in at least 30 minutes of brisk walking daily, or an equivalent amount of physical activity (PNNS 2011-2016, PNNS 2006-2010, PNNS 2001-2005), and for youth should engage in at least 60 minutes of brisk walking daily, or an equivalent amount of PA (PNNS 2011-2016). Recently, the French Agency

for Food, Environmental and Occupational Health & Safety (Anses), at the request of the Directorate General for Health (French Ministry of Health), has published updated recommendations for physical activity in toddlers (0-5 years), children (6-11 years), adolescents (12-17 years), adults (18-65 years) and elderly (65 and above) (Anses, 2016).

The term sedentary behaviors covers a whole range of different activities spent sitting, including watching TV, using a computer, driving a car, working at a desk and eating breakfast. Based on international data, worldwide siting time was estimated to be five hours per day (Bauman et al., 2011). Sedentary behaviors are recognized as a health risk associated with increased morbidity and mortality (Jeffery and French, 1998; Van Der Ploeg et al., 2012; Biswas et al., 2015). A systematic literature review and meta-analysis published by Biswas and colleagues reported positive associations between time spent in sedentary behaviors and type 2 diabetes incidence, cancer incidence and mortality, cardiovascular disease incidence and mortality, and all-cause mortality (Biswas et al., 2015). Individuals who accumulate low levels of physical activity and high sedentary time are at highest risk for the associated health risks of these behaviors (Chau et al., 2013; Biswas et al., 2015; Ekelund et al., 2016).

WHO has not made recommendations for the minimal time spent in sedentary behaviors. This is attributable to the fact that epidemiology of sedentary behaviors is a new field of research, thus at the time when WHO published its recommendations for physical activity, little was known on the relationship between sedentary behaviors and health-related outcomes. Since then many countries have published recommendations for sedentary behaviors (Tremblay et al., 2011a; Parrish et al., 2013; Kahlmeier et al., 2015), including France (Anses, 2016).

Being a major determinant of health and well-being, and in regard to the burden of mortality and morbidity associated with insufficient physical activity levels and too much sedentary behaviors, public health systems have integrated surveillance of physical activity and sedentary behaviors (WHO, 2005; Fulton et al., 2016; Craig et al., 2017). Public health surveillance is the foundation of public health systems. Surveillance activities are used to estimate the health status and health determinants of populations, evaluate existing interventions, and plan for future interventions (Macera and Pratt, 2000; German et al., 2001). Public health surveillance is an indispensable process for decision-makers in planning strategies and actions by providing timely, useful evidence. However, the implementation of reliable surveillance systems is complicated. To measure physical activity and sedentary behaviors, one of the main challenges is to rely on accurate measurement of physical activity and sedentary behaviors. Accurate and reliable measures of these behaviors are important for surveillance systems to assess the

prevalence of physical activity levels and sedentary lifestyles, to study the relationships between physical and sedentary behaviors and health outcomes, to characterize the patterns of the population and to plan and evaluate health promotion interventions.

Two main methods of measurement are used to survey these behaviors: self-report questionnaires and objective methods, including pedometers and accelerometers. Questionnaires are cost-effective, readily accessible to the majority of the population, have a relatively low participant burden, and can be used to identify types of behaviors in the context in which the behaviors occur. Therefore, population-based studies have mostly relied on self-report questionnaires (Sjöström et al., 2006; Beck et al., 2008; Fulton et al., 2016; Craig et al., 2017). Questionnaires are prone to both over and underestimating physical activity and sedentary time (Prince et al., 2008). Alternatively, objective methods might improve quantification of these behaviors. Accelerometers provide a measurement of the frequency and time spent in body movement by intensity used to discriminate between physical activity and sedentary behaviors (Hills et al., 2014). Accelerometers have been used in national (Troiano et al., 2008; Hagströmer et al., 2010; Colley et al., 2011), European (Konstabel et al., 2014; Loyen et al., 2016) and international surveys (Van Dyck et al., 2005) to measure physical activity and sedentary behaviors. Accelerometers also have their limitations. In particular, they do not provide information on the type or context of the behaviors and they measure sedentary behaviors poorly. Ideally national surveys should rely on both self-report and objective methods to provide a complete picture of the population physical activity and sedentary behaviors (Troiano et al., 2012).

Research aims and questions

Physical activity and sedentary behaviors are major health determinants and are being surveyed worldwide (WHO, 2005; Fulton et al., 2016; Bel-Serrat et al., 2017; Craig et al., 2017). In some countries, such as the United States and Canada (Fulton et al., 2016; Craig et al., 2017), the implementation of surveillance studies measuring physical activity and sedentary behaviors is well defined. In France, physical activity and sedentary behaviors surveillance is still in an early stage, and needs improvement. There is no consensus about what is the optimal survey and how best to measure physical activity and sedentary behaviors in surveillance setting. In France, questionnaires are used primarily, but there is a lack of consistency in the choice of the

questionnaire. Therefore, this thesis aimed to add to the current knowledge by answering three research questions:

- What is the current state of physical activity and sedentary behaviors surveillance in France?
- What are the psychometric properties of the French version of the Global Physical Activity Questionnaire?
- What do sedentary behaviors questionnaires measure?

Research studies

To answer these questions, this thesis includes four studies. Two studies have been published in international peer-reviewed journals, and two have been submitted to international peer-reviewed journals. The four studies focus on one of the two research axes as presented below.

Axis 1. Surveillance of physical activity and sedentary behaviors

- Study 1. **Rivière, F.**, Escalon, H., Duché, P., Drouillet-Pinard, P., & Vuillemin, A. Surveillance of physical activity and sedentary behaviors: case-study using French surveillance data.
- Study 2. Aucouturier, J., Ganière, C., Aubert, S., **Riviere, F.**, Praznoczy, C., Vuillemin, A., Tremblay, M. S., Duclos, M., & Thivel, D. (2017). Results From the First French Report Card on Physical Activity for Children and Adolescents (2016). *Journal of Physical Activity and Health*, 1-14.

Axis 2. Measurement of physical activity and sedentary behaviors

- Study 3. **Rivière, F.**, Widad, F. Z., Speyer, E., Erpelding, M. L., Escalon, H., & Vuillemin, A. (2016). Reliability and validity of the French version of the global physical activity questionnaire. *Journal of Sport and Health Science*.
- Study 4. **Rivière, F.**, Aubert, S., Yacoubou Omorou, A., Ainsworth, B.E., & Vuillemin, A. Content comparison of sedentary behaviors questionnaires: a systematic review.

Thesis outline

Chapter one provides an introduction to the thesis.

Chapter two provides an overview of the complex and multidimensional nature of physical activity and sedentary behaviors, as well as the complexity of measuring and surveying these behaviors. Chapter two has three sections. The first section provides information regarding definitions and frameworks of physical activity and sedentary behaviors. It also describes the multidimensional nature of physical activity and sedentary behaviors. The second section provides an overview of measurement methods used in large-scale physical activity and sedentary behaviors studies. The last section discusses worldwide and French surveillance of physical activity and sedentary behaviors.

Chapter three presents the research manuscripts included in this thesis. The first study analyzes and discusses the present situation of French national surveillance studies, including measurement of physical activity and sedentary behaviors. The second study presents the results from the first French report card on physical activity for children and adolescents. The third study discusses the validity and reliability properties of the French version of the Global Physical Activity Questionnaire. The fourth study examines the content of questionnaires measuring sedentary behaviors.

Chapter four presents a general discussion of the four studies completed for the thesis. In this context, the studies are summarized and discussed in a broader perspective. In addition, the strengths and limitations of the research included in this thesis are discussed with recommendations made for future research and practice.

Chapter 2

Literature Review

1 Physical activity and sedentary behaviors: concepts and definitions

1.1 Definitions of physical activity

Prior to 1985, a consensual definition of physical activity did not exist (Laporte et al., 1984; Stephens, 1987). In 1985, Caspersen and colleagues defined physical activity as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen et al., 1985). This definition has received wide acceptance among the scientific community, as evidenced by the number of times it has been cited (more than 6,000 citations). In 2012, Pettee-Gabriel et al. introduced a framework for physical activity and proposed to define physical activity as "the behavior that involves human movement, resulting in physiological attributes including increased energy expenditure and improved physical fitness" (Pettee-Gabriel et al., 2012). According to Pettee-Gabriel, physical activity includes all kinds of activity that could occur in different contexts including occupational, transport, domestic and leisure time, which consists of exercise, sport and unstructured recreation (Pettee-Gabriel et al., 2012; Khan et al., 2012). These two definitions appear to be used most frequently by researchers who study physical activity.

1.2 Terms used in the measurement of physical activity

Physical activity characteristics in terms of mode, frequency, intensity, and duration are usually used to quantify physical activity. These terms are defined in Table 1 and are discussed in the following section 1.2.1, to 1.2.4.

Table *1*. Physical activity quantitative components (definitions from Strath et al., 2013).

Mode	Specific activity performed (e.g. walking, gardening, cycling). Mode can also be defined in the context of physiological and biomechanical demands/types (e.g. aerobic versus anaerobic activity, resistance or strength training).
Frequency	Number of sessions per day or per week. In the context of health-promoting physical activity, frequency is often qualified as number of sessions (bouts) ≥10 min in duration/length.
Duration	Time (minutes or hours) of the activity bout during a specified time frame (e.g. day, week, year, past month).
Intensity	Rate of energy expenditure. Intensity is an indicator of the metabolic demand of an activity. It can be objectively quantified with physiological measures (e.g. oxygen consumption, heart rate), subjectively assessed by perceptual characteristics (e.g. rating of perceived exertion, walk-and-talk test), or quantified by bodily movement (e.g. stepping rate, 3-dimensional body accelerations).

1.2.1 Intensity

Intensity is an important determinant of the physiological responses to physical activity. Time spent in moderate-to-vigorous physical activity may be one of the most common measure of physical activity. Either moderate- or vigorous- intensity physical activity, or a combination of both, can be undertaken to meet the WHO physical activity guidelines (WHO, 2010). Intensity can be expressed in absolute or relative values (see Table 3). Physical activity intensities are categorized into five levels that include cut-points for relative and absolute intensity levels. Absolute intensity refers to the amount of work required to perform a specific activity regardless of an individual's physical attributes. Absolute intensity is often expressed in multiples of resting energy expenditure (METs), with 1 MET=3.5 ml/kg/min. Physical activity intensity varies along a continuum from sedentary (≤1.5 METs) to high intensity activity (≥ 8.8 METs). As an example, absolute intensity can be as low as 0.95 METs for sleeping and as high as 23.0 METs for running at 22.5 kilometers per hour (Ainsworth et al., 2011). For aerobic activities, intensity may be expressed in physiological values as heart rate (pulses/minutes) and oxygen consumption (VO_2 in l/min), or as a rate (running speed per hour). As an example, running at 22.5 kilometers per hour corresponds to an intensity of 23.0 METs and requires an oxygen consumption of 80 ml/kg/min (23.0 METs * 3.5 ml/min/kg = 80) to be performed. For strength

exercises, intensity can be expressed as the amount of weight lifted (for example a maximal weight of 100 kilograms lifted during squat).

Relative intensity refers to the amount of work required to perform a specific activity adjusted for an individual physiological capacity. Therefore, it can be expressed using the same indicators as for absolute intensity, but adjusted for the percent of maximal capacity of the individual. In this way relative intensity may be expressed as percentages of maximal heart rate, maximal oxygen consumption, maximum rate of energy expenditure, maximum aerobic speed or maximum weight lifted. In addition, relative intensity can be expressed as perceived exertion. Various perceived exertion scales have been developed, but the most popular is the Borg RPE scale (Borg, 1998). The Borg RPE scale is a scale for ratings of perceived exertion (RPE) based on the physical sensations a person experiences during physical activity, including breathlessness, increased heart rate and fatigue. The Borg RPE scale ranges from 6 to 20, where 6 means "No exertion at all" and 20 means "Maximal exertion". Perceived exertion as measured using Borg RPE scale has been shown to be associated with physiological measures such as percent maximal oxygen uptake and percent maximal heart rate (Chen et al., 2002). While doing physical activity, RPE can be used to determine perceived physical activity intensity by choosing the number that best describes the level of exertion during the physical activity. For example, 13 is defined as a level of exertion somewhat hard, and corresponds to a moderate-intensity physical activity.

Table 2. Classification of aerobic exercise intensity (adapted from ACSM, 2011 and Norton et al., 2010).

Intensity category	Relative intensity	Absolute intensity
Sedentary	< 40% HRmax <20% VO_{2max} RPE < 8	≤1.5 METs
Light	40 – 63% HRmax 20 – 45% VO_{2max} RPE 9 - 11	1.6 – 2.9 METs
Moderate	64 – 76% HRmax 46 – 63% VO_{2max} RPE 12-13	3.0 – 5.9 METs
Vigorous	77 – 95% HRmax 64 – 90% VO_{2max} RPE 14 - 17	6.0 – 8.7 METs
High	≥ 96% HRmax ≥ 91% VO_{2ma} RPE ≥18	≥ 8.8 METs

HRmax: maximal heart rate ; VO_{2max}: maximal oxygen consumption; METs: multiples of resting energy expenditure; RPE: rating of perceived exertion.

1.2.2 Duration

An aspect of duration is to describe the length of time an individual engages in physical activity over a specified period. For example, WHO recommends children and adolescents aged 5-17 years engage in 60 minutes of moderate-to-vigorous physical activity every day of the week. Adults aged 18 and older should perform 150 minutes of moderate-intensity physical activity throughout the week, or 75 minutes of vigorous-intensity physical activity, or an equivalent combination of moderate- and vigorous intensity physical activity (WHO, 2010). A second aspect of duration is to describe the time spent in continuous physical activity at a certain intensity, or engaged in a given activity. For example, an individual could engage in a continuous 30-minute brisk walk, or accumulate the same duration of exercise in bouts (e.g. 2 brisk walks of 15 minutes). WHO recommends to accumulate physical activity in bouts lasting at least 10 minutes (WHO, 2010).

1.2.3 Frequency

Frequency refers to how often an individual engages in physical activity in terms of the number of times a week, month, or year. For example, WHO's physical activity guidelines advise for adults aged 18 years and older to perform muscle-strengthening activities 2 or more days a week (WHO, 2010). The 1995 CDC-ACSM (Centers for Disease Control and Prevention – American College of Sports Medicine) physical activity guidelines recommended adults engage in moderate-intensity physical activity 5 days per week (Pate et al., 1995). The 1978 ACSM guidelines recommended adults engage in vigorous exercise 3-5 days per week (ACSM, 1978). Another important aspect of frequency is the number of times an individual engages in bouts of physical activity. Individuals can perform short bouts of activity throughout the day or engage in continuous physical activity. For example, in Figure 1, the participant engaged in one continuous bout of moderate-to-vigorous intensity physical activity, while in Figure 2 the participant engaged in many short bouts of moderate-intensity physical activity.

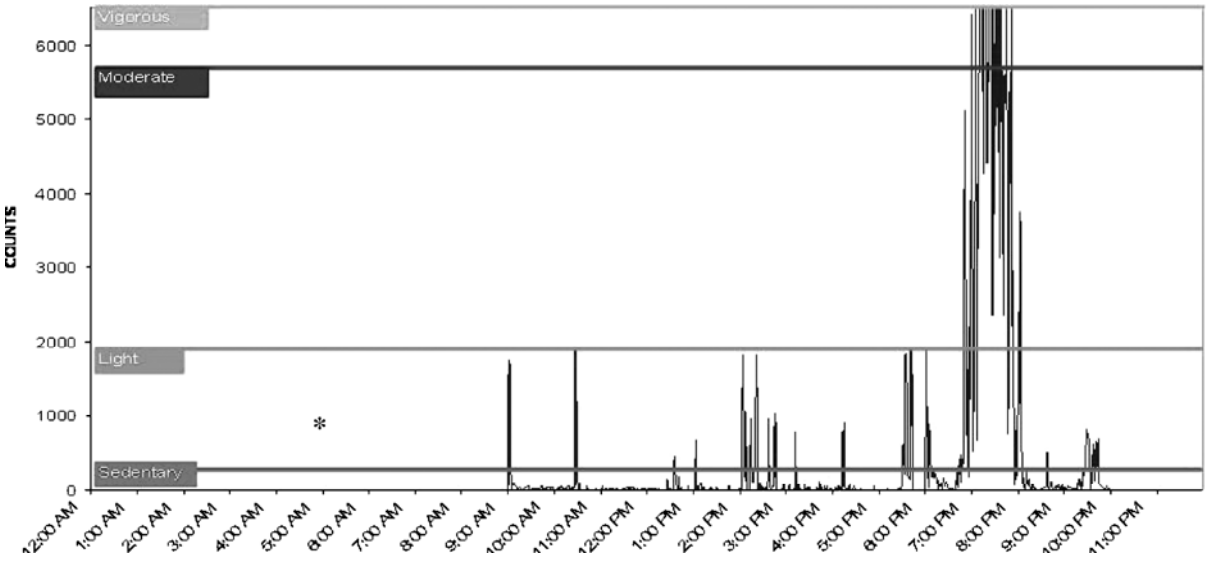

Figure 1. ActiGraph representation of physical activity. * Monitor was not worn. (from Pate et al., 2008).

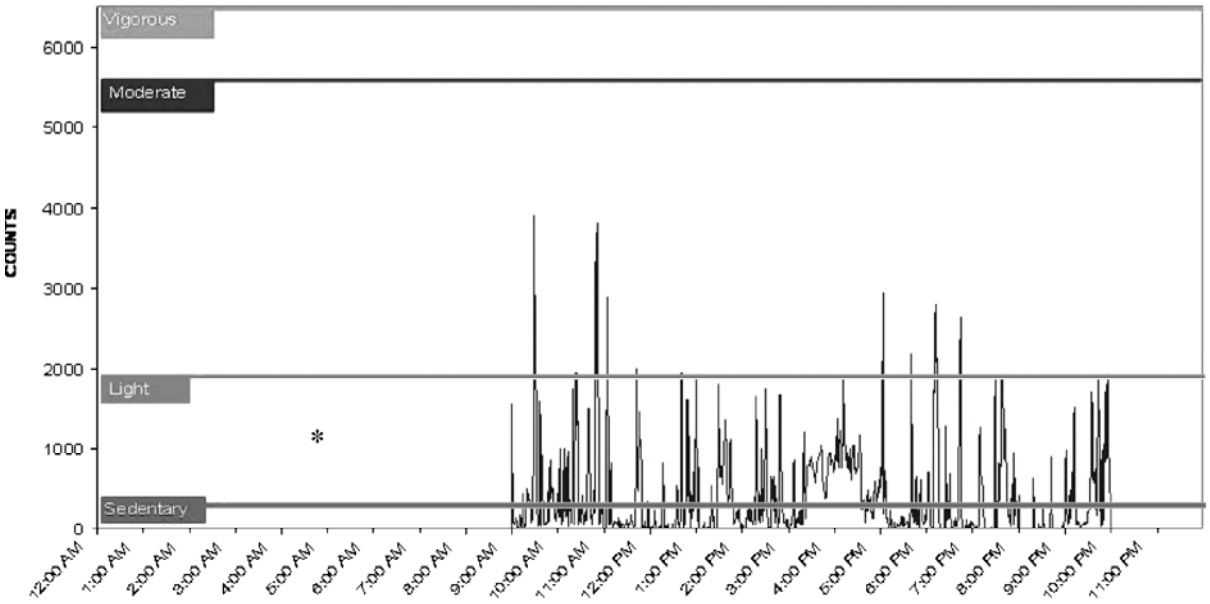

Figure 2. ActiGraph representation of physical activity. * Monitor was not worn. (from Pate et al., 2008).

1.2.4 Mode

The mode refers to the specific activity performed (e.g. walking, running) or to the type of physical activity (e.g. aerobic activity, muscle-strengthening activity). Recommendations for physical activity include different types of physical activity, such as aerobic physical activity, muscle-strengthening activities, flexibility and balance exercises (Haskell et al., 2007; WHO, 2010; Anses, 2016). For example, Anses recommends adults engage in 30 minutes of physical activity of moderate-to-vigorous intensity at least 5 days a week to develop cardiorespiratory capacity. Specific activities that increase cardiorespiratory capacity include running, swimming and cycling. In addition, Anses recommends adults perform muscle strengthening activities once or twice a week and flexibility exercises 2 or 3 times a week (Anses, 2016). Strengthening activities refer to weight lifting activities, such as pressing a weight upwards from a supine position and carrying shopping. Stretching activities include yoga and tai chi type activities.

1.3 Definition of sedentary behaviors

As the term sedentary behaviors has gained in popularity over the last two decades, different definitions have emerged. Historically, the term sedentary was used to describe a person with low physical activity levels (Paffenbarger et al., 1986, Lowry et al., 2002) and it was used interchangeably with physical inactivity (Dietz, 1996). In 2007, the term sedentary behaviors was used to describe a distinct and specific behavior, primarily sitting, including activities such as watching TV or using a computer (Hamilton et al., 2007). In 2008, Pate et al. more clearly defined sedentary behaviors based on the activity energy expenditure, and made the

differentiation between sedentary behaviors (1.0-1.5 METs), and light physical activities (1.6-2.9 METs) (Pate et al., 2008). According to Pate et al. "sedentary behavior refers to activities that do not increase energy expenditure substantially above the resting level and includes activities such as sleeping, sitting, lying down, and watching television, and other forms of screen-based entertainment" (Pate et al., 2008, p. 174). In 2010, Owen et al. made explicit that sedentary behaviors involve a specific posture (sitting) combined with a low level of energy expenditure (1.0-1.5 METs) (Owen et al., 2010). Furthermore, Owen et al. highlighted the fact that sedentary behaviors could occur in different contexts, including during commuting, in the workplace and the domestic environments, and during leisure time (Owen et al., 2010). In 2012, the Sedentary Behavior Research Network (SBRN) defined sedentary behaviors as "as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting, or reclining posture" (SBRN, 2012), thus excluding sleeping as a sedentary behavior (Pate et al., 2008). The SBRN definition has been largely used since, and seems to have received broad acceptance among the academic community. In 2017, the SBRN complemented their definition by including the posture of lying down. The SBRN now defines sedentary behaviors as "any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting, reclining, or lying posture" (Tremblay et al., 2017).

1.4 Terms used in the measurement of sedentary behaviors

Sedentary behaviors can be described using the SITT formula (Tremblay et al., 2010), corresponding to: Sedentary behaviors frequency (operationalized as number of bouts of a certain duration), Interruptions or breaks in sedentary time (such as standing up or walking), Time (operationalized as the duration of sedentary behaviors), and Type (mode of sedentary behaviors, such as watching TV or driving a car).

1.4.1 Sedentary time

Sedentary time, expressed in seconds, minutes or hours, can refer to the total time spent in sedentary behaviors, or to the time spent in each sedentary activity. For example, in France it is recommended for adults to reduce the total time daily spent in a sitting position, as much as possible, and to limit each sedentary activity, to not exceed 90 to 120 minutes continuously (Anses, 2016). Total time spent in sedentary behaviors can be measured directly or calculated by summing time spent in specific sedentary activities.

1.4.2 Interruptions in sedentary time

Interruption in sedentary time is defined as a non-sedentary period in between two sedentary bouts and is often referred to as break in sedentary time (Altenburg and Chinapaw, 2015). Figure 3 illustrates how two individuals can accumulate the same volume of total sedentary time with two different patterns of breaks in sedentary time. Sedentary time can be accumulated in extended continuous bouts, or with frequent interruptions and in short bouts (Dunstan et al., 2010). One difficulty in measuring breaks in sedentary time is the lack of an operational definition. In their study, Healy et al. (2008) defined a break as a 1-minute interruption in sedentary time with accelerometer counts higher than 100 counts per minute (Healy et al., 2008). This definition seems to have received acceptance among the academic community as it has been widely used (Cooper et al., 2012; Saunders et al., 2013; Colley et al., 2013). However, others have made different choices. Carson et al. have operationalized breaks as interruptions of more than 5 seconds and Verloigne et al. have defined breaks as interruptions of 15 seconds (Carson et al., 2014; Verloigne et al., 2017).

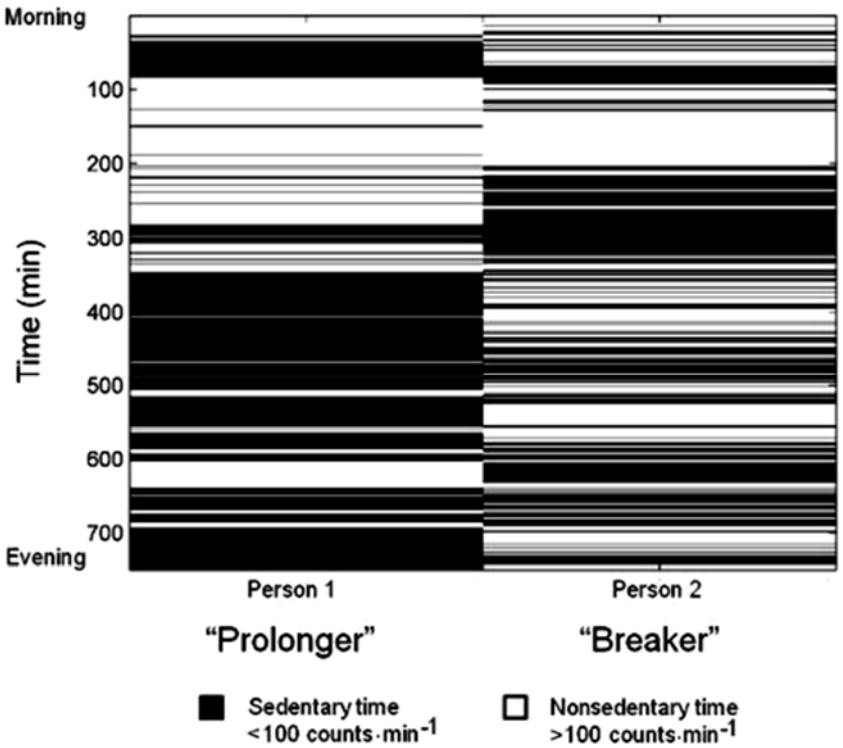

Figure 3. Illustration of different patterns of breaks in sedentary time, based on accelerometer data from 2 adults with identical total time spent being sedentary (from Dunstan et al., 2010).

1.4.3 Frequency of sedentary bouts

Frequency of sedentary bouts refers to the number of sedentary bouts of a certain duration. To date, there is no consensus on the minimum period a sedentary bout should last. In a discussion of sedentary time, Altenburg and Chinapaw observed that many different operational definitions of sedentary bouts were used in research (Altenburg and Chinapaw, 2015) including at least 30 min with ≥80% of time below the sedentary cut-point of 100 counts/minute (Carson et Janssen, 2011) and at least 20 min with ≥80% of time below the sedentary cut-point of 100 counts/minute (Colley et al., 2013). Others have defined a sedentary bout as a continuous period of sedentary time below the sedentary cut-point of 100 counts/minutes (Saunders et al., 2013; Carson et al., 2014) or 25 counts per 15 seconds (Verloigne et al., 2017). Because it is unknown how long a sedentary bout is related to negative health effects, Altenburg and Chinapaw recommended a sedentary bout be defined as a minimum period of uninterrupted sedentary time not allowing any "tolerance time" (defined as non-sedentary time) (Altenburg and Chinapaw, 2015).

1.4.4 Mode of sedentary behaviors

Type of sedentary behaviors refers to the mode of sedentary behaviors, such as watching TV, using a computer or driving a car. Often, time spent in TV viewing is used as a proxy measure of sedentary behaviors duration (Dunstan et al., 2005). Time-use surveys have reported that, aside from sleeping, watching TV was the behavior that occupies the most time in the domestic setting (Office for National Statistics, 2005; Australian Bureau of Statistics, 2006; United States Departement Labor, 2007). However, it has been suggested that TV viewing may not always be a robust marker of a sedentary lifestyle (Sugiyama et al., 2008, Owen et al., 2010). Therefore, all types of sedentary behaviors need to be measured.

1.5 Conceptual models of physical activity and sedentary behaviors

This section will present three conceptual models used in the field of physical and sedentary behaviors epidemiology that can be used to guide research. The work of LaMonte and Ainsworth (2001), Pettee-Gabriel and Morrow. (2012), and Chastin et al. (2013) will be presented following a chronological order. In addition, an ongoing project (ALPHABET project) will be presented.

1.5.1 Measurement model for physical activity and energy expenditure (LaMonte and Ainsworth, 2001)

In 2001, LaMonte and Ainsworth proposed a framework for measuring physical activity and energy expenditure, collectively referred to as human movement (Figure 4) (LaMonte and Ainsworth, 2001). This framework made the distinction between physical activity, as a behavior, and energy expenditure, as the energy cost of the behavior. The framework provides examples of measurement methods using direct and indirect measures of physical activity and energy expenditure. For physical activity, direct measures include motion sensors, direct observation and global positioning system. Indirect measures include physical activity records, 24-hour recalls and questionnaires. For energy expenditure, direct measures include calorimetry and doubly labeled water. Indirect measures include oxygen uptake, heart rate, body temperature and ventilation. For each measurement method, it is possible to extrapolate each metric to energy expenditure for use in analysis of energy expenditure and health outcomes.

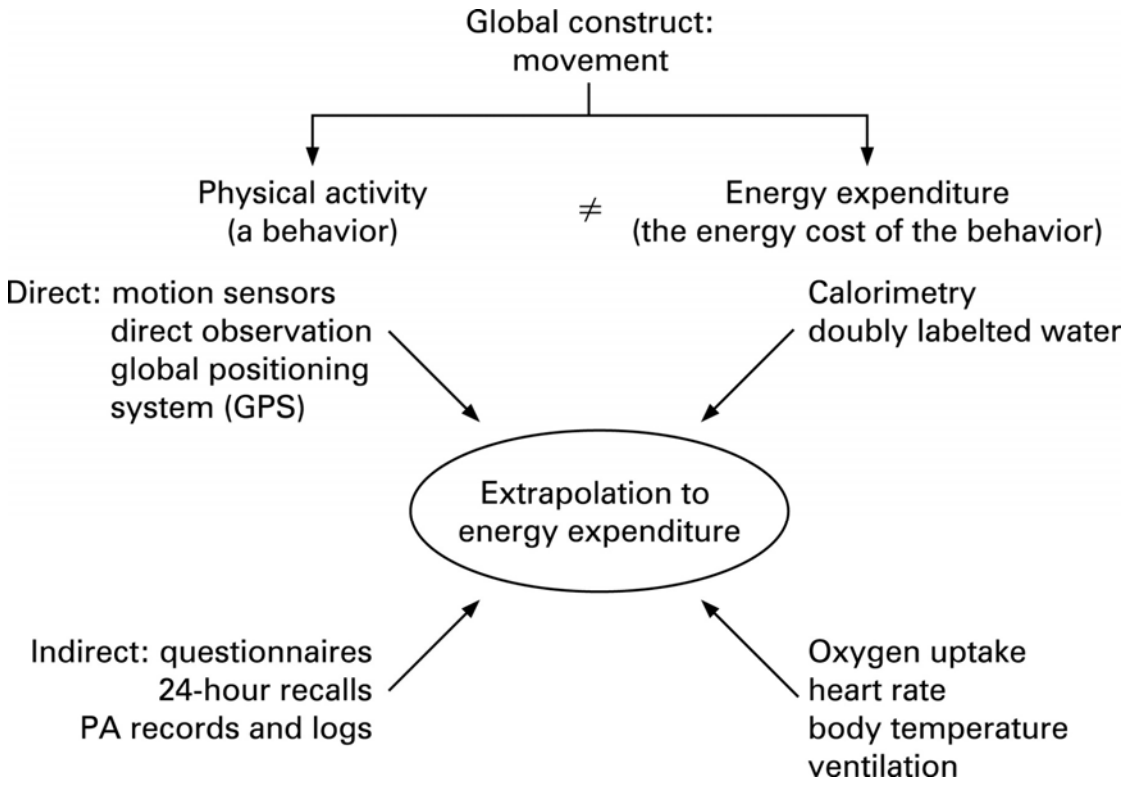

Figure 4. Conceptual model for defining and assessing physical activity and energy expenditure (from LaMonte and Ainsworth, 2001).

1.5.2 Model for the physical activity domains (Pettee-Gabriel and Morrow, 2010)

In 2010, Pettee-Gabriel and Morrow, proposed a framework for human movement, representing physical activity and sedentary behaviors as two components of human movement (see Figure 5) (Pettee-Gabriel and Morrow, 2010). The framework makes the distinction between the behaviors (physical activity and sedentary behaviors) and the physiological results or consequences of movement (energy expenditure and physical fitness). The framework identifies four domains where physical activity can take place (leisure, occupation, household, and transport), and classifies sedentary behaviors as non-discretionary or discretionary. Examples of discretionary and non-discretionary sedentary behaviors are presented. Discretionary sedentary behaviors include sitting, media use, non-occupational, school and computer use. Non-discretionary sedentary behaviors include sleeping, occupation, school, sitting while driving and sitting while riding.

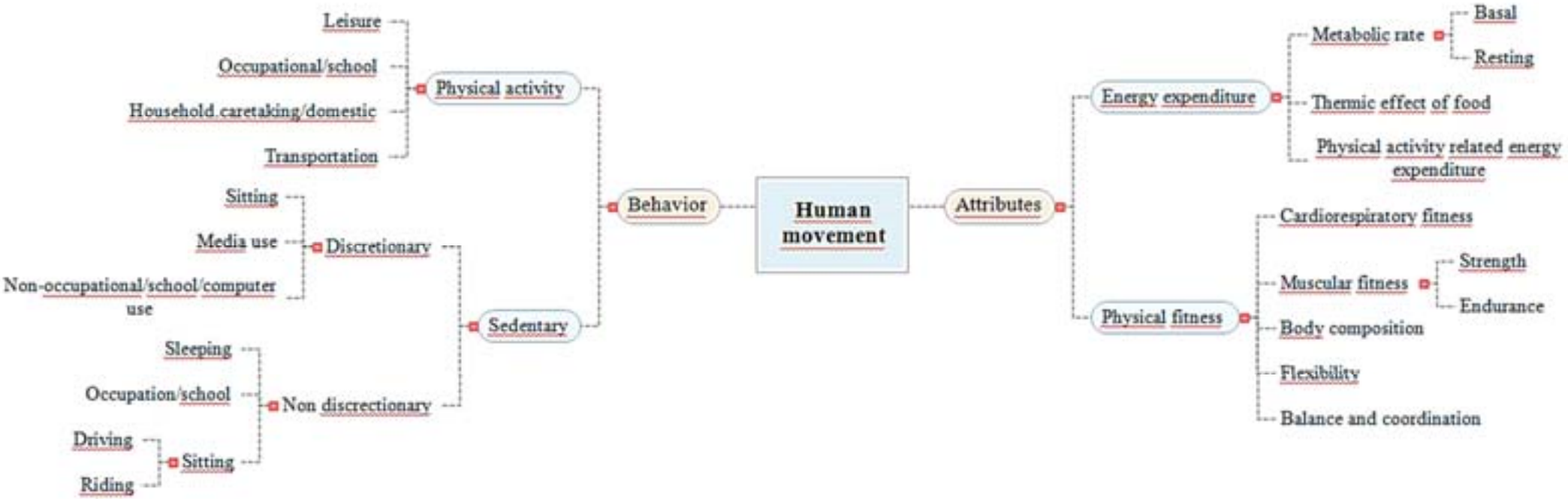

Figure 5. Conceptual framework for physical activity and sedentary behaviors (from Pettee-Gabriel and Morrow., 2010).

1.5.3 Taxonomy of sedentary behaviors

In 2013, Chastin and colleagues developed a taxonomy (naming and cataloging system) of sedentary behaviors (Chastin et al., 2013). The taxonomy of sedentary behaviors is the result of the first round of an open science project (collaborative work opened to everyone) called "SIT" (Sedentary behaviors International Taxonomy project). Led by Chastin et al. this formal consensus process offered a comprehensive frame of reference for sedentary behaviors developed through a Delphi method involving international experts. The Delphi method is a collaborative forecasting technique that relies on a panel of experts. Delphi method combines independent analysis with maximum use of feedback, for building consensus among experts who interact anonymously during 2 or more rounds. At each round, experts answer questions and provide input on the subject of interest, until some degree of mutual agreement is reached among the experts. The taxonomy includes 9 complementary facets (categories) (see Figure 6) characterizing the purpose (why), the environment (where), the social context (with whom), the type or modality (what), associated behaviours (what else), when the behaviour take place (when), the mental and functional states of sedentary individual (state), the posture, and the measurement and quantification issues (Chastin et al., 2013). The taxonomy provides a standardized classification of sedentary behaviors, and should help in harmonizing the collection, organization and retrieval of relevant data and information on sedentary behaviors.

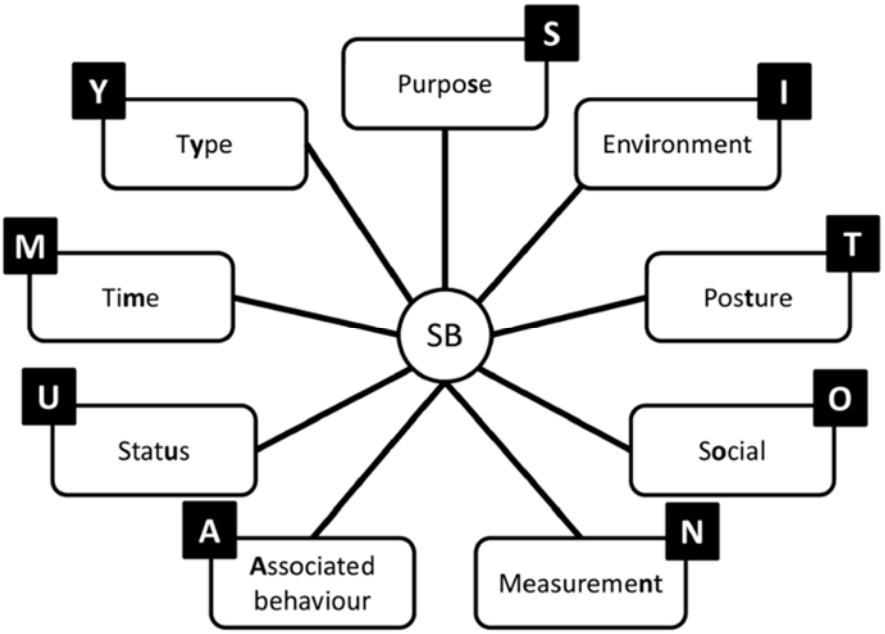

Figure 6. Taxonomy level one facets and coding labels (from Chastin et al., 2013).

1.5.4 ALPHABET project

ALPHABET is described as an open science project aiming to develop a common taxonomy for classification, harmonization and storage of objective tracking sensor data of human physical behavior in daily life, through an international consensus process using the Delphi Method. It aims to reach international consensus on an overarching definition for the study of how activities, physical actions and movements as part of human daily behavior impacts health and well-being; and on an integrated classification system, data model and nomenclature. A brief description is available online (AlPHABET: Development of A Physical Behaviour Taxonomy with an international open consensus. Retrieved October 14, 2017 from https://osf.io/2wuv9/).

1.6 Summary

Physical activity and sedentary behaviors are human movement behaviors, and are commonly defined based on their energy expenditure attribute. To avoid confusion, definitions and conceptual models have been developed. Sedentary behavior is defined as "as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting, reclining or lying posture" (Tremblay et al., 2017). Physical activity has been defined as "the behavior that involves human movement, resulting in physiological attributes including increased energy expenditure and improved physical fitness" (Pettee-Gabriel and Morrow 2012). In addition, conceptual models emphasize the importance to make the distinction between the behaviors, that could occur in different settings, and the physiological consequences of the behaviors (LaMonte and Ainsworth, 2001; Pettee-Gabriel and Morrow, 2010). Depending on the construct of interest, different measuring tools must be used (LaMonte and Ainsworth, 2001).

2 Measurement of physical activity and sedentary behaviors with questionnaires in surveillance systems

Physical activity and sedentary behaviors are complex behaviors; and their assessment is a challenge implying strategic choices. When selecting a measurement tool, one should determine which characteristics of physical activity or sedentary behaviors are of interest as it is unlikely that a tool measure all facets of a behavior, then one must consider which assessment method is best able to measure the characteristics of interest while minimizing bias. Ideally, the measurement is reproducible, valid, and responsive. Methods to measure physical activity and/or sedentary behaviors include subjective instruments (questionnaires, logs, ecological momentary assessment), and objective methods (motion and posture sensors, physiological sensors, direct observation, and context awareness using cameras and GPS). In the setting of surveillance studies, questionnaires commonly are used.

2.1 Classification of self-report tools of sedentary behaviors

Dall et al. developed a framework to help in the development, comparison and evaluation of self-report tools. The framework, named TASST for Taxonomy of Self-reported Sedentary Behavior Tool, consists in four domains: type of assessment, recall period, temporal unit and assessment period (Dall et al., 2017). The framework is represented in Figure 7. The type of assessment includes whether sedentary is measured using a single item or a composite item. For single item instrument sedentary time can be measured directly or using a proxy (such as TV viewing). For composite measures, the instrument can ask about the pattern of sedentary behaviors (i.e. how the behavior is accumulated throughout a given period), or the time spent in sedentary behavior can be estimated by summing the time spent in a range of different activities. When summed, the calculation can be made from questions asking about specific behaviors (for example, reading a book) or time spent in specific domains (for example, at home or at work). The recall period is the time frame over which the respondent is asked to consider his sedentary behaviors, and includes previous day, previous week, longer period, and unanchored (i.e. a general period of time such as a typical week). The temporal unit refers to the time frame, within the recall period, that the respondent is asked to report their sedentary behaviors, including single day, week and longer. The assessment period provides information regarding whether a respondent is asked questions about specific days (for example only weekend day) or specific time of a day (for example only morning). Authors mapped self-report instruments of sedentary behaviors to the TASST framework, and reviewed the psychometric properties (accuracy and sensitivity to change) of included instruments. By doing so, Dall and

colleagues observed that tools assessing total sedentary time as a sum of behaviors seemed to provide better accuracy than single-item direct measurement tools (Dall et al., 2017), and tools with a previous day recall period tended to provide better accuracy than those with longer periods. Yet, the overall accuracy remained poor for all instruments reviewed, with both over- and under- estimation reported. As for sensitivity to change, almost no information were available.

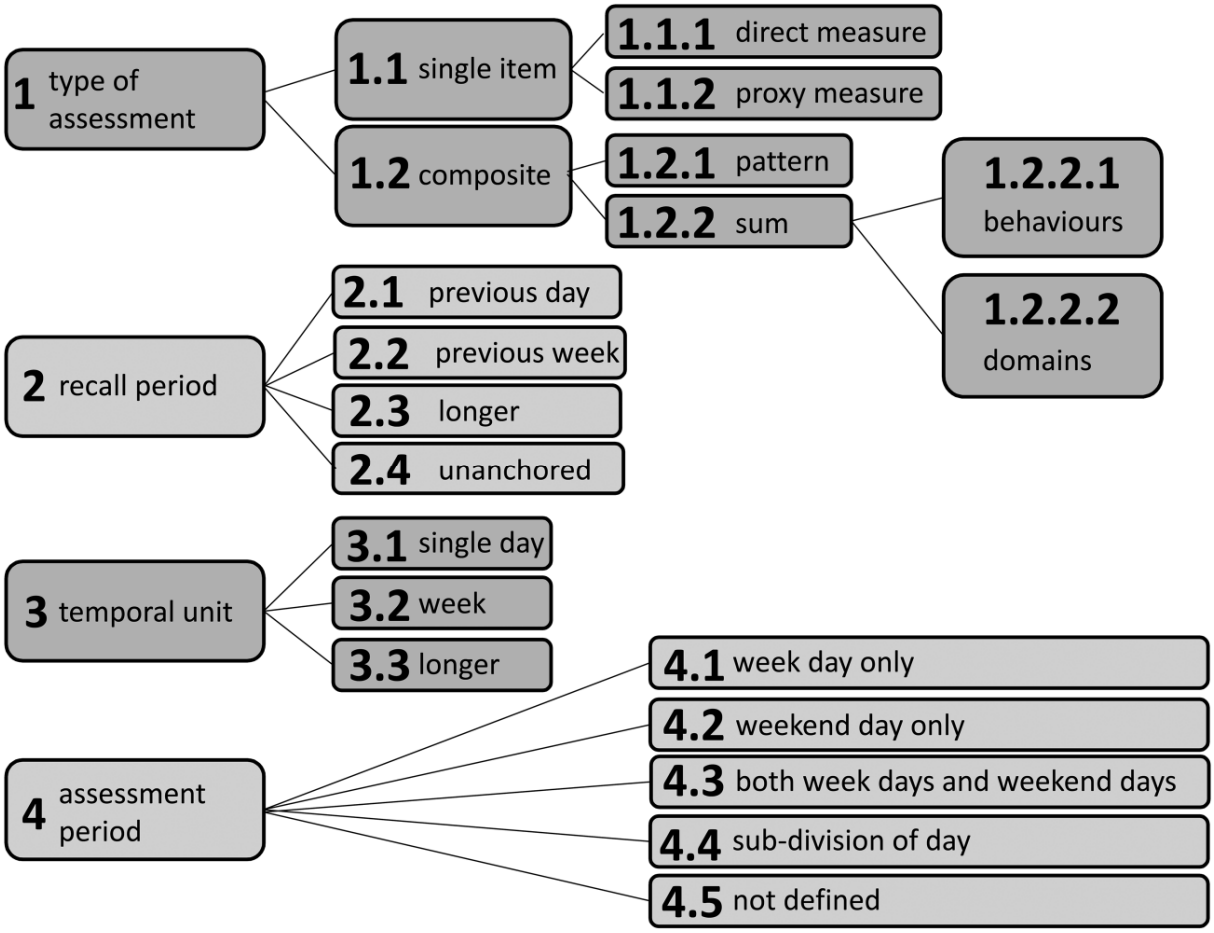

Figure 7. Taxonomy of Self-reported Sedentary Behavior Tools (from Dall et al., 2017)

2.2 Type of questionnaires

Questionnaires are composed of a selected number of items aiming to standardize the collection of information over a defined period of time. Three types of questionnaires can be differentiated by their purposes and time of completion. Global questionnaires are short questionnaires aiming to provide general information of one individual's behaviors and are best suited for use in population health surveys where questions are limited by space constraints. Short-term recall questionnaires require the respondents to recall somewhat detailed information of activities performed in the past week or month. Quantitative history recall questionnaires are developed

to recall detailed information and enable to characterize the patterns of the behaviors in the past year, or during one's lifetime.

Global questionnaires are brief, easy, and quick to answer and are comprised of a very few items. They require minimal information to estimate one's physical activity level, sitting time, or to classify respondents. An example is a single item question used in the Eurobarometer survey asking about the time spent sitting on a usual day (Eurobarometer, 2014). In the United States, the Behavioral Risk Factor Surveillance System Survey (BRFSS) assesses physical activity using a single question ("During the past month, other than your regular job, did you participate in any physical activities or exercise, such as running, calisthenics, golf, gardening, or walking for exercise?") to classify adults as engaging or not engaging in leisure-time physical activity (Kruger et al., 2005). In the National Health and Nutrition Examination Survey (NHANES), both global sitting and TV viewing time were measured with self-reported questionnaire (www.cdc.gov/nchs/nhanes/index.htm). Sedentary behaviors can also be measured in specific setting, such as for transportation, work, or at home. For example, in the Stand Up Australia study, workplace sedentary time was estimated from the following question: *"Please estimate the total time during the last week that you spent sitting down as part of your job while at work or working from home?"* (Clark et al., 2011). In addition, breaks in sitting time were measured by asking '*how many breaks from sitting (such as standing up, or stretching or taking a short walk) during one hour of sitting would you typically take at work?*" (Clark et al., 2011). Global questionnaires have been used frequently in surveillance studies because of their simplicity and shortness, however they do not measure many characteristics of the behaviors of interest. Short-term recall questionnaires can be composed of few items measuring a very limited number of physical activity and sedentary behaviors characteristics, up to around a hundred items asking about characteristics of selected activities or behaviors. Short-term recall questionnaires can differ in their mode of administration (self- or interviewer-administered), in their recall frame (1 day, 1 week, 1 month), in the quantitative information measured (intensity, duration and frequency of physical activity and sedentary behaviors, and break in sedentary time), and in the facets of the behaviors measured. For instance, short-term recall questionnaires can ask for the setting and purpose (e.g. sitting time or walking at or, for work), and the type of behavior (e.g. watching TV, using computer, playing soccer, doing calisthenics). The questionnaires are scored by multiplying frequency, duration, and intensity to estimate compliance with physical activity guidelines. For instance, the Global Physical Activity Questionnaire (GPAQ) and the International Physical Activity Questionnaires measure

moderate-to-vigorous physical activity, expressed as minutes per week, to categorize one individual's level of physical activity, and to determine the proportion of participants meeting the WHO guidelines of at least 150 minutes per week of at least moderate-intensity physical activity (IPAQ Research Committee, 2005). The Last 7-day Sedentary Time Questionnaire comprises 68 items asking about sedentary time for work, transportation, domestic, education, eating and care giving behaviors, during both a week day and a week-end day (Wijndaele et al., 2014). Quantitative history recall questionnaires are used to retrospectively investigate the physical activity during the past year or lifetime. Questionnaires may be specific to a physiological system or about general physical activities and/or sedentary behaviors. For example, the Minnesota Leisure Time Physical Activity Questionnaire measure the frequency and amount of time spent in 63 activities over the previous year on a month-by-month basis (Taylor et al., 1978). The Past Year Total Physical Activity Questionnaire is a 1-year recall physical activity questionnaire assessing the frequency, duration, and intensity of occupational, household, and recreational activities, that has been used to investigate physical activity in the past year (Friedenreich et al., 2006). The Bone Loading History Questionnaire is a retrospective lifetime questionnaire, asking about type and frequency of physical activities performed across the lifespan, and used to investigate association of physical activity with fracture risks (Dolan et al., 2006).

Questionnaires provide useful information to characterize the patterns of the behaviors and are often preferred in large-sample epidemiological studies due to their ease-of-use, relatively low costs, and low participant burden. However, no single questionnaire measures all characteristics and one should identify which characteristics are of interest prior to select the questionnaire that best fits the purpose of his study.

2.3 Measurement properties of questionnaires

2.3.1 Validity

The validity refers to the extent to which the instrument accurately measures the construct it intends to measure (Terwee et al., 2010). Different aspect of validity can be distinguished, including face validity, content validity, floor or ceiling effects, and construct validity. Face validity refers to whether the information sought are an adequate reflection of the construct of interest. Questions to answer are: does the questionnaire seem to measure what it intends to measure? Are the items comprehensible? Face validity is commonly addressed by performing cognitive interviews (Neilson et al., 2013). For example, in the development of the European

Health Interview Survey Physical Activity Questionnaire (EHIS PAQ), Finger and colleagues performed two rounds of cognitive testing to assess the respondents comprehension of the questions, and their appreciation of the questionnaire in terms of simplicity and adequacy of answer categories (Finger al., 2015). Content validity refers to the degree to which the content of the instrument is relevant to the measurement of the construct it is supposed to measure (e.g. are all the relevant questions to measure the construct of interest being asked?). It can be investigated by conducting focus group with subjects and by asking a group of experts to review the instrument (Armstrong & Bull, 2006). For example, if the questionnaire intends to measure physical activity and sedentary behaviors in different settings, items would need to address activities for work, transportation, household and leisure time. The questionnaire's content validity is deemed acceptable when all experts agree that the questionnaire collects all relevant information to measure the construct of interest. Floor or ceiling effects are considered present when more than 15% of participants have the lowest or highest possible score, respectively. Such phenomenon makes it impossible to distinguish between participants, therefore it impairs reliability and responsiveness of the instrument. Finally, construct validity relates to how well the instrument measures the construct of interest. Construct validity of an instrument is investigated by looking at how closely outputs of the instrument are related to outputs from an accepted instrument of reference, also called a gold standard (criterion validity). A gold standard would be an instrument of reference measuring the same construct, and with perfect reliability and validity. However, there is no gold standard for physical activity and sedentary behaviors questionnaire as no instrument measures the exact same construct as questionnaires. The instrument of reference will depend of the output of interest. When the output of interest is energy expenditure, doubly labelled water (DLW) often is considered as the reference (Schoeller, 1999). Accelerometers are a good choice if the purpose is to quantify movement behavior (Troiano et al., 2014), while pedometers would be a good option if the purpose of the instrument is to estimate the number of steps per day walked (Schneider et al., 2003). If the construct of interest is the type of physical activity or sedentary behaviors an individual engages in (i.e.: watching TV vs reading a book) then direct observation would be a good reference. (Keadle et al., 2014). There is no perfect instrument of reference for physical activity and sedentary behaviors questionnaires as no instrument measures the exact same construct.

Construct validity is measured most often by correlating responses from the questionnaire with outputs from wearable activity monitors (accelerometer or inclinometer), or with another previously validated questionnaire that has a similar content. For example, estimates of physical

activity (in min/day and MET-min/day) from the European Health Interview Survey Physical Activity Questionnaire (EHIS PAQ) have been correlated with estimates of physical activity in min/day as measured with the IPAQ, and estimates of physical in counts/minutes/day and in minutes/day as measured with GT3X+ accelerometer (Baumeister et al., 2016). Spearman correlations often are used to study validity, and a Spearman correlation <0.50 is considered as poor, between 0.50 and 0.75 as moderate, and >0.75 as good (Portney and Watkins, 2000). When self-reported physical activity and sedentary time are compared with accelerometer data, correlations between the two measures with $r \geq 0.50$ are considered satisfying (Terwee et al., 2010; Hidding et al., 2017). Table 3 presents expected correlation between questionnaire outputs and instruments of reference.

Overall, low validity in measuring time spent in physical activity and sedentary behaviors with questionnaire is frequently reported, with validity coefficients mostly lower than 0.50 (van Poppel et al., 2010; Healy et al., 2011; Vuillemin et al., 2012; Helmerhorst et al, 2012. Depending of the study, questionnaire may over- or underestimate sedentary and physical activity time (Prince et al., 2008); and newly developed questionnaires do not seem to perform any better than existing questionnaires (Shephard, 2003; Helmerhorst et al., 2012). Table 3 presents an overview of the measurement qualities of a sample of questionnaire used in physical activity and sedentary behaviors surveillance systems.

Table 3. Quality assessment of questionnaire (from Terwee et al., 2010)

Construct of interest	**Preferred instrument of reference**	**Expected correlation**
Total energy expenditure	Doubly labelled water	$r \geq 0.70$
Total physical activity	Accelerometer total counts	$r \geq 0.50$
Vigorous physical activity	Accelerometer vigorous activity time	$r \geq 0.50$
Moderate physical activity	Accelerometer moderate activity time	$r \geq 0.50$
Walking	Pedometer or accelerometer walking time	$r \geq 0.70$
Leisure-time physical activity	Accelerometer leisure-time activity	$r \geq 0.50$
Occupational physical activity	Direct observation	$r \geq 0.60$

2.3.2 Reliability

Reliability of an instrument refers to the degree to which the measurement is free from measurement error (Terwee et al., 2010). It concerns the degree to which repeated measurements under similar conditions provide similar results. However, physical and sedentary activities may change over time, thus it is often difficult to differentiate systematic and random errors resulting from the instrument to true changes in the behavior. Changes in behavior can be random (ex: one day one individual can engage little in sedentary activities, while spending a lot of sedentary time another day), or systematic (ex: systematic differences in physical activity level have been reported depending on the season – summer vs winter (Tucker & Gilliland, 2007). Other changes in measurement may come from the instrument itself, or the conditions under which the measurement takes place. For example, measurements based on questionnaires administered during an interview might be influenced by the interviewer. Therefore, measurement error that is not attributed to true changes in the behavior must be distinguished from reliability that is the proportion of the total variance in the measurements which is due to true differences (Terwee et al., 20010). To explore measurement error and reliability, the instrument of interest can be tested twice at the same time to measure the construct of interest over the same period, and identify true measurement errors, or twice at two different time, to ensure that the instrument obtains consistent results for repeated measurements when including possible natural variation of the behavior. Ideally, an instrument would have small measurement error, and high degree of reliability.

Reliability is commonly assessed by administering the questionnaire twice to the same participants, one day (short-term reliability) to few months (long-term reliability) apart. Correlation between the two measures with intraclass correlation and kappa coefficients ≥ 0.70 are considered appropriate.

The validity and reliability of a sample of questionnaires used for surveillance purpose are presented in table 4.

2.3.3 Responsiveness

Responsiveness is the ability of an instrument to detect changes over time in the participant's behaviors (Terwee et al., 2010). Responsiveness is of particular importance in longitudinal study and surveillance system intending to determine changes in physical activity and sedentary behaviors over time. It can be assessed by comparing the changes observed with the instrument tested with the changes measured with the instrument of reference (Tudor-Locke, 2001). Responsiveness for physical activity and sedentary behaviors questionnaires is rarely assessed,

and available information suggest questionnaires have poor sensitivity to change (van Poppel et al., 2010; Dall et al., 2017).

Table 4. Overview of the measurement qualities of a sample of questionnaire used in physical activity and sedentary behaviors surveillance systems.

Name	**Construct**	**Validity**		**Reliability**	
		Criterion measure	**Coefficient**	**Test-retest recall frame**	**Coefficient**
IPAQ-SF (Rosenberg et al., 2008; Craig et al., 2003)	Moderate-to-Vigorous Physical Activity (MVPA) and walking	Accelerometer (ActiGraph CSA)	Spearman's rho ranged from 0.02 to 0.47 (for total PA in MET-min/wk vs activity counts/min)	3 - 7 days	Spearman's rho ranged from 0.66 to 0.85 for total physical activity in MET-min/wk
	Total sitting time	Accelerometer (ActiGraph CSA) (cut off points ≤ 100 counts min−1)	Spearman's rho = 0.34	3 - 7 days	Spearman's rho = 0.81
GPAQ (Herrmann et al., 2013; Cleland et al., 2014)	MVPA at work and for leisure, and active transportation.	Accelerometer (ActiGraph GT3X)	Spearman's rho =0.48 (for MVPA in min/day)	10 days	ICC = 0.89 (0.68-0.96) (for MVPA in min/day)
	Total sitting time	Accelerometer (ActiGraph GT3X) (cut off points ≤ 100 counts min−1)	Spearman's rho =0.19	10 days	ICC=0.92 (0.78-0.97)
EHIS PAQ (Baumeister et al., 2016)	PA during work, transportaiton and leisure time	Accelerometer (ActiGraph GT3X+)	Spearman's rho ranged from 0.15 for cycling time to 0.43 for HEPA index[a] with total activity (counts/min/d)	30 days	ICC ranged from 0.43 (0.23-0.58) for HEPA index to 0.73 (0.61-0.82) for leisure time physical activity
BRFSS PAQ (Brown et al., 2004; Yore et al., 2007)	Leisure time, household and transportation PA, walking	Accelerometer (ActiGraph CSA)	Pearson correlation coefficients ranged from r = 0.16 to 0.27, and r = 0.52 to 0.63 for time spent in moderate and vigorous physical activity, respectively	1 day	ICC = 0.59 (0.46 – 0.69) for total physical activity

RPAQ (Besson et al., 2010)	PA for transportation, leisure, home activities and work	Combined heart rate and movement sensor	Spearman's rho = 0.39, p<0.01 for total physical activity energy expenditure	2 weeks	ICC = 0.76 for total physical activity energy expenditure
	Time spent watching TV, playing video games or using a computer (for leisure)	Combined heart rate and movement sensor (<2METs)	Spearman's rho = 0.27, p=0.06 for total sedentary time	2 weeks	ICC = 0.76 for total sedentary time
ALS WH (Brown et al., 2008; Marshall et al., 2010)	Leisure time MVPA and walking	Accelerometer WAM	Spearman's rho = 0.52, p<0.001 for MVPA	7 - 28 days	Spearman's rho = 0.64 for total physical activity
	Sitting time for transportation, work, leisure, watching tv and using a computer at home	Accelerometer (ActiGraph GT1M)	Spearman's rho ranged from 0.13 to 0.74 (men) and 0.20 to 0.74 (women) for sitting time in each domain	7 days	Spearman's rho ranged from 0.31 to 0.74 for women, and 0.23 to 0.68 for men, for sitting time in each domain
HBSC (Rangul et al., 2008; Liu et al., 2010)	Vigorous PA outside of school hours	ActiReg (measures body position and movement)	Spearman's rho = 0.01 for total PA	8 -12 days	ICC = 0.71 (0.57-0.81) for total PA
	TV viewing, using a computer, and school homework	Not measured	Not measured	3 weeks	ICC ranged from 0.33 (0.14-0.50) (Using PC on school day) to 0.78 (0.68-0.85) (doing homework on school days

a. index of HEPA was derived by summing the minutes per day spent walking, cycling and engaging in leisure time moderate-intensity PA, where walking minutes were weighted by 0.5. PA: Physical Activity; MVPA: Moderate to Vigorous Physical Activity.

IPAQ-SF: International Physical Activity Questionnaire – Short Form; GPAQ: Global Physical Activity Questionnaire; EHIS PAQ: European Health Interview Survey Physical Activity Questionnaire; BRFSS PAQ: Behavioral Risk Factor Surveillance System Physical Activity Questionnaire; RPAQ: Recent Physical Activity Questionnaire; ALS WH: Australian Longitudinal Study on Women's Health; HBSC: Health Behavior in School Children Survey.

2.4 Validity and reliability studies of the GPAQ

Because the GPAQ has been developed for use worldwide, the validity and reliability of the GPAQ has been investigated frequently in many languages (Bull et al., 2009; Trinh et al., 2009; Thuy et al., 2010; Hoos et al., 2012; Herrmann et al., 2013; Soo et al., 2015; Mumu et al., 2017; Wanner et al., 2017). Bull and colleagues were the first to undertake a validity study for the GPAQv1 (in its 19 items form) (Bull et al., 2009). Criterion validity was investigated in eight countries, against pedometers or accelerometers worn seven days to cover the same time frame than the recall period of the GPAQv1 (i.e., one week). Reliability was assessed by administering the questionnaire at two occasions, 3 to 7 days apart. The reliability and validity was assessed using Spearman's rho coefficients due to the skewed distribution of the data. The pooled result from six countries showed a correlation between GPAQv1 and pedometers for total physical activity time of r = 0.31 (n=1507). Two countries used accelerometers to assess criterion validity by comparing measures of minutes of total moderate- and vigorous-intensity physical activity, and total sedentary time from the GPAQv1 with measures of time derived from accelerometer counts. Correlations for sedentary time ranged from r = -0.02 to 0.40, and the correlations for moderate and vigorous physical activity ranged from r = -0.03 to 0.23, and r = 0.26 to 0.23, respectively (Bull et al., 2009). Stronger correlations were reported for 3 to 7 days test-retest reliability, ranging from r = 0.67 for vigorous intensity leisure physical activity to r = 0.73 for sedentary and vigorous intensity physical activity at work (Bull et al., 2009).

The first version of the GPAQ with 19 items evaluated by Bull and colleagues (Bull et al., 2009) has been subsequently modified. The GPAQ in its second version[1] has 16 items, as some items were deemed redundant and were removed (Armstrong and Bull., 2006). When tested against accelerometry, the GPAQ showed poor correlations, frequently below the threshold of r = 0.50, for moderate- and vigorous-intensity physical activity (Hoos et al., 2012; Herrmann et al., 2013; Mumu et al., 2017; Wanner et al., 2017). For test-retest reliability, correlations ranged from poor (test-retest recall frame = 3 weeks, r = 0.13 for women, r = 0.32 for men) (Thuy et al., 2010), moderate (tet-retest recall frame = 2 weeks, r = 0.69) (Trinh et al., 2009) and good (test-retest recall frame = 10 days, ICC = 0.83-0.92) (Herrmann et al., 2013) for physical activity and sitting time. Long-term reliability (2-3 months) was lower that short-term reliability over 10 to 14 days in Trinh and colleagues' study (2 weeks test-retest: r = 0.50 to 0.74; 2 months test-

[1] In this thesis, the term GPAQ is used to refer to the GPAQ in its second version.

retest: r = 0.32 – 0.68) and in Herrmann and colleagues' study (10 days test-retest: ICC = 0.83 – 0.96; 3 months test-retest: ICC = 0.53 – 0.83) (Trinh et al., 2009; Herrmann et al., 2013)

Responsiveness is less frequently assessed than reliability and validity. Cleland and colleagues assessed the validity of the GPAQ when estimating changes in physical activity and sedentary behaviors over 3 to 6 months (Cleland et al., 2014). Participants worn an accelerometer (ActiGraph GT3X+) for seven days and completed the GPAQ on day 7, on two occasions, with an interval of 3 to 6 months. The extent of change from the first measurement (T1) to measurement 2 (T2) was assessed as the difference in moderate-to-vigorous physical and total sedentary time between measures at T1 minus T2. Spearman's rho coefficient was calculated to assess correlation between the change scores derived from the two instruments (i.e. accelerometer and questionnaire). Results for agreement in change over time showed moderate correlation ($r = 0.52$, $p = 0.12$) for moderate-to-vigorous physical activity and poor correlation for total sedentary time ($r = -0.024$, $p = 0.916$) (Cleland et al., 2014).

2.5 Summary

In population-based studies, questionnaires are often preferred due to their ease-of-use, relatively low costs, and low participant burden. Three types of questionnaires can be differentiated by their purposes and time to complete: Global questionnaires (best suited for use in surveillance system where the number of items is limited by space constraints), Short-term recall questionnaires (provide somewhat detailed information of activities performed in the past week or month), and Quantitative history recall questionnaires (collect detailed information of one's physical activity in the past year, or during one's lifetime). Ideally, the questionnaire must be reproducible, valid, and responsive. Important variability has been reported in validity and reliability of physical activity and sedentary behaviors questionnaires. Overall, good test-retest reliability and low validity in measuring time spent in physical activity and sedentary behaviors with questionnaire are frequently reported.

3 Public health surveillance

3.1 Definition and concepts

Surveillance is a key element for public health policy making. The World Health Organization (WHO) defines public health surveillance as "the continuous and systematic collection, orderly consolidation and evaluation of pertinent data with prompt dissemination of results to those who need to know, particularly those who are in a position to take action". Public health surveillance data are used to identify immediate public health priorities, plan public health strategies and actions, determine whether these actions are effective, and develop public health research (Macera et Pratt, 2000, Lee, 2010).

A good public health surveillance system must respect a number of principles, enumerated by German et al. (2001):

Acceptability Individuals and organizations must be willing to participate. This is largely dependent of the time and effort required to participate.
Flexibility The method used for surveillance must be flexible enough to accommodate changes in operating conditions or information needs with little additional cost in tome, personnel, or funds (for example, to adapt to changes in physical activity guidelines).
Simplicity refers to the ease of operation of surveillance as a whole and of each of its components (e.g., how easily case definitions can be applied or how easily data for surveillance can be obtained). The method for conducting surveillance typically should be as simple as possible while still meeting its objectives.
Data quality reflects the completeness and validity of the data used for surveillance, where validity refers to how well surveillance data are measuring what they are intended to measure.
Representativeness refers to whether the data are representative of the population (are the participants different from the overall population?).
Sensitivity refers to the ability of the surveillance to accurately identify participants according to the health outcome of interest, and to detect changes over time.
Specificity refers to the ability of the surveillance to accurately exclude participants according to the health outcome of interest.
Stability refers to the reliability of the methods for obtaining and managing surveillance data and to the availability of those data.
Timeliness refers to the availability of data rapidly enough for public health authorities to take appropriate action. Any unnecessary delay in the collection, management, analysis,

interpretation, or dissemination of data for surveillance might affect a public health agency's ability to initiate prompt intervention or provide timely feedback.

3.2 Objectives of public health surveillance

Public health surveillance constitutes an important public health activity since it helps in identifying health needs through data collection, and contributes to decision making and actions by analyzing and interpreting data and communicating key results. A health problem must be well defined before it can be solved. Without a proper understanding of the health problem, it would be difficult to ameliorate the health issue. Surveillance systems generate data that help public health officials understand the health issues and plan actions to prevent and control the health hazards (Berkelman et al., 2009).

Data disseminated by a public health surveillance system can be used for immediate public health action, program planning and evaluation, and formulating research hypotheses (German et al., 2001). For example, data from a public health surveillance system can be used to:

- guide immediate action for cases of public health importance;
- measure the burden of a disease (or other health-related event), including changes in related factors, the identification of populations at high risk, and the identification of new or emerging health concerns;
- monitor trends in the burden of a disease (or other health-related event), including the detection of epidemics (outbreaks) and pandemics;
- guide the planning, implementation, and evaluation of programs to prevent and control disease, injury, or adverse exposure;
- evaluate public policy;
- detect changes in health practices and the effects of these changes;
- prioritize the allocation of health resources;
- describe the clinical course of disease;
- provide a basis for epidemiologic research.

Surveillance systems can be developed to collect data on various outcomes, including communicable diseases, non-communicable diseases (NCDs), environmental factors and health-related behaviors. Depending on the public health objectives, the actions required to reach these objectives require different surveillance systems (WHO, 2017). For example, if the objective is to prevent the spread of epidemics of acute infectious diseases, such as severe acute respiratory syndrome, then the system must provide rapid early information. If the objective is to prevent communicable diseases, surveillance systems usually collect information every one

to five years. The principle is that different objectives require different systems, providing different data. Surveillance systems should have clear objectives of how data will be used to define how data must be collected and analyzed (Nsubuga et a., 2006).

3.3 Types of surveillance systems

Public health surveillance data are collected in many ways, depending on what information is needed and how it will be used. Among the commonly used one are:

Vital Statistics. Keeping records of the number of births and deaths has been long used as indicator of overall population health. Infant mortality rate (the 5 number of deaths among infants per 1,000 births) is also used as risk factor for a variety of adverse health outcomes (Hetzel, 1997).

Registries. Registries are a simple type of surveillance system used for particular conditions (e.g., cancer or birth defects). They are often established at a state level to collect information about the number of people diagnosed with certain conditions and are generally used to improve prevention programs (Allemani et al., 2015).

National Passive Surveillance. National Passive Surveillance consists in the regular reporting of disease data by all institutions that see patients, therefore it relies on an extensive network of health workers. Once the data have been received, they must be compiled and then analysed to monitor disease patterns and identify possible outbreaks. Passive surveillance involves the regular collection and reporting of surveillance data and is the commonest method used to detect vaccine-preventable diseases (WHO, 2008).

National Active Surveillance. Active surveillance involves visiting health facilities, talking to health-care providers and reviewing medical records to identify suspected cases of disease under surveillance. This method is usually used when a disease is targeted for eradication or elimination, when every possible case must be found and investigated. It is also used for outbreak investigations (Vogt et al., 1983; WHO, 2008).

Sentinel Surveillance. A sentinel surveillance system is used when high-quality data are needed about a particular disease that cannot be obtained through a passive system. Sentinel systems involves only a limited network of carefully selected reporting sites. Selected reporting units, with a high probability of seeing cases of the disease in question, good laboratory facilities and experienced well-qualified staff, identify and notify on certain diseases. When properly implemented, sentinel-based systems offer an effective method of flexible monitoring with limited resources. While these systems are very effective in detecting large health

problems, they may be insensitive to rare events (e.g., emergence of a new disease) (WHO, 2008).

Population Surveys. Population surveys are surveillance tools that are generally repeated on a regular basis and can be very useful in monitoring chronic diseases and health-related behaviors. Surveys require a clear definition of the target population to which the results can be generalized. In addition, to avoid bias, the sample size needs to be adequate to the health condition under surveillance (i.e., rare conditions require substantial samples) (Birkhead and Maylahn, 2000).

Population surveys are of particular interest in the context of this thesis as they effectively enable surveillance of physical activity and sedentary behaviors. For example, the United States Behavioral Risk Factor Surveillance (BRFSS) consists in repeated surveys that measure self-reported chronic health conditions and behaviors that are known to cause disease or injury such as tobacco, alcohol use, or physical inactivity, and use of preventive healthcare services (www.cdc.gov/brfss/). By interviewing more than 400,000 adults each year, the BRFSS is the largest continuously conducted health survey system in the world. Because the aim of many intervention program strategies is to prevent disease by preventing unhealthy behavior, population surveys provide a direct measure of their effect in the population. Population surveys are useful for providing timely measures of program effectiveness for noncommunicable disease interventions (Nsubuga et al., 2006).

3.4 Historical overview of WHO non-communicable diseases surveillance

Historically, infectious diseases have been the primary subject of surveillance systems, but over the last 30 years surveillance of NCDs has become a priority with the growth of NCDs globally (Declich and Carter, 1994; WHO, 2011; Chaud, 2014). The increasing burden of NCDs represents a new and major challenge to population health. In 2011, the General Assembly of the United Nations adopted the Political Declaration of the High-level Meeting of the General Assembly on the Prevention and Control of Non-Communicable Diseases (United Nations General Assembly, 2011). It was the second time only in the history of the United Nations that the General Assembly met about a specific health issue (the first one concerned AIDS), illustrating the global concern for NCDs. This political declaration committed member states to a comprehensive set of actions to prevent and control NCDs, with a specific goal on strengthening country-level surveillance systems, including the monitoring of risk factors, as such surveys are recognized critical in appropriately addressing NCDs.

Soon after the United Nations political declaration, WHO developed a monitoring framework to track global progress in preventing and controlling major NCDS, and their key risk factors (WHO, 2013a). This framework includes 9 global targets to be attained in 2025, and 25 indicators. Global targets include:

1. A 25% relative reduction in the overall mortality from cardiovascular diseases, cancer, diabetes, or chronic respiratory diseases;
2. At least 10% relative reduction in over-consumption of alcohol 2, as appropriate, within the national context;
3. A 10% relative reduction in prevalence of insufficient physical activity[2];
4. A 30% relative reduction in mean population intake of salt/sodium;
5. A 30% relative reduction in prevalence of current tobacco use in persons aged 15+ years;
6. A 25% relative reduction in the prevalence of raised blood pressure or contain the prevalence of raised blood pressure, according to national circumstances;
7. Halt the rise in diabetes & obesity;
8. At least 50% of eligible people receive drug therapy and counseling (including glycaemia control) to prevent heart attacks and strokes;
9. An 80% availability of the affordable basic technologies and essential medicines, including generics, required to treat major noncommunicable diseases in both public and private facilities.

This framework aimed to drive progress in prevention and control of NCDs and provided the foundation for advocacy, raising awareness, reinforcing political commitment and promoting global action to tackle these deadly diseases. Key elements in controlling and preventing NCDs are identification, prevention and control of the major common risk factors. The objectives of surveillance of NCDs and their risk factors are therefore to: collect consistent data across and within countries; develop standardized tools to enable comparisons over time and across countries/sites; prevent chronic disease epidemics before they occur; help health services plan and determine public health priorities; predict future caseloads of chronic diseases; and monitor and evaluate population-wide interventions.

Early 2000s, WHO has developed a tool for surveillance of NCDs and their risk factor, named the WHO STEPwise approach (WHO, 2005). The WHO STEPwise approach is a standardized

2 Indicators associated with global target number 3 are: Prevalence of insufficiently physically active adolescents, defined as less than 60 minutes of moderate to vigorous intensity activity daily and age-standardized prevalence of insufficiently physically active persons aged 18+ years (defined as less than 150 minutes of moderate-intensity activity per week, or equivalent).

method for collecting, analyzing and disseminating data on the established risk factors in WHO member countries. The STEPwise approach is characterized by 3 steps of data collection:
Step 1. Gathering demographic and behavioral information by questionnaire in a household setting;
Step 2. Physical measurements in a household setting;
Step 3. Taking blood samples in a clinic.

Within each Step, there are three levels of data collection. The implementation of each step depends on what can realistically be accomplished (financially, logistically and in terms of human and clinical resources) in each country setting. Table 5 provides a good illustration of the conceptual framework underlying STEPS. By using the same standardized questions and protocols, all countries can use STEPS information not only for monitoring within-country trends, but also for making comparisons across countries.

Table 5. Illustration of the conceptual framework underlying the WHO STEPwise approach (from WHO, 2005).

	Core items	**Expanded items**	**Optional modules**
Step 1 Behavioral	Basic demongraphic information, including age, sex, literacy and highest level of education	Expanded demographic information including years at school, ethnicity, marital status, employment status, household income	Mental health, intentional and unintentional injury and violence and oral health
	Tobacco use	Smokeless tobacco use	
	Alcohol consumption	Past 7 days drinking	
	Fruit and vegetable consumption	Oil and fat consumption	
	Physical activity		Objective measurement of physical activity
		History of blood pressure, treatment for raised blood pressure	
		History of diabetes, treatment for diabetes	

Table 5. Contd

	Core items	**Expanded items**	**Optional modules**

Step 2 **Physical measurements**	Weight and height Waist circumference Blood pressure	Hip circumference, heart rate	Skin fold thickness, assessment of physical fitness
Step 3 **Biomechanical measurements**	Fasting blood sugar Total cholesterol	Fasting HDL-cholesterol and triglycerides	Oral glucose tolerance test, urine examination, salivary cotinine

3.5 Surveillance of physical activity and sedentary behaviors

Surveillance of physical activity and sedentary behaviors in the general population is a necessity to estimate how much the population engage in these behaviors, and to appreciate these results with regard to the recommended targets and the prevalence of health conditions linked to physical inactivity and sedentary behaviors (WHO, 2011). By doing so, surveillance allows to elaborate national policies and to evaluate the efficiency of current strategies in promoting physical activity and preventing sedentary behavior.

3.5.1 Worldwide surveillance

3.5.1.1 International calls for surveillance

During the 57th World Health Assembly, in May 2004, the WHO endorsed the Global Strategy on Diet, Physical Activity and Health, urging Member States to develop, implement and evaluate actions to promote lifestyles that include a healthy diet and physical activity and foster energy balance (WHO, 2004). In 2010 the Global Advocacy Council for Physical Activity, of the International Society for Physical Activity and Health published The Toronto Charter for Physical Activity: A Global Call for Action (Bull et al., 2010). The Charter outlined 4 actions based upon nine guiding principles for a population-based approach to physical activity. These principles were consistent with the Global Strategy on Diet, Physical Activity and Health (WHO, 2004) to increase physical activity and decrease sedentary behaviors worldwide. Among the 9 principles, the Charter encouraged countries and organizations to build capacity and support training in research, practice, policy, evaluation and surveillance. In July 2013, European Ministers of Health from the WHO's European Region adopted the Vienna declaration on nutrition and NCDs in the context of Health 2020 (WHO, 2013b), to address the root causes of obesity and diet-related NCDs. The declaration calls, for the first time, for the development of a strategy on physical activity aiming to support public institutions in increasing physical activity levels of the population. The 2016-2025 European strategy on physical activity (WHO, 2015) identifies 5 priority areas for actions, one of them being the need to support action through monitoring and surveillance. Recently, delegates and hosts of the 6th International

Congress on Physical Activity and Public Health, the biennial meeting of the International Society for Physical Activity and Health (ISPAH), with representatives from 72 countries and held in Bangkok, Thailand and ISPAH Members have released the Bangkok Declaration on Physical Activity for Global Health and Sustainable Development (ISPAH, 2017). This declaration identifies opportunities for urgent prioritization and implementation that will support and promote reduction in physical inactivity and contribute to achieving specific 2030 Agenda's Sustainable Development Goals (SDGs). The Bangkok declaration encourages to strengthen monitoring and surveillance as "regular monitoring and reporting on progress of physical activity, its determinants, and policy implementation are essential in all countries to hold agencies accountable to their commitments and guide effective resource allocations. Yet significant gaps exist in the surveillance of physical activity in children, young people, older adults and within minority populations". Collectively, these advocacy tools reinforced a movement in favor of the promotion and surveillance of physical activity worldwide.

3.5.1.2 International initiatives of global surveillance

Two initiatives of global surveillance of physical activity and sedentary behaviors have been implemented in the past decade. The Global Observatory for Physical Activity (GoPA!), was established in 2012, as a Council of the International Society of Physical Activity and Health, to provide each country information in the areas of surveillance, policy and research in physical activity. Since 2012, GoPA! has collaborated with other institutions and governments worldwide to track progress in physical activity, and to achieve the WHO target of reducing the prevalence of inactivity by 10% by 2025 (Varela et al., 2017). In 2017, Varela et al. presented descriptive information on surveillance, policy and research from the first round of data collection by GoPA!, which have also been published as the "1st Physical Activity Alamac", available on the GoPA! Website (www.globalphysicalactivityobservatory.com) (Varela et al., 2017). Results are encouraging as 90.6% of the 139 included countries had at least 1 national survey with physical activity questions, 13 (9.4%) had no representative national survey with physical activity questions, 39 (28.1%) had one question, 55 (39.6%) had two questions, and 32 (23.0%) had completed three or more national surveys with physical activity questions. Physical activity surveillance activities varie by world region and country income classification. High-income (33.3%) and middle-income (21.6%) countries were more likely to complete three or more surveys, and had another survey scheduled. Conversely, up to one third (33.3%) of participating low-income countries had not completed a national survey. Although most of the countries have at least one survey on physical activity, less than one third of the countries maintain a continuous surveillance studies (Varela et al., 2017). Overall, GoPA! reports high

prevalence of physical inactivity (23%), in all regions of the world for adults aged 18 or older (Sallis et al., 2016).

The Active Healthy Kids Global Alliance was established in 2014 and is a network of researchers, health professionals and stakeholders who are working together to advance physical activity in children and youth from around the world. They developed a Global Matrix of 9 common indicators related to children and adolescents' physical activity and sedentary behaviors has been reported for 38 countries on 6 continents (Tremblay et al., 2016). The Global Matrix indicators relate to individual behavior (overall physical activity levels, organized sports participation, active play, active transportation, sedentary behaviors), sources of influence (family and peers, school, community and built environment), and government strategies and investments. For each indicator, grades ranging from A (excellent) to F (failing) were developed. Grades of A, B or C indicate that at least 40% of youth meet the recommendations. Average grades for both overall physical activity and sedentary behaviors across the 38 countries were D, meaning that in average less than half of children and adolescents met the recommendations on physical activity and sedentary behaviors (20–39%). Among the 38 countries, only 26% (physical activity) and 29% (sedentary behaviors) earned a grade of A, B, or C. for overall physical activity and sedentary behaviors, respectively. The next Global Matrix aims to increase substantially the number of participant involved and should be released in November 2018.

3.5.1.3 International surveys

International surveys have been implemented to gather information on physical activity and sedentary behaviors. In 2001, WHO launched a large cross-sectional study, the World Health Survey (WHO, 2017), conducted in 70 countries in 2002-2003. Countries were able to choose from a range of questionnaire modules, one of which contained the questions on physical activity from the short form of the International Physical Activity Questionnaire (IPAQ-SF). The IPAQ-SF asks about the frequency and duration of vigorous intensity, moderate intensity, and walking physical activity. Fifty-one countries from mainly low- and middle-income countries included this module and submitted the questionnaire to 259,526 people (Guthold et al., 2008). IPAQ-SF was translated through use of a WHO translation protocol involving a bilingual group with both translation and back-translation of the instrument. Of the 259,526 observations from 51 countries, 212,021 participants with complete and consistent information were included in the analysis conducted in 2007 by Guthold et al. (overall response percentage 81.7%). As the IPAQ-SF is valid only for adults up to age 69, the age range for analysis was

restricted to 18–69 years. Overall, about 15% of men and 20% of women did not meet the WHO recommendation for physical activity levels (150 minutes/week of moderate-, or 75 minutes/week of vigorous-intensity physical activity, or an equivalent combination of moderate-to-vigorous physical activity) (WHO, 2010). Country prevalence of physical inactivity ranged from 1.6% (Comoros) to 51.7% (Mauritania) for men and from 3.8% (Comoros) to 71.2% (Mauritania) for women (Guthold et al., 2008). While the IPAQ includes questions on both physical activity and sitting time, the WHO survey only included physical activity questions.

Using the same questionnaire (IPAQ-SF), the International Prevalence Study collected information on physical activity and sitting time from population samples in 20 countries between 2002 and 2004 (Bauman et al., 2011). Sitting time was measured using the IPAQ-SF single item on sitting: *During the last 7 days, how much time did you usually spend sitting on a weekday?* Data were available for 49,493 adults aged 18–65 years. The median reported sitting time was 300 minutes/day, with an interquartile range of 180–480 minutes. Countries reporting the lowest amount of sitting included Portugal, Brazil, and Colombia (medians 180 min/day), whereas adults in Taiwan, Norway, Hong Kong, Saudi Arabia, and Japan reported the highest sitting times (medians 360 min/day) (Bauman et al., 2011).

In Europe, the Eurobarometer is a series of public opinion surveys conducted regularly on behalf of the European Commission throughout the EU Member States since 1974. Eurobarometer might include special reports based on in-depth thematic studies carried out for various services of the European Commission or other EU Institutions and integrated in the Standard Eurobarometer's polling waves. As part of these special reports, Eurobarometers of 2002, 2009 and 2013 have included questions on physical activity and sedentary time (European commission, n.d.). All 3 surveys have used the IPAQ-SF to collect data on physical activity and sedentary time. Special Eurobarometer 412 collected data in 2013 among 27,919 individuals from the 28 EU member countries (Gerovasili et al., 2015; Loyen et al., 2016). Analysis for physical activity levels included 19,978 individuals aged 18-64 years (Gerovasili et al., 2015). In all 28 EU countries the proportion of physically inactive individuals was 28.6% (95% CI: 27.6%– 29.6%), while 71.4% (95% CI: 70.4%–72.4%) were classified as adequately active according to WHO's guidelines. There was great variability between countries with the highest proportion of inactive individuals noted in Southern European countries, such as Cyprus (53.7%), Portugal (50.6%) and Malta (48.7%), and the lowest proportion in Northern and Western Europe, namely in Sweden, (12.4%), the Netherlands (14.9%) and Finland (15.9%),

Sweden (72.2%), Germany (71.5%) and Latvia (71.4%) (Gerovasili et al., 2015). Sitting time was measured using a variant of the IPAQ-SF sitting item: *How much time do you spend sitting on a usual day?* A total of 26,617 respondents aged 18 and more were included in the analyses (Loyen et al., 2016). Median sitting time was five hours per day. Across Europe, 18.5 percent of the respondents reported to sit more than 7.5 hours per day, with substantial variation between countries (ranging from 8.9 to 32.1 percent). In general, northern European countries reported more sitting than countries in the south of Europe (Milton et al., 2015; Loyen et al., 2016).

3.5.2 National surveillance

3.5.2.1 Examples of national surveillance systems

Countries around the world have implemented surveillance systems at national levels. Some examples are presented below. For instance, physical activity surveillance in the United States has included national and state-based surveys. The NHANES is a population-based survey collecting information on the health and nutrition of the United States population (CDC, 2017). The NHANES was first implemented in 1971, and it is composed of 2 parts: the home interview, and the health examination. Physical activity questions were introduced in 1999, allowing analyzes of secular trends in the proportion of physical activity levels and its correlates. NHANES provides data for adults (leisure-time, transportation and household activities) and children (leisure-time activities). In 2003, accelerometry data were collected in addition to self-report. In the 2003–2004 and 2005–2006 cycles of the National Health and Nutrition Examination Survey (NHANES) in the United States, survey participants ages 6 years and older were asked to wear an ActiGraph 7164 on a waist belt during all non-sleeping hours for seven days. By including nearly 15,000 participants, it represented the largest population-based survey using accelerometers at the time (Troiano et al., 2014). In addition to NHANES, the BRFSS collects physical activity data since 1984, although it focused only on leisure-time activity until 2000. Beginning in 2001, other domains of physical activity were added, including domestic or household activities, occupational activities or physical education, transport-related and leisure-time physical activity (CDC, 2017). Other ongoing surveys complement surveillance of physical activity and sedentary behaviors in the United States, such as the American Community Survey (United States Census Bureau, n.d.), the American Time Use Survey (Bureau of Labor Statistics, n.d.), the National Household Travel Survey (United States Department of Transportation, n.d.), and the National Health Interview Survey (CDC, 2017).

Canada has also a well-developed surveillance system of physical activity and sedentary behaviors relying on many surveys. The Canadian Health Measures Survey (CHMS), launched in 2007, is an ongoing survey collecting physical activity and sedentary behaviors data from a nationally representative sample of the population aged 3 to 79 years (6 to 79 years in cycle 1). CHMS uses both questionnaires and accelerometers and provides information regarding adherence to physical activity guidelines, total moderate-to-vigorous physical activity, total sedentary time, and recreational screen time for adults and youth (Statistics Canada, 2015). In addition, the Canadian Fitness and Lifestyle Research Institute conducts the Physical Activity Monitoring (PAM) surveys, and Statistics Canada conducts the National Population Health Survey - Canadian Community Health Survey (CCHS), providing valuable information for the population surveillance of physical activity in Canada. The NPHS was conducted from 1994 to 1999, and has been replaced by the CCHS. The PAM survey has first been implemented in 1995, and provides information on the percentage of adults intending to be physically active, who report that physical activity is generally pleasant, and who report being confident for engaging in 30 minutes of moderate physical activity three or four times a week (Katzmarzyk and Tremblay, 2007; Canadian Fitness and Lifestyle Research Institute, 2017a). For youth, the PAM survey asks for participation in sports, level of parental support and level of community safety. The CCHS provides information on occupational, household and leisure time physical activity, active travel, and the built environment (for examples the presence of parks and recreation facilities) (Canadian Research Data Center Network, n.d.). In addition, the surveillance system of physical activity and sedentary behaviors in Canada includes the Physical Activity Longitudinal Study (Canadian Fitness and Lifestyle Research Institute, 2017b), the Canada's Physical Activity Levels among Youth survey (Canadian Fitness and Lifestyle Research Institute, 2017c), and setting-based surveys assessing policies, practices, and opportunities to support physical activity of Canadians in key settings (municipalities, schools and workplaces) (Canadian Fitness and Lifestyle Research Institute, 2017d).

In Australia, the Australian Health Survey (AHS) is a large, nationally representative survey of the health status of the Australian population. The AHS is conducted by the Australian Bureau of Statistics since 1989, and includes questions on leisure time exercise since its first edition providing comparable trends for nearly two decades. The AHS implemented in 2014-2015 provides the latest information on the percentage of a representative sample of Australian adults meeting the WHO physical activity guidelines for self-reported moderate-to-vigorous physical activity (150 minutes/week) and muscle-strengthening exercises (≥2 sessions per week). In

addition, the 2011-2013 AHS used pedometers to determine the proportions of adults meeting the recommendations for 10,000 steps daily (Australian Government Department of Health, n.d.). Other national surveys, such as the ERASS surveys (Exercise, Recreation and Sport Surveys) implemented by the Australian Sports Commission and State and Territory Departments of Sport and Recreation since 2001 provides information on aerobic exercise, and travel surveys conducted by the Australian department of transport, provide information on active transportation. In addition, state-based surveys provide regional information on physical activity and sedentary behaviors. For example, the South Australian Monitoring and Surveillance System (SAMSS) monitors population trends in health risk factors and chronic diseases in the South Australian population. SAMSS includes questionnaires for physical activity and data is collected every month for about 600 adults and children. SAMSS provides trends in the proportion of youth and adults meeting the moderate-to-vigorous physical activity guidelines of 60 minutes daily (youth) or 150 minutes weekly (adults) (Government of South Australia, 2017).

Not all countries have implemented such advanced surveillance of physical activity and sedentary behaviors. For example, Belgium mainly relies on the ongoing Health Interview Survey (HIS), which was first conducted in 1997 (Belgian Scientific Institute of Public Health, n.d.). The HIS only includes individuals aged 15 and more. In 1997, HIS collected data on leisure time physical activity, then it used the IPAQ-SF to measure physical activity and sitting time in the following surveys (2001, 2004 and 2008).

3.5.2.2 French surveillance system of physical activity and sedentary behaviors

3.5.2.2.1 National legislative framework

Following a Minister's referral, the High Committee on Public Health (HCSP) in France submitted, in 2000, a report for a public health nutritional policy, to the Secretary of State for Heath, in which it concluded that there was a need to implement a nutritional policy whose programs' evaluation is a necessity and should be planned from the beginning (HCSP, 2000). In December of same year, the Prime Minister declares the launch, in January 2001, of the French National Nutrition and Health Program; the main objective of this program is to improve the health of the overall population by acting on one the main determinant that is nutrition. Among the 9 priority nutritional goals identified, was the increase of daily physical activity by a 25% increase in the percentage of the population engage in at least 30 minutes of brisk walking daily. Simultaneously, the implementation of the Organic Law on the Finances Laws (LOLF)

in 2000 made mandatory the evaluation of public policies. The Public Health Law of 2004[3] also imposes that all health strategies and programs include key elements allowing to evaluate the actions implemented. In this new legislative framework, and following the launch of the 1st public health program including national objectives on physical activity, were implemented the first surveillance studies measuring prevalence of physical activity at a national level[4] (Beck and Guilbert, 2005, Usen, 2006; Beck et al., 2008).

3.5.2.2.2 Institutions implementing national studies measuring physical activity and sedentary behaviors

Two institutions placed under the authority of the Health Ministry ensure the implementation of surveillance studies as part of their missions, including questions on physical activity and sedentary behavior: the French Public Health Agency and Anses. The French Public Health Agency results from the merging of the National Institute for Prevention and Health Education (Inpes), the Institute for Public Health Surveillance (InVS) and the French Preparedness and Sanitary Emergency Response Establishment (Eprus), in May 1st of 2016.

Public Health France is an administrative public establishment placed under the authority of the Health Ministry. It was created by the ordonnance n° 2016-462 of 14th April 2016, and the decree n° 2016-523 of 27th April 2016, and was thought in the law on the modernization of the health system (art. 166 of the law n° 2016-41 of 26th January 2016). As defined by these documents, Public Health France must carry out the tasks previously accomplished by InVS, Inpes and Eprus.

To that end, Public Health France:

- Analyzes up-to-date knowledge and data on the determinants of health and risk factors;
- Provides decision makers at all levels with independent evidence-based guidance and recommendations. It will be supported by expert committees;
- Proposes measures to health authorities to protect the population from health threats;
- Develops evidence-based interventions for prevention and health promotion;

[3] Law n° 2004-806, August 9th, 2004, relative to public health policy (accessible on www.legifrance.gouv.fr).

[4] Data sources on physical activity, other than surveillance studies, were already available (Inserm, 2008).

- Contributes to preparedness and management of health crisis, and provide support for the implementation of response plans.

Among its mission, Public Health France has to implement the National Nutrition and Health Program, previously under the responsibility of Inpes. In this context, Public Health France must produce national indicators on nutrition, physical activity, and sedentary behavior, and contributes to the promotion of physical activity and reduction of sedentary behavior.

Like Public Health France, Anses is an administrative public establishment, and is accountable to the French ministries in charge of Health, Agriculture, the Environment, Labour and Consumer Affairs. Anses exists since the first of July 2010, following the ordonnance of 8th January 2010, and results from the merging of the French Food Safety Agency, and the French Agency for Environmental and, Occupational Health Safety. Anses is now in charge of their previous missions and ensure human health and safety with regard to the environment, the workplace and food. In doing so, Anses has a major role in health monitoring, vigilance, and alert.

3.5.2.2.3 National studies measuring physical activity and sedentary behaviors

As part of their mission, these different establishments have implemented national studies including questions on physical activity and sedentary behavior. Since more than 25 years, Inpes implements a Health Barometer aiming to track knowledges, behaviors, attitudes, and perceptions toward risk-taking and health status of the overall French population; including, but not limited to, smoking, eating habits, vaccination, as well as physical activity and sedentary behavior. Health Barometer is a periodic survey, and the 9th edition has been implemented during the year 2017. From the 8 previous Health Barometers, only the surveys of 2005 and 2008 included questions on physical activity and sedentary behaviors (Beck and Guilbert, 2005, Beck et al., 2008). InVS has implemented in 2006 the National Health and Nutrition Study (leaded by a joint team Invs – Paris 13 University), and more recently the Esteban study (Esen, 2017). National Health and Nutrition Study (ENNS) aimed to be a surveillance tool to assess indicators of the National Nutrition and Health Program, and to provide descriptive information on eating habits, nutritional status and physical activity of the overall metropolitan population (Usen, 2006). Esteban study addresses multiple needs: it includes a biomonitoring component to respond the needs of the National Plan on Health and Environment, a nutritional component including diet, physical activity and sedentary behaviors to meet the requirements of the National Nutrition and Health Program, and the surveillance of chronic diseases.

Finally, among the studies implemented by Anses, the ones on eating habits (INCA studies) address the issue of physical activity and sedentary behavior. The objective of INCA studies is to assess risks relative to food and nutrition (Lafay et al., 2009). To do so, INCA studies assess food consumption, food composition, and life habits. INCA studies happen every 7 years, since 1999, and has been implemented 3 times so far.

3.5.2.2.4 Main results of French surveillance studies measuring physical activity and sedentary behaviors

Physical activity and sedentary behaviors surveillance studies have been analyzed and discussed in Study 1 of this thesis. The results of French surveillance studies measuring physical activity and sedentary behaviors are presented in Study 1.

In summary, 6 studies have been implemented from 2006 to 2015, measuring physical activity and sedentary behaviors with questionnaires, in representative sample of the French population. French national studies showed 61.3% to 79.4% of the adult population met the WHO recommendations for moderate-to-vigorous physical activity. For sedentary behaviors, mean total sitting time of 4h41 and 4h38 per day were reported among adults

Rough estimates of youth meeting the WHO recommendation for 60 minutes of moderate-to-vigorous physical activity daily reported prevalence of 43.2% for adolescents aged 15 to 17 years, between 32.3% and 401% for children and adolescents aged between 11 to 17 years, and between 17.8 to 24.4% for children aged 10 years and younger. Mean daily screen time ranged between 1h47 for children aged 3-6 years, to 4h50 for adolescents aged 15-17 years.

3.6 Summary

Surveillance of physical activity and sedentary behaviors levels and patterns is important for the effective implementation of actions, as well as for the definition and evaluation of strategies and policies. Strengthened by international strategies and plans, global surveillance initiatives have been implemented in the past 15 years and showed that physical inactivity is highly prevalent at all age groups and in all region of the world. So far, 139 countries have participated in the Global Observatory for Physical Activity, from which 90.6% had at least national survey with physical activity questions for adults and 38 countries participated in the Global Matrix 2.0 on children and adolescents. These international studies report a prevalence of physical inactivity of 23.3% among adults aged 18 and older, and between 61-80% among children and adolescents aged 0-17 years.

There is no consensus about what is the optimal system for surveillance of physical activity and sedentary behaviors. Therefore, each country implements different surveillance systems, as illustrated with examples from Canada, United Sates, Australia end Belgium. In France, three main institutions have been implemented national surveillance studies of physical activity and sedentary behaviors. French surveillance studies have been the focus of the first study composing this thesis.

Chapter 3

Personal contributions

To contribute to the measurement and surveillance of physical activity and sedentary behaviors, this thesis relied on 4 studies. Two studies have been published in international peer-reviewed journal, and 2 have been submitted in international peer-reviewed journal. The four studies fold into one of the two research axes of this thesis as presented below.

Axis 1. Surveillance of physical activity and sedentary behaviors

- Study 1. **Rivière F.**, Escalon H., Duché P., Drouillet-Pinard P., Vuillemin A. **National surveillance of physical and sedentary behaviors in France.** (Submitted)
- Study 2. Aucouturier J., Ganière C., Aubert S., **Riviere F.**, Praznoczy, C., Vuillemin A., Tremblay M.S., Duclos M., Thivel D. **Results from the first French Report Card on Physical Activity for Children and Adolescents (2016).** Journal of Physical Activity and Health. in press.

Axis 2. Measurement of physical activity and sedentary behaviors

- Study 3. **Rivière F.**, Aubert S., Yacoubou Omorou A., Ainsworth B.E., Vuillemin A. **Content comparison of sedentary behavior questionnaires: a systematic review.** (Submitted).
- Study 4. **Rivière, F.**, Widad, F. Z., Speyer, E., Erpelding, M. L., Escalon, H., Vuillemin, A. (2016). **Reliability and validity of the French version of the global physical activity questionnaire.** Journal of Sport and Health Science.

Study 1. Surveillance of physical activity and sedentary behaviors: case-study using French surveillance data

Abstract

Background: This work aims to shed light on limitations of current physical activity surveillance by describing French national surveillance studies as examples.

Methods: Five national experts of physical activity and public health gathered to discuss the main results and the measurement tools of French surveillance studies.

Results: Six studies published since 2005 monitored physical activity and sedentary behaviors among adults; 4 included youth and children. From 62.8% to 79.4% of adults and 29.8% to 43.2% of adolescents 15-17 years old reported a level of physical activity meeting the recommended target. All studies focused on aerobic physical activity, and none measured muscle-strengthening and joint mobility exercises, and all relied on questionnaires. Because different questionnaires were used or because of changes in wording, comparison over time is limited. In addition, questionnaires showed poor accuracy in estimating compliance with physical activity guidelines.

Conclusion: Although guidelines provide recommendations on muscle-strengthening and joint mobility exercises, only aerobic physical activity has been assessed in questionnaires. This paper highlights the complexity in measuring physical activity and sedentary behavior and the need to develop recommendations for best practices in measuring physical activity and sedentary behavior for surveillance study.

Title: Surveillance of physical activity and sedentary behaviors: case-study using French surveillance data

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Introduction

Surveillance is a key element for public health policy making. The World Health Organization (WHO) defined public health surveillance as "the continuous and systematic collection, orderly consolidation and evaluation of pertinent data with prompt dissemination of results to those who need to know, particularly those who are in a position to take action". Public health surveillance data are used to identify immediate public health priorities, plan public health strategies and actions, determine whether these actions are effective, and develop public health research. [1,2]

Being a major determinant of health and well-being, and in regards to the burden of noncommunicable diseases associated with insufficient physical activity levels and too much sedentary behaviors (SB), a stand-alone physical activity (PA) strategy for the European Region has been recently developed. The 2016-2025 European Strategy on PA identify 5 priority areas, from which one is supporting action through monitoring and surveillance. There is currently a consensus on the need for harmonized surveillance systems providing more comparable data across European countries, and to identify trends and regional variations in PA and SB.

The Global Observatory for Physical Activity (GoPA!), was established in 2012, as a Council of the International Society of Physical Activity and Health, to provide each country information in the areas of surveillance, policy and research. A recent paper presents the results from the first round of data collection by GoPA!,[3] which have also been published as the "1st Physical Activity Alamac". The results from this work are encouraging as 90.6% of the 129 included countries had at least 1 national survey with questions on PA. Similarly, initiated by the Active Health Kids Global Alliance, a Global Matrix of 9 common indicators has been published, with participation from 38 countries on 6 continents.[4] The indicators include overall PA levels, organized sports participation, active play, active transportation, SB, family and peers, school, community and built environment, and government strategies and investments. For each indicator, a grade ranging from A for excellent, to F for failing is proposed. Average grades for both overall PA and SB across the countries were D,

meaning that in average less than half of children and adolescents met PA guidelines, and SB or screen-time guidelines (20–39%).

These international initiatives show a promising trend toward a global surveillance of PA, yet the implementation of reliable surveillance systems is hard and complex work, and results on national and international prevalence of physical inactivity should be interpreted carefully.

In this paper, we aim to take a step back from the results of such international report and to shed light on the complexity and possible limitations of PA and SB surveillance, by describing French national surveillance studies. This paper presents findings on the prevalence of PA and SB in France, and discusses measurement issues.

Material and methods

National experts of physical activity and public health gathered to discuss the current state of French surveillance studies including questions on physical activity and sedentary behaviors. Two of them have contributed to the implementation of such national studies.

In this article, PA was considered as "the behavior that involves human movement, resulting in physiological attributes including increased energy expenditure";[5] and SB as "any waking behavior characterized by an energy expenditure ≤ 1.5 METs while in a sitting, reclining or lying posture".[6]

From a public health perspective, the article focused only on national studies measuring PA and SB, as defined previously, in the French metropolitan population of all ages, and aiming to compare PA levels and sedentary time with the recommended values. Over the last 2 decades, recommendations on PA have not fundamentally changed, and the most remarkable change is the recent formulation of recommendations on SB. In France, since the early 2000s, the French Ministry of Health, as part of the National Nutrition and Health Program (PNNS), recommended for adults to engage in at least 30 minutes of brisk walking daily, or an equivalent amount of PA, and for youth to engage in at least 60 minutes of brisk walking daily, or an equivalent amount of PA (PNNS 2011-2016, PNNS 2006-2010, PNNS 2001-2005).

Six national health studies enabling an estimate of PA prevalence have been implemented, from 2005 to nowadays, by different actors of the health sector:

- 2005 Health Barometer and 2008 Health and Nutrition Barometer by the National Institute for Prevention and Health Education (Inpes) (,which recently became Santé publique France, the national public health agency),[7,8]
- National Nutrition and Health Study in 2006-2007 and Esteban study in 2014-2016 by InVS (Institute for Public Health Surveillance, which became Santé publique France, the national public health agency after merging with Inpes and the Establishment for Public Health Emergency Preparedness and Response (Eprus)),[9,10]
- INCA2 in 2006-2007 and INCA3 in 2014-2015 studies by Anses,[11,12]

For each study, used measurement tools were described as well as main results. In addition, information on validity and test-retest reliability of the measurement tools were presented.

Results

Measurement tools

Questionnaires' content

From the 6 studies identified, the measurement of PA and SB is based on 3 different questionnaires in adults, 3 in adolescents aged 15-17 years, 1 in adolescents aged 11-14 years, and 1 questionnaire in children aged 3-10 and under.

ENNS, 2005 Health Barometer, and INCA2 used the short form of the *International Physical Activity Questionnaire* (IPAQ-SF) for adults, 2008 Health Barometer used the *Global Physical Activity Questionnaire* (GPAQ), and Inca 3 and Esteban studies used a slightly modified form of the *Recent Physical Activity Questionnaire* (RPAQ). The IPAQ-SF is the shortest and is composed of 8 items measuring overall moderate and vigorous PA, walking, and sitting time during the last 7 days. The GPAQ includes 16 items, asking for moderate to vigorous PA at work (including paid and unpaid work, household chores, and study/training), during leisure-time transportation, and sitting time, in a

typical week. The French form of the RPAQ is composed of 3 parts with several questions, measuring in the last 4 weeks, PA at work, for transportation, for home activities, leisure or sports, and sedentary time spent at home (watching TV, playing video games or using a computer), at work, and for transportation. The GPAQ, IPAQ-SF and RPAQ scoring protocols provide information on PA energy expenditure, and estimate levels of PA among adults.

ENNS and Esteban, as well as Inca 2 and Inca 3 studies used the questionnaire developed by the French Nutritional Epidemiological and Surveillance Unit (Usen) for children aged between 3 and 10, and the *Youth Risk Behavior Survey Questionnaire* (YRBS) for adolescent aged between 11 and 14. For adolescents aged 15-17, Health Barometer 2005, ENNS and INCA2 used the IPAQ-SF, whereas Esteban and INCA3 used the YRBS as for younger adolescents. The IPAQ-SF and GPAQ used with adolescents are the same as the ones used with adults and previously described. The YRBS used in ENNS and INCA2 is comprised of 6 items, from which 4 ask about frequency of moderate PA (lasting at least 30 minutes), frequency of vigorous PA (lasting at least 20 minutes), and frequency and duration of physical education at school, during the last 7 days. The other 2 items measure time spent watching TV, playing video games or using a computer, in the last 7 days. Esteban and INCA3 studies have used a modified version of the YRBS questionnaire. Major modifications concern moderate and vigorous PA lasting at least 60 minutes and 40 minutes respectively, instead of 30 minutes and 20 minutes, and the description of screen time in 3 items instead of 2. For children, the questionnaire developed by Usen to assess PA and SB was completed by parents. This questionnaire has some similarities with the YRBS, 4 items ask about mode of transportation, frequency of outdoor active playing, frequency of physical education at school, and frequency of organized sport outside of school; and 2 items ask about time spent watching TV, playing video games or using a computer. Esteban and INCA3 studies also used a modified version of the questionnaire; the major modification concerns the description of screen time in 3 items instead of 2. As for adults, IPAQ-SF and GPAQ provides estimate of PA levels among adolescents aged between 15 and 17. The YRBS provides estimate of PA levels based on former US recommendations on physical activity (at least 20 minutes

of vigorous-intensity physical activity on 3 or more days of the week, or 30 minutes of moderate-intensity physical activity at least 5 days a week). Finally, the questionnaire used with children aged 6 and under doesn't provide estimate of PA levels.

Questionnaires' validity

All questionnaires used in the 6 studies rely on the respondent's ability to recall PA and SB during a defined period in the past. In order to be able to properly interpret the results from a questionnaire, it is necessary to know its validity and reliability; in other words, we must understand how well it measures PA and SB and ensure it produces the same results when administered to the same person multiple times under similar conditions.[13]

The IPAQ-SF and GPAQ have been extensively tested and validated at an international level. They both have been developed to standardized surveillance of PA and facilitate international comparison between countries.[14] A review including 23 studies testing the validity of the IPAQ-SF showed that it tends to overestimate PA as compared with objective measurement,[15] with a mean difference between the 2 instruments of 84% in estimating the amount in PA; however, it has not been tested in France. As for the reliability, Craig and colleagues tested the IPAQ-SF in 12 countries and reported Spearman's correlation from 0.66 to 0.88 for total PA, and from 0.50 to 0.95 for total sitting time.[16] In France, Spearman's correlation coefficients ranging from 0.18 to 0.50 have been reported .[17] The GPAQ has been tested in 6 countries against pedometers among a total 1507 adults .[18] This study found correlation coefficients for estimate of total PA time between the 2 instruments ranging from 0.06 to 0.35. The GPAQ has been recently tested in France among adults ;[19] it showed acceptable reliability with intra class correlation ranging from 0.58 for total PA to 0.80 for total sitting time, but only poor validity with a mean underestimation of -443±157 minutes/week of total PA and -251±161 minutes/day of total sitting time when measured with GPAQ as compared with accelerometers. Bull et al. compared total PA between GPAQ and IPAQ-SF in 9 countries. [18] They showed great disparity, with a correlation between the 2 questionnaires ranging from 0.23 to 0.92 (sample size, n=2657). The RPAQ is a recent questionnaire, which has firstly been tested in England against doubly labeled water

technique and combined heart rate and movement sensing, with 51 adults.[20] This study reported correlation coefficient of 0.67 for total energy expenditure, 0.39 for PA energy expenditure, 0.70 for vigorous PA time, and 0.27 for sedentary time. Reliability of the RPAQ was assessed by administering twice the questionnaire 2 weeks apart, in an independent sample of 131 adults; the intra class correlation coefficient for reliability of total PA energy expenditure was 0.76. Following this study, the validity of the RPAQ has been tested among 1923 adults from 10 European countries, including France (French population consisted of 174 women only).[21] This study tested the RPAQ against combined heart rate and movement sensing, and found in the French population that the questionnaire underestimated moderate to vigorous PA, with a median difference of -17,1 minutes/day, and sedentary time, with a median difference of -3.7 hours/day. To our knowledge, no information is available about the reliability of the RPAQ in France.

As for youth, the YRBS has been tested among 125 American students aged 12.7±0.6, against accelerometers.[22] The questionnaire seemed to underestimate by 70% the proportion of students doing at least 30 minutes/day of moderate PA, at least 5 days a week. Conversely, it overestimated by 60% the proportion of students doing at 20 minutes/day of vigorous PA, at least 3 days a week. This study also showed moderate reliability of the questionnaire, when administered 6 days apart, with an intra class correlation coefficient around 0.50. The IPAQ-SF has also been tested among Norwegian adolescents aged between 13 and 18 against an activity monitor sensitive to body position and acceleration,[23] and showed low Spearman correlation ranging from 0.01 and 0.43. The questionnaire was administered twice, 8 to 12 days apart, and showed low to substantial intra class correlation coefficient from 0.10 to 0.62 for frequency and duration of PA. From all 3 questionnaires used in France, only the questionnaire developed by Usen has been tested in France (against accelerometer), but to our knowledge the results haven't been published yet.

Physical activity and sedentary behavior in France

Physical activity and sedentary behavior of adults

The GPAQ, IPAQ-SF and RPAQ[5] enable to estimate the participant's level of PA based on the frequency, duration, and intensity of the reported physical activities. Three categories of PA levels are proposed to classify the participant:

- 'high': this category describes higher levels of participation. It equates to approximately at least 1 hour per day or more, of moderate- to vigorous intensity PA.
- 'moderate': this category is defined as a level of PA equivalent to half an hour of at least moderate-intensity PA on most days, which is equivalent to the minimum level of PA for meeting the WHO recommendations on PA for adults.[24]
- 'low': this category is defined as not meeting any of the criteria of the other 2 categories.

Using these 3 questionnaires, French national studies showed that between 61.3% (2015 Esteban study) to 79% (2005 Health Barometer) of the adult population met the recommendations on PA (see Table 1). In the INCA2 study, 75.3% of the population aged between 15 and 79 met the recommendations, 62,8% in INCA3 (18-79 years), 63.2% in ENNS (18-74 years), and 66.9% in Health Barometer 2008 (15-75 years). As for SB, the Health Barometers 2005 and 2008 found a mean sitting time of 4h41 and 4h38, respectively. ENNS study reported a mean time spent watching a screen (TV, playing video games and computer) of 3h21; whereas INCA2 studies reported screen time of 3h30, and INCA3 reported a sedentary time of 4h52 in 2014-2015. Esteban reported the higher sitting time with a mean value of 6h35 per day.

[5] Because of content differences, the scoring protocole to estimate PA levels with the RPAQ was different, but the categories are similar.

Physical activity and sedentary behavior of children and adolescents

ENNS, Inca 2, and Health Barometers studies enable to estimate the percentage of adolescents aged 15 to 17 years who meet the recommendations on PA, based on the 'high' category of the GPAQ and IPAQ-SF. ENNS found that 29.8% of adolescents met the recommendations, against 43,2% for INCA2 study, and 52% for 2008 Health Barometer. To our knowledge, 2005 Health Barometer has published the results for the all population aged between 15 to 75, and hasn't studied the proportion of adolescents only (aged 15 to 17 years) meeting the recommendations. INCA3 and Esteban studies proposed to estimate the percentage of children and adolescents aged 15 and under who met the recommendations, by using the 'high' level from the modified YRBS questionnaire (engaging in at least 60 continuous minutes of moderate intensity PA everyday, or 40 continuous minutes of vigorous PA at least 5 days a week) and from the Usen questionnaire (engaging in PA at least 5 days a week, and using active transportation to go to school). The prevalence of youth, from INCA3 study, meeting the recommendations was 24.4% (3-6 years), 38.1% (11-14 years), and 24.2% (15-17 years). Esteban sutdy reported that 17.8% of children aged 6-10 years and 40.1% of adolescents aged 11-17 years met the recommended PA levels. Other studies showed that 39% (ENNS) and 48% (Inca 2) of youth aged 3 to 10 years engaged in organized sporting activities outside of school, and 67% (ENNS) and 41% (Inca 2) used active transportation to go to school. Among adolescents aged 11 to 14, 60% reported engaging in at least 150 minutes of at least moderate PA per week (ENNS) and in average, they engaged 2 days per week in at least 30 minutes of moderate PA and 2 days per week in at least 20 minutes of vigorous PA (Inca 2).

Discussion

While in France sporting activities have been surveyed for a long time now, the measurement of PA and SB in regards to the recommendations has not been implemented before the 2000s.[25] France, as many other Europeans countries is facing great challenges in implementing ongoing and standardized surveillance of PA and SB.[26] Surveillance is crucial to understand how people of different groups (by

age, sex, socioeconomic status) engage in PA and SB, to identify their determinants, and to estimate the percentage of the population meeting the recommendations and track how it changes over time.[27]

Overall, questionnaires used in national studies showed at best weak to moderate validity, but they showed acceptable reliability and their psychometric properties are comparable to those find in the scientific literature.[28] One of the main limitations of the French national studies lies in the modifications, small or big, made in the questionnaires. In 1987, it was already reported that, even a slight modification in the items of a questionnaire could induce substantial changes in the results.[29] As a consequence, the use of different questionnaires, as well as the modifications made, impair inter-studies comparison, and thus to survey changes over time. Broadly speaking, we should consider that questionnaires may not be optimal measurement tools to estimate prevalence of PA as they lack precision. Among a sample of 144 Nigerian adults, the sensitivity of the IPAQ-SF to identify insufficiently active people was correct (76.2%), but the specificity to classify sufficiently active people was low (33.3%), when compared with accelerometers.[30] Conversely, in a sample of 185 adults, the IPAQ-SF was better to classify those who met the recommendations on physical activity (specificity of 77%), whereas only 45% (sensitivity) of those not meeting the recommendations were classified correctly.[31] These findings, although contradictory, are not surprising as self-report measures of PA have been shown to be both higher and lower than directly measured PA.[32] Such discrepancies are observed in French national studies, as the prevalence of physical inactivity range from 20.6% to 36.8% between 2005-2007, while the same questionnaire was used.[9,33] It seems clear that the accuracy of questionnaires in quantifying PA is too low to be used in surveillance studies with the purpose of measuring current and changing PA levels. In 2003, RJ Shephard wrote that "despite extensive use over 40 years, physical activity questionnaires still show limited reliability and validity", and more than a decade later we still seem to be unable in improving questionnaires' reliability and validity.[28] Recall of PA is mentally challenging. Despite the call of leading experts for using cognitive psychology methods when designing questionnaires to improve the recall process,

little if any work has been done, which might explain that the accuracy of questionnaires has not improved over years.[34,35]

Historically, international studies interested in PA and health used to focus on self-reported leisure-time PA.[36,37] Therefore, recommendations on PA are mostly based on the dose-response relationship observed between leisure-time PA as measured with questionnaires, and health-related outcomes.[38] It has since been suggested to broaden the concept of PA beyond traditional sports-related physical activity as it may under represent the PA level of one individual.[39] In current surveillance studies, PA in different settings (home, work, transportation, leisure) is measured with questionnaire, and defacto total time engaged in PA is more important than when measuring leisure-time physical activity only. As a consequence, it has been suggested that the 'moderate' category of IPAQ and GPAQ may not be high enough to represent a level of PA leading to substantial health benefits, and the 'high' category would be more appropriate.[40] Investigators of health Barometers and INCA2 study, decided to use the 'high' category from the questionnaires to express a level of PA equivalent to a health-enhancing level of PA. They reported that only 45.7, 42.5 and 44.8% of adults met the recommendations on PA, in Health Barometer 2005, Health Barometer 2008 and Inca 2 respectively, against 79.4, 66.9 and 75.3% when using the 'moderate' and 'high' categories. Inversely, ENNS made the decision to use the 'moderate' plus "high" category, as it seems equivalent to the recommendations. However, in a public health perspective for promotion of health-enhancing physical activity, the category 'high' might be a better indicator to represent a sufficiently high level of physical activity when measuring all contexts of physical activity with questionnaires such as IPAQ, GPAQ, and RPAQ.

Interestingly, we observed a trend toward a more comprehensive measurement of PA and SB in adult population. The first studies (Health Barometer in 2005, INCA2, and ENNS in 2006-2007) used the IPAQ-SF, which, at that time, was recommended in an attempt to harmonized PA surveillance in population aged 15 and over.[16] However, the IPAQ-SF, doesn't measure any contextual information on PA, nor SB, thus a WHO working group developed and released the GPAQ in 2006,[14] which was

then used in the Health Barometer in 2008. GPAQ indeed measure PA in different settings (work, home, leisure, transportation), but only measure overall sitting time during a typical day. In the last national studies, the RPAQ was preferred as it measures both PA and SB in different settings. Conversely, none of the questionnaires used among children and adolescents measure PA and SB with as much information as the RPAQ. The questionnaire developed by Usen and the YRBS, in their original (ENNS and Inca 2) or modified forms (Inca 3 and Esteban), don't allow to report as much information on type and setting of PA. Similarly, they only measure screen time (TV, video games, computer), which represents only a part of sedentary. Lastly questionnaires used among children and adolescents aged 15 and under make it difficult to estimate the prevalence of youth meeting the recommendations.

Even though surveillance studies mainly rely on questionnaires, today's technology allow the use of objective measurement in large-scale studies. Objective measurement, such as accelerometers, enable the accurate quantification of body movement while removing measurement error related to participant's recall.[41] A recent inventory of surveillance systems assessing PA in Europe reported that, although all surveys used questionnaires, seven combined questionnaires with accelerometers.[42] However, accelerometry is not the silver bullet we could hope for. Pedisic & Bauman reported numbers of factors limiting the use of accelerometers in population-based study.[43] Issues identified by authors revolved around the generalizability, validity and reliability of the data, simplicity and affordability of the accelerometers, sustainability and continuity of the surveys, adaptability of the instruments and finally the difficulty of between-study and international comparability. Accelerometers have better reliability and validity when compared with questionnaires, however they may underestimate total physical activity levels, they can potentially be influenced by participants (when changing the position or shaking the device, intentional non-wearing, altering their habitual behavior), and they don't provide valid data on some common activities such as cycling, resistance and static exercises. In addition, the results from accelerometers are largely reliant on the intensity

cut-off points that are being used for the study. As an example, depending on which cut-off point was used, the prevalence of sufficiently active European youth ranged from 3 to 100%.[44]

Finally, it should be repeated that accelerometers and questionnaires don't measure the same concept. Physical activity and sedentary behaviors are complex, multifaceted, and ubiquitous behaviors; making their measurement intricate. For a long time, questionnaires have been the measurement tool of preference; however, it was chosen because of technical reasons (easy to use, low-cost) and not for its intrinsic qualities. Accelerometers are motion sensors and quantify the human movement by measuring acceleration of the body in 1, 2 or 3 axes. Questionnaires collect qualitative information on the behaviors, such as the purpose, the social and physical context, and type of the behavior.[5,28] Whether we use questionnaires or accelerometers should not be based on technical reasons, but rather on what we purport to measure. If the study aims to estimate the prevalence of physical inactivity, then objective measurement is more appropriate, although less easily feasible. However, the recommendations on PA for adults encompass different type of PA, and are not limited to non-aerobic physical activity. Since 2016, French national guidelines includes recommendations on aerobic physical activity, muscle-strengthening exercises, and joint mobility exercises, as well as recommendations on reducing total sedentary time.[45] However, accelerometers do not provide any information on muscle-strengthening exercises or joint mobility exercises, thus questionnaires are more appropriate. In the United states, the Center for Disease Control and Prevention reported that in 2011, 51.6% of adults met the aerobic activity guidelines, 29.3 met the muscle-strengthening guideline, and only 20.6 met both aerobic and muscle-strengthening guidelines;[46] which highlight the importance of measuring all activities. However, few surveillance studies measure the compliance of adults with muscle-strengthening and flexibility guidelines, and the 1st PA Almanach reports information only on aerobic PA.

One possible explanation is that only few questionnaires assessed muscle-strengthening exercises or joint mobility exercises. Although WHO recommends to engage in such exercises, the GPAQ, which is recommended as part of the WHO STEPwise approach, only measures aerobic PA. [47] Thus, it might

be asked if WHO should develop and recommend questions to address muscle-strengthening and joint-mobility exercises. Evolving recommendations make it difficult to survey changes over time. Surveillance systems need to rely on repeated measurement to observe trends in PA and SB, while being sufficiently flexible to adapt to changing information needs. In France, no core questions (standardized set of questions repeated over time) were used. Instead, different questionnaires have been used, impairing any long-term comparison.

Surveillance studies of PA should provide accurate estimate of PA prevalence, and be sensitive enough to track changes over time. Good quality surveillance data are important as they can be used for different purpose by health professionals, researchers, and decision-makers, and must be largely communicated to promote the importance of PA and SB. Currently, the overall data quality remains low, but it could be improved by using the appropriate measurement tools depending on what component of PA the study aims to measure. Nevertheless, the 1st PA Almanach and the Global Matrix are great initiatives to increase awareness of physical inactivity among youth and adults worldwide.[3,4] As for example, over a 10 years period, the Canadian Report Card has achieved more than 1 billion media impressions, distributed more than 120,000 printed copies and more than 200,000 electronic copies. It has been used to bring public awareness in the media, and increase awareness among government and non-government stakeholders; and has been successful at "powering the movement to get kids moving".[48]

Conclusions

Global surveillance report such as the 1st Almanac on PA and the Global Matrix are powerful advocacy tools. However, measurement issues impair the overall data quality, and limit within- and between-countries comparisons. Because the current situation regarding the measurement of PA and SB is complex, and best practices are unclear, international recommendations on PA and SB measurement should be developed.

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Authors' contributions

All authors participated in the design of the study. All authors contributed to write the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests: HE and PDP work for Santé Publique France and Anses, respectively. The findings and conclusions in this report are those of the authors and do not represent the official position of any national institution. The authors declare that they have no other competing interests.

References

1. Macera CA, Pratt M. Public Health Surveillance of Physical Activity. *Research Quarterly for Exercise and Sport* 2000;71(sup2):97-103.

2. Lee LM. *Principles and Practice of Public Health Surveillance*. Oxford University Press, USA; 2010.

3. Varela AR, Pratt M, Powell K, et al. Worldwide Surveillance, Policy and Research on Physical Activity and Health: The Global Observatory for Physical Activity–GoPA! *Journal of Physical Activity and Health* 2017:1–28.

4. Tremblay MS, Barnes JD, González SA, et al. Global Matrix 2.0: Report Card Grades on the Physical Activity of Children and Youth Comparing 38 Countries. *Journal of Physical Activity and Health* 2016;13(11 Suppl 2):S343-S366.

5. Gabriel KKP, Morrow Jr JR, Woolsey A-LT. Framework for physical activity as a complex and multidimensional behavior. *Journal of Physical Activity and Health* 2012;9(s1):S11–S18.

6. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN)–Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity* 2017;14(1):75.

7. Beck F, Guilbert P. Baromètres santé: un éclairage sur leur méthode et leur évolution. *Baromètre santé* 2005:27–43.

8. Beck F, Gautier A, Guignard R. Méthode d'enquête du Baromètre santé nutrition 2008: une évolution dans la continuité *Baromètre santé nutrition*. 2008:39–63.

9. Unité de surveillance et d'épidémiologie nutritionnelle (Usen). Situation nutritionnelle en France en 2006 selon les indicateurs d'objectif et les repères du Programme National Nutrition Santé

(PNNS) [Nutritional Situation in France in 2006 Relative to the Objectives and Markers of the National Programme on Nutrition and Health (PNNS)]. Paris: Institut de Veille Sanitaire INVS 2006.

10. Étude de santé sur l'environnement, la biosurveillance, l'activité physique et la nutrition (Esteban), 2014-2016. http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Environnement-et-sante/2017/Etude-de-sante-sur-l-environnement-la-biosurveillance-l-activite-physique-et-la-nutrition-Esteban-2014-2016. Accessed July 16, 2017.

11. Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses). INCA 3 : Evolution des habitudes et modes de consommation, de nouveaux enjeux en matière de sécurité sanitaire et de nutrition. https://www.anses.fr/fr/content/inca-3-evolution-des-habitudes-et-modes-de-consommation-de-nouveaux-enjeux-en-mati%C3%A8re-de. Accessed July 16, 2017.

12. Lafay L, Bénetier C, Bertin M, Calamassi-Tran G, Dubuisson C, Dufour A, et al. Étude individuelle nationale des consommations alimentaires: 2006-2007 (INCA 2). 2009. www.anses.fr/fr/system/files/PASER-Ra-INCA2.pdf Accessed September 22, 2017.

13. Terwee CB, Mokkink LB, Poppel MNM Chinapaw MJM, van Mechelen W, de Vet HCW. Qualitative Attributes and Measurement Properties of Physical Activity Questionnaires. *Sports Med* 2010;40(7):525-537.

14. Armstrong T, Bull F. Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). *J Public Health* 2006;14(2):66-70.

15. Lee PH, Macfarlane DJ, Lam TH, Stewart SM. Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity* 2011;8(1):115.

16. Craig CL, Marshall AL, Sjöström M, Bauman AE, Both ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35(8):1381-1395.

17. Rütten A, Vuillemin A, Ooijendijk WTM, Schena F, Sjöström M, Stahl T, et al. Physical activity monitoring in europe. The European Physical Activity Surveillance System (EUPASS) approach and indicator testing. *Public health nutrition* 2003;6(4):377–384.

18. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *Journal of physical activity & health* 2009;6(6):790.

19. Rivière F, Widad FZ, Speyer E, Erpelding M-L, Escalon H, Vuillemin A. Reliability and validity of the French version of the global physical activity questionnaire. *Journal of Sport and Health Science* 2016.

20. Besson H, Brage S, Jakes RW, Ekelund U, Wareham NJ. Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. *The American journal of clinical nutrition* 2010;91(1):106–114.

21. Golubic R, May AM, Borch KB, et al. Validity of electronically administered Recent Physical Activity Questionnaire (RPAQ) in ten European countries. *PloS one* 2014;9(3):e92829.

22. Troped PJ, Wiecha JL, Fragala MS, Matthews CE, Finkelstein DM, Kim J, et al. Reliability and validity of YRBS physical activity items among middle school students. *Medicine and science in sports and exercise* 2007;39(3):416–425.

23. Rangul V, Holmen TL, Kurtze N, Cuypers K, Midthjell K. Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. *BMC medical research methodology* 2008;8(1):1.

24. World Health Organization. Global recommendations on physical activity for health. http://www.who.int/dietphysicalactivity/factsheet_recommendations/en/. Accessed July 16, 2017.

25. Aubel O, Lefèvre B. The comparability of quantitative surveys on sport participation in France (1967–2010). *International Review for the Sociology of Sport* 2015;50(6):722-739.

26. World Health Organization. Review of physical activity surveillance data sources in European Union member states. 2011. http://apps.who.int/iris/handle/10665/108041. Accessed October 17, 2016.

27. Pratt M, Fulton JE. Staying on task: challenges of global physical activity surveillance. *Journal of physical activity & health* 2008;6:S3–4.

28. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *British journal of sports medicine* 2003;37(3):197–206.

29. Bauman A. Trends in exercise prevalence in Australia. *Australian and New Zealand Journal of Public Health* 1987;11(3):190–196.

30. Oyeyemi AL, Umar M, Oguche F, Aliyu SU, Oyeyemi AY. Accelerometer-determined physical activity and its comparison with the International Physical Activity Questionnaire in a sample of Nigerian adults. *PloS one* 2014;9(1):e87233.

31. Ekelund U, Sepp H, Brage S, et al. Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults. *Public health nutrition* 2006;9(2):258–265.

32. Prince SA, Adamo KB, Hamel ME, Hardt J, Gorber SC, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity* 2008;5(1):56.

33. Beck F, Guilbert P, Gautier A, Lamoureux P. Baromètre santé 2005. *Paris, INPES* 2007. https://pdfs.semanticscholar.org/3678/0a65d343a32c1d5c7ffe48e6e010680447be.pdf. Accessed September 22, 2017.

34. Baranowski T. Validity and reliability of self report measures of physical activity: an information-processing perspective. *Research Quarterly for Exercise and Sport* 1988;59(4):314–327.

35. Durante R, Ainsworth BE. The recall of physical activity: Using a cognitive model of the question-answering process. *Medicine & Science in Sports & Exercise* 1996;28(10):1282-1291.

36. Stephens T, Jacobs DR, White CC. A descriptive epidemiology of leisure-time physical activity. *Public Health Rep* 1985;100(2):147-158.

37. Centers for Disease Control and Prevention (CDC). Prevalence of sedentary lifestyle--Behavioral Risk Factor Surveillance System, United States, 1991. *MMWR Morb Mortal Wkly Rep* 1993;42(29):576-579.

38. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 1995;273(5):402-407.

39. Macera CA, Jones DA, Ham SA, Kimsey CD, Neff LJ, Ainsworth BE. Physical activity surveillance in the 21st century. *Annals of epidemiology* 2000;10(7):456.

40. Sjöström M, Oja P, Hagströmer M, Smith BJ, Bauman A. Health-enhancing physical activity across European Union countries: the Eurobarometer study. *J Public Health* 2006;14(5):291-300.

41. Fulton JE, Carlson SA, Ainsworth BE, Berrigan D, Carlson C, Dorn J, et al. Strategic Priorities for Physical Activity Surveillance in the United States. *Medicine and science in sports and exercise* 2016;1(13):111-123.

42. Bel-Serrat S, Huybrechts I, Thumann BF, Hebestreit A, Abuja PM, de Henauw S, et al. Inventory of surveillance systems assessing dietary, physical activity and sedentary behaviours in Europe: a DEDIPAC study. *The European Journal of Public Health* 2017:27(4);747-755.

43. Pedišić Ž, Bauman A. Accelerometer-based measures in physical activity surveillance: current practices and issues. *Br J Sports Med* 2015;49(4):219–223.

44. Guinhouya BC, Samouda H, De Beaufort C. Level of physical activity among children and adolescents in Europe: a review of physical activity assessed objectively by accelerometry. *Public health* 2013;127(4):301–311.

45. Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (Anses). OPINION of ANSES on the "Updating of the PNNS guidelines:Revision of the guidelines relating to physical activity and sedentarity". https://www.anses.fr/en/content/opinion-anses-updating-pnns-guidelinesrevision-guidelines-relating-physical-activity-and. Accessed July 16, 2017.

46. Centers for Disease Control and Prevention (CDC). Adult participation in aerobic and muscle-strengthening physical activities--United States, 2011. *MMWR Morb Mortal Wkly Rep* 2013;62(17):326-330.

47. World Health Organization. STEPS instruments for NCD risk factors (core and expanded version 1.4): the WHO STEPwise approach to Surveillance of noncommunicable diseases (STEPS). 2001. http://apps.who.int/iris/bitstream/10665/68346/1/WHO_NMH_CCS_03.03.pdf. Accessed September 22, 2017.

48. Tremblay MS, Barnes JD, Bonne JC. Impact of the Active Healthy Kids Canada report card: a 10-year analysis. *Journal of Physical Activity and Health* 2014:*11*(1);3-20.

Table

Table 1. Descriptive information on French national studies of physical activity and sedentary behavior

Year	Study	Population (age, years)	Measurement tool	Sample size	Level of physical activity (%)		Mean screen time[a] (hr-min)
					Active	Inactive	
2005	Health Barometer	15-74	IPAQ-SF	8708	79.4	20.6	4h41[b]
2006-7	ENNS	18-74	IPAQ-SF	3115	63.2	36.8	3h21
		15-17	IPAQ-SF	389	29.8	70.2	3h01[c]
		11-14	YRBS questions	456		–	
		3-10	Usen questions	574		–	
2006-7	INCA2	18-79	IPAQ-SF	2610	75.3	25	3h30
		15-17	IPAQ-SF	424	43.2	56.8	3h50
		11-14	YRBS questions	454		–	3h13
		3-10	Usen questions	574		–	2h12
2008	Health Barometer	15-75	GPAQ	3489	66.9	33.1	4h38[b]

[a] Mean screen time including watching TV, using a computer and playing video games; [b] Total sitting time; [c] Mean result for the overall population 3 to 17 years old; [d] Not communicated

Table 1. Contd

Year	Study	Population (age, years)	Measurement tool	Sample size	Level of physical activity (%)		Mean screen time[a] (hr-min)
					Active	Inactive	
2014-15	INCA3	18-79	RPAQ	2180	62.8	37.2	4h52[b]
		15-17	Modified YRBS questions	1291	32.3	67.7	4h50
		11-14	Modified YRBS questions				3h38
		7-10	Modified Usen questions	644	19	81	2h28
		3-6	Modified Usen questions	489	24.4	75.6	1h47
2014-15	Esteban	18-79	RPAQ	2678	61.3	38.7	6h35
		11-17	Modified YRBS questions	1182	40.1	59.9	4h11
		6-10	Modified Usen questions		17.8	82.2	

[a] Mean screen time including watching TV, using a computer and playing video games; [b] Total sitting time; [c] Mean result for the overall population 3 to 17 years old; [d] Not communicated

Study 2. Results from the first French Report Card on Physical Activity for Children and Adolescents

Abstract

Background: Many countries publish periodic Report Cards on physical activity for children and youth. This paper presents the results from the first French Report Card providing a systematic synthesis and assessment of the national engagements to facilitate childhood physical activity.

Methods: A search for nationally representative data on 8 indicators of physical activity was conducted and the data were assessed by an expert panel according to international procedures. Whether or not children across France are achieving specific benchmarks was rated using an established grading framework [A,B,C,D,F or INC(incomplete)]. Data were interpreted, grades assigned and detailed in the 2016 Report Card that was produced and disseminated.

Results: The expert panel awarded the following grades: Overall Physical Activity: INC; Organized Sport Participation: D; Active Transportation: D; Sedentary Behaviors: D; Family and Peers: INC; School: B; Community and the Built Environment: INC; Government Strategies and Investment: INC.

Conclusions: The grades reveal that efforts must be done to improve youth's physical activity and that several gaps in the literature still need to be addressed. Collectively the results highlight that children's physical activity levels are low and that further national supports and investments are needed to promote childhood healthy active living in France.

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Section: Original Research

Article Title: Results From the First French Report Card on Physical Activity for Children and Adolescents (2016)

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Results from the first French Report Card on Physical Activity for Children and Adolescents (2016)

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"Results From the First French Report Card on Physical Activity for Children and Adolescents (2016)"
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Introduction

Low levels of physical activity and high levels of sedentary behaviors are now recognized as major risk factors for many chronic cardiovascular, metabolic and cognitive diseases [1-4]. A high physical activity level during youth is protective against excessive body fat [5], the development of cardiovascular risks factors during childhood [6], or later during adulthood [7]. Moreover, there is significant tracking of physical activity, particularly organized sport [8] and physical inactivity behaviors from youth into adulthood, which predisposes inactive children to become inactive adults [7-9]. The World Health Organization, and at the national level, the French governmental agency in charge of physical activity recommendation indicate that children aged 5-17 years should accumulate at least 60 minutes of moderate-to-vigorous-intensity physical activity daily [10].

Since 2005, Canada has been releasing an annual *Report Card on the Physical Activity of Children and Youth* [11,12]. The Canadian Report Card has resulted in impressive impact on research, policy and practice [12]. In 2014, 15 countries participated in a harmonized project called the "Global Matrix" where comparable grades were released concurrently, exploiting opportunity for comparisons and cross-fertilization of ideas to "improve the grades" [13]. More recently, 38 different countries published a Report Card as part of the "Global Matrix 2.0" project [14]. Each report card provides a state-of-knowledge review of the children's physical activity level in the country, which can serve to determine the proportion of children reaching the physical activity recommendations, assist in the development of evidence-based physical activity policy, identify research gaps, raise awareness of the importance of physical activity and monitor program effectiveness [15].

Although lower than in many countries, there has been a clear trend toward an increase in the prevalence of overweight and obesity in French youth [16]. Currently, 15.8% of 7-9 year old French children are overweight and 2.8 % are obese [17]. The primary cause of the rising prevalence of obesity is a disturbed energy balance, with energy intake that exceeds

energy expenditure, the latter being partly determined by physical activity-related energy expenditure.

The purpose of this paper is to report a summary of the first *French Report Card on the Physical Activity of Children and Adolescents* adhering to the procedures outlined by Active Health Kids Canada [15]. The data reported in the present article are based on a review and synthesis of the academic peer-reviewed literature from 2006 to 2016 and the compilation and analysis of evidence available from French governmental bodies.

Methods

This first French Report Card was prepared and redacted with the collective work of an expert panel including academics from 5 Universities across France, representatives from the French National Observatory for Physical Activity and Sedentary Behaviors (ONAPS; http://www.onaps.fr/) and researchers from France, with guidance from the Active Healthy Kids Global Alliance (www.activehealthykids.org). The expert panel leader was responsible for integrating each expert's contribution and for writing the Report Card main document. All members reviewed the whole document and contributed to the grade assignment process for each indicator.

All the authors contributed to identify key data sources and synthesized the evidence from a range of national surveys. The Report Card has been realized thanks to a close collaboration with the ONAPS whose main activity was to gather and synthetize national database results and surveys.

The Report Card assessed eight indicators of physical activity: 1) Overall Physical Activity Levels, 2) Organized Sport Participation, 3) Active Transportation, 4) Sedentary Behaviors, 5) Family and Peers, 6) School setting, 7) Community and the Built Environment, and 8) Government Strategies and Investment. These indicators are consistent with the indicators used by the Global Matrix projects (http://www.activehealthykids.org/) (except that this first issue of the French Report Card does not include active play as an indicator due to a clear lack of data and clear identification in national studies and surveys) [13,14]. Data used to

inform the grades for these indicators were provided from several national surveys including the National Nutrition and Health Survey [18]; the National study of individuals' food consumption [19]; the National Survey of school-aged children [20]; the International study on Health Behaviour in School-aged Children [21]; National Observatory for Road Safety; others sources including reports from the Minister for National Education, from Sport Federations among other institutions.

The expert panel first met in March 2016 and then indicators were collectively targeted and assigned to specific members of the panel according their area of interest and expertise. Grades were discussed and assigned in October 2016 where members of the expert panel presented the available evidence; final grades were then collectively assigned for each indicator once consensus agreement had been reached. The nature and origin of the data sources, the sample size, age range of participants considered, and year of publication were parameters considered to establish the quality of the available data.

Grades were assigned following the framework and benchmarks used by the Active Healthy Kids Global Alliance [13,14]. The grading framework was: A: 81% to 100%, B: 61% to 80%, C: 41% to 60%, D: 21% to 40%, F: 0% to 20%. An incomplete (INC) grade was assigned where insufficient data were available or due to the absence of a suitable benchmark.

Results and Discussion

The grades assigned for the 2016 French Report Card are summarized in Table 1. Results are discussed herein on a grade by grade basis.

Overall Physical Activity Levels: INC

While 83% of the 3-10 years old kids receive at least one hour of Physical Education at school, only 2/3 are engaged in extra-school physical activity (INCA 2). Between 11 and 14 years of age, 55% of girls and 65% of boys declare at least 150 minutes per week of moderate physical activity [18], which remains below the recommended 60 min a day. Although it remains difficult to precisely estimate the percentage of the pediatric population meeting the actual

physical activity guideline, the presented data urge us to alert all the concerned stakeholders. Most of the available data are about 10 years old and have been carried out as part of only one survey [19] and are self-reported data only (nationally representative). There is a clear need for stronger evidence based data at a national level regarding the physical activity level in children and adolescents in France. Overall, the research activity in the field of physical activity in youth is weak. As an indicator, approximately only 2% of the obtained results using « Physical Activity » and « Children » as key words for a Medline search are based on studies including French children. Moreover, data reported in the present report are the most recent that can reflect the French youth population are already close to 10 years old. Results from the INCA 3 as well as the Esteban survey studies are expected for 2017 and will constitute an important update.

Organized Sport Participation: D

We assessed participation to organized Sport based on the number of sports licenses delivered by French sports federations after registration in sports club in 2015. Licenses delivered for school-based organized sports are excluded of the current section.

From 0 to 24 years old, 40% of the population is engaged in a sport club. The age range with the highest participation is between 10 to 14 years old for both boys and girls. The proportion of children with a sport license decreases significantly after 14 years old. Large differences in organized sports participation were seen between gender, and between areas of low- and high-incomes. Overall, only a little more than 1/3 of sports licenses (64%) from 0 to 24 years old are delivered to girls. Close to 40% (39.7%) of the national sport federations have at least 75% of their affiliates as boys. Some of the main federations (>40 000 affiliates from 0 to 19 years old), such as soccer, rugby or cycling have more than 90% of participants being boys.

Active Transportation: D

Close to 40% of the 3-10 years old [18,19] and 30% of the 11-14 years old [19,21] use active transportations to go to school, mainly walking, with however important disparities between [21]. The proportion of French children cycling to school appear very low (>10%), with large differences between regions, and evidences suggesting that boys are twice more likely to cycle to school compared with girls [19,21].

Sedentary Behaviors: D

According to the INCA 2 survey, 3 to 17 years old children and adolescents spend about 02:48 hours per day in front of a screen [19]. 26% and 24% of 3 to 10 years old boys and girls devote more than 3 hours a day in front of a screen respectively, 46% and 46% between 11 and 14 years old and 64% and 43% between 15 and 17 years old [19]. Only 17% of the 5-6 years old children spend less than an hour per day in front of a screen during school days, 24% of the 10-11 years old and 43% of the 14-15 years old youth spend more than 3 hours in front of a screen daily [20,22]. This daily screen time is inversely related with the family socio-economic status and the parents' academic level in 3 to 17 years old youth [19,20,22].

Family and Peers: INC

Based on the available evidence, it remains today difficult to grade this Family and peers indicator. One study showed that 46% of fathers and 42% of mothers of 12 years old children are regularly engaged in physical activity [23]. In addition, girls and boys were more likely to participate in organized PA when the two parents themselves practiced sports. At the opposite, sedentary behaviors of the parents were associated with sedentary behaviors of the children. Since these data were gathered more than 10 years ago, we are missing recent and accurate surveys considering the effect of parents or siblings and friends physical activity on our kids and adolescents physical activity level.

School setting: B

10% of the school curriculum in primary school and 14% in secondary school are devoted to physical education. In primary schools, 3 hours of physical education per week are recommended and between 4 to 3 hours per week in secondary schools. In high schools, students follow between 2 to 3 hours of PE per week. Among the OCDE countries, France is the one that devotes the more time to PE in secondary schools. The number of children and adolescents affiliated to school-based extra-curricular physical activity keeps growing since 2009 (2009 = 1 006 419; 2015 = 1 050 000) reaching the world highest number of affiliations in 2014. The number of affiliated children decreases with age.

Community and the Built Environment: INC

Based on the 2014 report of "L'Observartoire des Mobilités Actives" which gathered data of cities with more than 50 000 inhabitants, 26% of the urban public roads currently benefit from specific cycling paths, against 21% in 2011 with an increase of 34% of the two-ways cycling paths between 2011 and 2013 [24]. Almost all the collectivities with more than 50 000 inhabitants have a budget specifically allocated to cycling paths in 2013 [24]. Accurate and valuable evidence and data are missing regarding urban parks and leisure areas. Regarding potential associations between the built environment and physical activity, there is currently a lack of studies and we therefore attributed the grade of "Incomplete" to this item.

Government Strategies and Investment: INC

Currently, there are few specific actions at the national level specifically devoted to the promotion of an active lifestyle in children and adolescents. Santé Publique France, a governmental agency in charge of promotion of health and prevention of health risk, offered in 2016 a Massive Open Online Course (MOOC) designed to provide support for the promotion of physical activity and prevention of sedentary behaviors in youth [25]. Santé Publique France reported that 1512 participants, with a majority of health and physical activity professionals and students attended the 6-week MOOC. Despite these efforts, the available information is

today insufficient to clearly evaluate the impact of the government for the promotion of physical activity in youth and there is no coordinated strategy of health-enhancing physical activity promotion. There is a clear gap that will need to be addressed to assess the efficacy of such interventions.

Conclusion

The redaction of the 1st Report Card for France was initiated after the launching in 2016 of the ONAPS on the initiative of the French Ministry of Sports, which is a structure in charge of physical activity and sedentary behaviors of the French population. The panel in charge of the Report Card included several members the ONAPS as well as external academic experts in the field of physical activity in children. The lack of grade for overall physical activity level is a major limitation of the present Report Card. This cast light on the need for studies based on a combination of objective and declarative assessment of PA level and PA characteristics in children. Several local and small scale studies have used objective methods, such as accelerometry in France to study physical activity behaviors in children. Although interesting, these studies may not accurately reflect whether children reach the PA recommendations at the country level. The current RC illustrates the gap that has grown in term of children physical activity research activity in France relative to countries with similar population and socio-economic characteristics. Given the time needed to implement such studies, it will take years before we are able to get data properly reflecting PA behaviors of French children.

A 2nd important limitation is that we were unable to provide grade for three other physical activity indicators. Again, this was related to the lack of nationally representative studies for these indicators. Regarding the remaining items 3 D grades were awarded, which indicate that similarly to children of most European countries, French children have low physical activity level and spend large amount of time engaged in sedentary behaviors.

In regards to the very low proportion of children using cycling as a mean of active transportation, there is a need to implement and strengthen cycling policies. Initiatives could include designing and building cycle routes that allow cycling in good conditions of effort and safety, in a time-efficient way to schools, and building bicycle parking near or within schools.

A positive note is the B grade attributed to school-based PA, which indicates that school fulfills its role of providing access to sports and PA to all children.

To conclude, the current RC emphasizes the need to implement national PA promotion programs which appears to be insufficient for indicators such as active transportation, and the need for larger scale studies to assess what French children are currently doing in terms of PA which remains largely unknown. Implementing such a national policy involving the different concerned sectors and based upon a clear coordination would fit within the 2016-2025 World Health Organization strategy for physical activity in European regions whose priorities are to support the development and health of children and adolescents as well as to favor better monitoring and surveillance, and to support the provision of tools and platforms to enhance evaluation and research processes.

Finally, while the redaction of this first French Report Card also gave its expert committee to settle its methodology, the ambition is clearly to develop and improve this process and to join the international Global Matrix.

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References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act.* May 11 2010;7:40.

2. Poitras VJ, Gray CE, Borghese MM, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab.* Jun 2016;41(6 Suppl 3):S197-239.

3. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab.* Jun 2016;41(6 Suppl 3):S240-265.

4. Bherer L. Cognitive plasticity in older adults: effects of cognitive training and physical exercise. *Ann N Y Acad Sci.* Mar 2015;1337:1-6.

5. Ruiz JR, Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjostrom M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *Am J Clin Nutr.* Aug 2006;84(2):299-303.

6. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet.* Jul 22 2006;368(9532):299-304.

7. Raitakari OT, Porkka KV, Taimela S, Telama R, Rasanen L, Viikari JS. Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. The Cardiovascular Risk in Young Finns Study. *Am J Epidemiol.* Aug 01 1994;140(3):195-205.

8. Kjonniksen L, Anderssen N, Wold B. Organized youth sport as a predictor of physical activity in adulthood. *Scand J Med Sci Sports.* Oct 2009;19(5):646-654.

9. Telama R, Yang X, Viikari J, Valimaki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med.* Apr 2005;28(3):267-273.

10. ANSES. *Actualisation des repères du PNNS - Révisions des repères relatifs à l'activité physique et à la sédentarité*: Agence Nationale de Sécurité Sanitaire, Alimentation, Environnement, Travail;2016.

11. Barnes JD, Cameron C, Carson V, et al. Results From Canada's 2016 ParticipACTION Report Card on Physical Activity for Children and Youth. *J Phys Act Health.* Nov 2016;13(11 Suppl 2):S110-S116.

12. Tremblay MS, Barnes JD, Cowie Bonne J. Impact of the Active Healthy Kids Canada report card: a 10-year analysis. *J Phys Act Health.* May 2014;11 Suppl 1:S3-S20.

13. Tremblay MS, Gray CE, Akinroye K, et al. Physical activity of children: a global matrix of grades comparing 15 countries. *J Phys Act Health.* May 2014;11 Suppl 1:S113-125.

14. Tremblay MS, Barnes JD, Gonzalez SA, et al. Global Matrix 2.0: Report Card Grades on the Physical Activity of Children and Youth Comparing 38 Countries. *J Phys Act Health.* Nov 2016;13(11 Suppl 2):S343-S366.

15. Colley RC, Brownrigg M, Tremblay MS. A model of knowledge translation in health: the Active Healthy Kids Canada Report Card on physical activity for children and youth. *Health Promot Pract.* May 2012;13(3):320-330.

16. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes.* 2006;1(1):11-25.

17. Salanave B, Peneau S, Rolland-Cachera MF, Hercberg S, Castetbon K. Stabilization of overweight prevalence in French children between 2000 and 2007. *Int J Pediatr Obes.* 2009;4(2):66-72.

18. USEN UdSedEN. *Étude nationale nutrition santé (ENNS, 2006). Situation nutritionnelle en France en 2006 selon les indicateurs d'objectif et les repères du Programme national nutrition santé (PNNS).* . Paris: Université de Paris 13.;2007.

19. (AFSSA) AFdSSdA. *Etude individuelle Nationale sur les Consommations Alimentaires 2006-2007 (INCA2).* Paris: AFSSA;2007.

20. DREES-DGESCO DdlR, des Etudes, de l'Evaluatio et des Statistiques - Direction générale de l'enseignement scolaire – Éducation nationale. Drees-DGESCO, Enquête nationale de santé auprès des élèves de CM2 (année scolaire 2007-2008). 2008.

21. Godeau EN, F., Arnaud, C. *La santé des collégiens en France/ 2010. Données Françaises de l'enquête internationale Health Behaviour in School-Aged Children (HBSC).* Saint-Denis: INPES, coll. Etudes Santé 2012.

22. DREES-DGESCO DdlR, des Etudes, de l'Evaluatio et des Statistiques - Direction générale de l'enseignement scolaire – Éducation nationale. *Enquête nationale de santé auprès des élèves de grande section de maternelle (année scolaire 2012-2013).*2013.

23. Wagner A, Klein-Platat C, Arveiler D, Haan MC, Schlienger JL, Simon C. Parent-child physical activity relationships in 12-year old French students do not depend on family socioeconomic status. *Diabetes Metab.* Sep 2004;30(4):359-366.

24. OMA OdMA. *Les politiques en faveur des piétons et des cyclistes les villes françaises. Résultats synthétiques de l'enquête nationale 2012/2013.*2014.

25. SPF SPF. *MOOC 2016 "promouvoir l'activité physique et limiter la sédentarité des jeunes" : bilan de la session*2016.

Table 1. Grades According to Physical Activity Indicator established by the Active Healthy Kids Global Alliance.

Indicators	Grades
Overall Physical Activity Levels	INC
Organized Sport Participation	D
Active Transportation	D
Sedentary Behaviors	D
Family and Peers	INC
School setting	B
Community and the Built Environment	INC
Government Strategies and Investment	INC

The grade for each indicator is based on the percentage of children and youth meeting a defined benchmark: A is 81%–100%; B is 61%–80%; C is 41%–60%, D is 21%–40%; F is 0%–20%; INC is Incomplete data.

Study 3. Reliability and validity of the French version of the global physical activity questionnaires

Abstract

Background: The Global Physical Activity Questionnaire (GPAQ) has been used to measure physical activity (PA) and sedentary time in France, but no study has assessed its psychometric properties. This study aimed to compare the reliability as well as criterion and concurrent validity of the French version of the GPAQ with the French International PA Questionnaire long form (IPAQ-LF) and use of an accelerometer in a general adult population.

Methods: We included 92 participants (students or staff) from the Medicine Campus at the University of Lorraine, Nancy (north-eastern France). The French GPAQ was completed twice, 7 days apart, to study test-retest reliability. The IPAQ-LF was used to assess concurrent validity of the GPAQ, and participants wore an accelerometer (ActiGraph GT3X+) for 7 days to study criterion validity. Reliability as well as concurrent and criterion validity of the GPAQ were tested by the intraclass correlation coefficient (ICC), Spearman correlation coefficient for quantitative variables, and Kappa and Phi coefficients for qualitative variables. Both concurrent and criterion validity of GPAQ were assessed by Bland-Altman plots.

Results: The GPAQ showed poor to good reliability (ICC = 0.37–0.94; Kappa = 0.50–0.62) and concurrent validity (Spearman r = 0.41–0.86), but only poor criterion validity (Spearman r = 0.22–0.42). Limits of agreement for the GPAQ and accelerometer were wide, with differences between 286.5 min/day and 601.3 min/day.

Conclusion: The French version of the GPAQ provides limited but acceptable reliability and validity for the measurement of PA and sedentary time. It may be used for assessing PA and sedentary time in a French adult population.

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Original article

Reliability and validity of the French version of the global physical activity questionnaire

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Abstract

Background: The Global Physical Activity Questionnaire (GPAQ) has been used to measure physical activity (PA) and sedentary time in France, but no study has assessed its psychometric properties. This study aimed to compare the reliability as well as criterion and concurrent validity of the French version of the GPAQ with the French International PA Questionnaire long form (IPAQ-LF) and use of an accelerometer in a general adult population.

Methods: We included 92 participants (students or staff) from the Medicine Campus at the University of Lorraine, Nancy (north-eastern France). The French GPAQ was completed twice, 7 days apart, to study test-retest reliability. The IPAQ-LF was used to assess concurrent validity of the GPAQ, and participants wore an accelerometer (Actigraph GT3X+) for 7 days to study criterion validity. Reliability as well as concurrent and criterion validity of the GPAQ were tested by the intraclass correlation coefficient (ICC), Spearman correlation coefficient for quantitative variables, and Kappa and Phi coefficients for qualitative variables. Both concurrent and criterion validity of GPAQ were assessed by Bland-Altman plots.

Results: The GPAQ showed poor to good reliability (ICC = 0.37–0.94; Kappa = 0.50–0.62) and concurrent validity (Spearman r = 0.41–0.86), but only poor criterion validity (Spearman r = 0.22–0.42). Limits of agreement for the GPAQ and accelerometer were wide, with differences between 286.5 min/day and 601.3 min/day.

Conclusion: The French version of the GPAQ provides limited but acceptable reliability and validity for the measurement of PA and sedentary time. It may be used for assessing PA and sedentary time in a French adult population.

Keywords: Measurement; Physical activity; Psychometric analysis; Questionnaire; Reliability; Self-report; Sitting time; Validity

1. Introduction

Physical activity (PA) surveillance is a public health preoccupation and is considered by the World Health Organisation (WHO) as a protective factor for non-communicable diseases.[1] A high PA level is associated with reduced mortality and the occurrence of diseases or their consequences and improved quality of life.[2,3] Because of its therapeutic role, PA is also used as adjuvant treatment in chronic diseases.[4,5]

In this context, the measurement of PA is essential to assess strategies promoting PA and to survey and compare PA levels between countries. Questionnaires are the most commonly used instrument in epidemiologic studies to assess PA because they are relatively inexpensive and easy to use both for a large population and in a short time. They can be self-administered, completed during an interview or administered by phone. Many different questionnaires have been developed and used to measure PA, so international comparison is difficult, and overall, their development lacked methodological quality.[6]

In the late 1990s, the International Physical Activity Questionnaire (IPAQ) was developed in 2 forms (short form (IPAQ-SF) and long form (IPAQ-LF)) to create national and international comparable and standardized measures of PA. The

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long form of the IPAQ (31 items) was developed to capture information about domains of PA but has been considered too long and too complex to be used in surveillance studies, while the short form (9 items) does not take into account the domains of PA.[7,8] For PA surveillance, the measurement of PA domains is needed to understand the patterns of PA and to develop interventions. Thus, in order to provide an instrument that would address the limits of these questionnaires, the Global Physical Activity Questionnaire (GPAQ) has been developed by the WHO, as part of the WHO STEPwise approach to survey chronic disease risk factors. It is now recommended by the WHO for national surveillance of PA.[1] Since its development, the GPAQ has been translated into and tested in many languages and is used in many countries.[9-16] In France, the GPAQ has been used to describe and analyse PA and sedentary time of the general population.[17] However, it has not been validated in the French language. Evidence for the validity and reliability of the French version of the GPAQ is needed because the results may be affected by the sociocultural specificities of the country.[18]

Rigorous methodology is needed to examine the degree in which an instrument is affected by measurement error (reliability) and measures the construct it intends to measure (validity).[19] Concurrent validity refers to the degree to which the GPAQ measures what it purports to measure, and criterion validity is the degree to which the results of the questionnaire are an adequate reflection of a "gold standard". Because of no satisfying available gold standard measurement for PA behavior, objective measures such as accelerometers and pedometers are commonly used. To appraise the concurrent validity of the GPAQ, a questionnaire measuring the same construct and with similar structure is considered relevant. Even if the IPAQ-LF is more detailed than the GPAQ, it is the most similar in its construct and its structure. For this reason, the IPAQ-LF has been considered relevant to examine the concurrent validity of the GPAQ.

This study aimed to assess the test-retest reliability as well as criterion and concurrent validity of the French version of the GPAQ by comparison with the IPAQ-LF and use of an accelerometer in a general adult population in France.

2. Methods

2.1. Patients and study design

A convenient sample was recruited from January 20, 2015 to April 20, 2015, from the Medicine Campus, University of Lorraine, Nancy (north-eastern France), by posting an advertisement on campus and by e-mailing students and staff. Participants had to be ≥18 years old, working or studying at the Medicine Campus, able to read and understand French, and willing to participate in the study. The study protocol was approved by the Legal representative of the French data protection authority (Commission Nationale Informatique et Libertés) of the University of Lorraine, France. All participants were asked to read and sign a consent form. A ratio of 5 subjects per item was used to determine the number of participants to include.[20] Because the GPAQ contained 16 items, a minimum number of 80 participants was required.

Each subject was invited to participate in a face-to-face interview on Day 0 (D0) and receive all explanations about the study and its purpose from an interviewer. After giving consent, participants answered sociodemographic and anthropometric questions, then completed the GPAQ and IPAQ-LF. Then, the interviewer gave the participant an accelerometer and explained its use. Participants were asked to wear the accelerometer for 7 consecutive days. Eight days after the first interview (D8), participants returned the accelerometer and completed the GPAQ and IPAQ-LF a second time. They were also asked if they had changed their activity during the week of the study as compared to a typical week.

2.2. Instruments

We used the French translation of the GPAQ (Version 2.0)[21] to gather information on the time spent in moderate and vigorous PA and in sedentary behavior. At the WHO level, the GPAQ has been translated in French by a professional translator, and back-translated by 2 independent technical experts. The versions were then compared, and where discrepancies existed, these were discussed and a consensus was found. The GPAQ contains 16 items designed to assess the frequency and duration of PA in 3 domains: during work, transportation, and leisure time as well as time spent sitting during a typical week. It distinguishes PA duration by min/day and min/week for each PA domain, which allows for calculating the energy expenditure scored in metabolic equivalent tasks (METs). One MET corresponds to resting energy expenditure. According to duration and energy expenditure, PA level was classified as low, moderate, and high.

The French IPAQ-LF was used to test the concurrent validity of the GPAQ. It contains 27 items designed to assess the frequency and duration of PA in 4 domains: during work, transportation, household activities, and leisure time, then time spent sitting.[22] The IPAQ-LF scores PA in terms of energy expenditure (MET), intensity (low, moderate, high, and sedentary), and duration (min/day, min/week).

The ActiGraph accelerometer, model GT3X+ (ActiGraph, Pensacola, FL, USA), was used as the criterion measure. The device is worn at the waist and measures and records the changes in acceleration and deceleration movements in 3 axes (anteroposterior, superio-inferior, and medial side). Data for measuring acceleration and deceleration are stored in non-volatile flash memory and can be read by using ActiLife software. Accelerometer data were scored using ActiLife 6 Data Analysis Software (ActiGraph) to assess time spent at various PA intensity levels (moderate and vigorous in min/day). Freedson's Adult VM3 (2011) cut-off points were used to determine several PA levels: light, 0–2690 counts per minute (CPM); moderate, 2691–6166 CPM; vigorous, 6167–9642 CPM; and very vigorous, 9643–∞ CPM. Minutes spent at each intensity level were averaged across valid days. Non-wear periods were identified as 60 consecutive minutes with no movement data o (0 counts).[23] All calculations were based on 60 s epochs; an epoch is a user-defined time-sampling interval used to filter the acceleration signal. In this study, we used 7-days PA questionnaires, so only

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data with ≥10 h of wear time per day for ≥7 days were considered valid and included in the analysis.[24,25]

Sociodemographic data such as age, sex, and education (high school or higher education) and socioprofessional status (student or staff) were collected. Anthropometric data including height (in cm) and weight (in kg) were reported by each participant for calculating body mass index (BMI, kg/cm^2), then participants were classified by BMI level: underweight (BMI <18.5 kg/cm^2), normal weight (18.5–24.9 kg/cm^2), overweight 25.0–29.9 kg/cm^2), and obese (>30 kg/cm^2). All data (except accelerometer data directly transferred into ActiLife software) were entered into an electronic case report form (CRF) created with Epidata 3.1 (The EpiData Association, Odense, Denmark).

2.3. Statistical analysis

Data analysis involved use of SAS 9.4 (SAS Inst., Cary, NC, USA). Qualitative variables were reported as relative frequency and quantitative variables as mean ± SD or median. The Kolmogorov-Smirnov test was used to assess the normality of data distribution. For participants who declared changing their PA, paired Student's *t* test was used to evaluate the difference in total PA between the 2 visits. Because the activity measured by the GPAQ includes work and household activities, it was compared to the sum of work and household PA measured by the IPAQ-LF.

Test–retest reliability was tested by the kappa coefficient for categorical data and the intraclass correlation coefficient (ICC) for quantitative data. Spearman correlation was also calculated for quantitative data to compare with previous studies.[11-14] Non parametric correlation coefficient was used because of non-Gaussian distribution for most of PA-score. For one of the GPAQ's question, one answer modality was overrepresented and the correlation was not concordant with the observed agreement (when visualizing the data, the agreement seems good but it was not observed when assessed with ICC and Spearman correlation). Thus the variable was converted into a discrete variable, and the prevalence-adjusted and bias-adjusted kappa (PABAK) was used to assess the agreement.[26] ***Concurrent validity*** was examined by comparing data for the GPAQ and IPAQ-LF at D0 and D8[19] with the Spearman correlation coefficient and its 95%CI for quantitative data and the Phi coefficient for qualitative data. ***Criterion validity*** was examined by comparing minutes of PA obtained with the GPAQ to accelerometer-obtained data at D8 by the Spearman correlation coefficient and its 95%CI.

Both the concurrent and criterion validity of the GPAQ were assessed by Bland-Altman plots to measure the agreement and bias for total PA and sedentary time between questionnaire's answers and results from accelerometer.[27] Correlation assesses the degree to which 2 variables are related. However, a high correlation does not necessary imply that there is good agreement between the 2 methods. Thus, Bland-Altman was used to quantify the agreement between 2 measurements by plotting the difference between the 2 measurements against the average obtained with each of the 2 methods.

Kappa and Phi coefficients were classified by the ratings suggested by Landis and Koch:[28] poor, <0.00; slight, 0.00–0.20; fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80; and almost perfect, 0.81–1.00. ICC and Spearman correlation <0.50 were considered as poor, between 0.50 and 0.75 as moderate, and >0.75 were as good.[29]

3. Results

3.1. Participant characteristics

In total, 92 subjects participated in the study (mean age 30.1 ± 10.7 years, range 19–58 years; 67 (72.8%) females); 56.5% were students, 95.6% had higher education, 9.8% had chronic disease, and 76.9% had normal BMI (Table 1). Overall, 25% of participants declared having changed their activity between the 2 visits, but the difference between the total PA means measured by the GPAQ was not statistically significant ($p = 0.49$).

3.2. Descriptive statistics for the GPAQ, IPAQ, and accelerometer

All descriptive statistics for GPAQ, IPAQ, and accelerometer are presented in Table 2.

3.3. Test-retest reliability

The ICCs ranged from 0.37 to 0.94, with the highest ICC for vigorous leisure PA. Only total vigorous and vigorous leisure PA showed good reliability, whereas all other PA scores were poor to moderate, with the lowest value for moderate leisure PA(ICC = 0.37, 95%CI: 0.15–0.56). A good reliability for total sitting time was also observed (ICC = 0.80, 95%CI: 0.69–0.87) whereas it was moderate for total PA (ICC = 0.58, 95%CI: 0.40–0.72). For PA level, the kappa coefficient showed moderate to substantial correlation, varying from 0.50 to 0.62 for moderate and low PA levels, respectively. For vigorous activity at work, the GPAQ showed an almost perfect reliability (PABAK = 0.91). Except for total PA, with ICC = 0.58, 95%CI: 0.40–0.72 and Spearman's r = 0.82, 95%CI: 0.72–0.88, most Spearman values were similar to the ICC (Table 3).

Table 1
Sociodemographic and anthropometric characteristics of participants.

	Total sample ($n = 92$, %)
Sex	
Male	25 (27.7)
Female	67 (72.8)
Socio-professional status	
Student	52 (56.5)
Staff	40 (43.5)
Education level	
High school	4 (4.4)
Higher education	88 (95.6)
Age (year)*	30.1 ± 10.7
BMI (kg/cm^2)*	22.6 ± 3.5
BMI classes (kg/cm^2)*	
Underweight <18.5	3 (3.3)
Acceptable weight 18.5-24.9	71 (76.9)
Overweight 25.0–29.9	14 (15.4)
Obese >30	4 (4.4)

* Data are presented as mean ± SD.
Abbreviation: BMI = body mass index.

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Table 2
Data for PA measured by the Global Physical Activity Questionnaire GPAQ, IPAQ and an accelerometer at day 0 (D0) and day 8 (D8) in 92 participants.

Variable	GPAQ				IPAQ				Accelerometer	
	D0		D8		D0		D8			
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
Total PA (MET min/week)	2011.1 ± 1940.5	1580.0	1818.0 ± 1478.2	40.7	2648.3 ± 2099.8	2251.5	2484.1 ± 2268.0	1777.5		
PA by domain										
Work										
Vigorous	31.3 ± 300.3	0	33.0 ± 230.6	0	34.8 ± 300.8	0	15.6 ± 85.7	0		
Moderate	467.4 ± 1575.3	0	321.1 ± 965.4	0	203.5 ± 758.1	0	212.4 ± 871.2	0		
Transport	375.9 ± 410.8	240.0	378.5 ± 426.2	250.0	306.8 ± 295.5	242.5	351.3 ± 414.0	260.7		
Household										
Vigorous	n/a	n/a	n/a	n/a	4.5 ± 35.4	0	22.1 ± 126.1	0		
Moderate	n/a	n/a	n/a	n/a	475.9 ± 785.2	150.0	356.7 ± 594.3	160.0		
Work + household										
Vigorous	n/a	n/a	n/a	n/a	39.3 ± 302.4	0	37.8 ± 171.8	0		
Moderate	n/a	n/a	n/a	n/a	695.0 ± 1080.1	240.0	596.1 ± 1189.1	190.0		
Leisure										
Vigorous	852.2 ± 1073.3	680.0	772.6 ± 955.9	480.0	868.7 ± 1085.9	600.0	691.3 ± 1011.5	0		
Moderate	284.3 ± 366.0	240.0	312.8 ± 382.9	240.0	193.9 ± 265.4	0	218.9 ± 415.4	340.0		
Sitting time (min/day)	570.0 ± 152.8	600.0	588.6 ± 146.4	600.0	554.5 ± 138.5	584.3	583.6 ± 143.2	597.1	843.6 ± 134.5	814.0
PA duration by intensity (min/week)										
Vigorous	883.5 ± 1090.1	720.0	805.6 ± 977.7	480.0	903.5 ± 1102.4	720.0	707.0 ± 1015.6	360.0	72.0 ± 67.2	46.7
Moderate	751.7 ± 1659.8	360.0	633.9 ± 990.3	360.0	903.8 ± 1131.4	480.0	860.6 ± 1266.9	370.0	426.2 ± 139.5	429.4
PA level (%)										
Low	29.4		22.8		8.7		15.2			
Moderate	44.6		45.6		60.9		54.3			
High	26.1		22.8		30.4		30.4			

Abbreviation: GPAQ = global physical activity questionnaire; IPAQ = international physical activity questionnaire; MET = metabolic equivalent task; n/a = not assessed by the questionnaire; PA = physical activity.

3.4. Concurrent validity

For both measurement times, we observed good correlations between the GPAQ and IPAQ for vigorous activity during leisure, total vigorous activity, and sitting time ($r = 0.76$–0.89) (Table 4). The values at D0 and D8 seemed almost identical, but important discrepancies were observed between vigorous work at D0 ($r = 0.58$, 95%CI: 0.43–0.70) and at D8 ($r = 0.81$, 95%CI: 0.73–0.87). Overall, total PA showed moderate

Table 3
Test-retest reliability of the GPAQ ($n = 68$).

Variables	ICC (95%CI)	Spearman's Rho (95%CI)	Kappa coefficient
Total PA	0.58 (0.40–0.72)	0.82 (0.72–0.88)	
PA by domain			
Work			
Vigorous			0.91(+)
Moderate	0.48 (0.28–0.64)	0.52 (0.33–0.68)	
Transport	0.67 (0.52–0.79)	0.69 (0.53–0.79)	
Leisure			
Vigorous	0.94 (0.91–0.96)	0.89 (0.84–0.94)	
Moderate	0.37 (0.15–0.56)	0.53 (0.33–0.68)	
Sitting time	0.80 (0.69–0.87)	0.78 (0.67–0.86)	
PA by intensity			
Total vigorous	0.84 (0.76–0.90)	0.80 (0.70–0.88)	
Total moderate	0.48 (0.28–0.65)	0.56 (0.38–0.71)	
PA level			
Low			0.62
Moderate			0.50
High			0.57

(+): Adjusted kappa (PABAK).
Abbreviations: GPAQ = global physical activity questionnaire; PA = physical activity; ICC = intraclass correlation coefficient; 95%CI = 95% confidence interval.

Table 4
Concurrent validity between the GPAQ and IPAQ-LF data at day 0 (D0) and day 8 (D8) ($n = 92$).

Variable	D0		D8	
	Spearman's Rho (95%CI)	Phi coefficient	Spearman's Rho (95%CI)	Phi coefficient
Total PA	0.66 (0.53–0.76)		0.67 ((0.54–0.77)	
PA by domain				
Work				
Vigorous	0.58 (0.43–0.70)		0.81 (0.73–0.87)	
Moderate	0.56 (0.40–0.68)		0.61 (0.46–0.72)	
Transport	0.52 (0.35–0.65)		0.69 (0.57–0.79)	
Leisure				
Vigorous	0.86 (0.79–0.90)		0.79 (0.70–0.85)	
Moderate	0.46 (0.28–0.61)		0.53 (0.36–0.66)	
Sitting time	0.85 (0.78–0.90)		0.89 (0.84–0.93)	
PA by intensity				
Total vigorous	0.86 (0.79–0.90)		0.76 (0.66–0.84)	
Total moderate	0.41 (0.22–0.56)		0.58 (0.42–0.70)	
PA level				
Low		0.22		0.49
Moderate		0.27		0.27
High		0.57		0.54

Abbreviations: GPAQ = global physical activity questionnaire; IPAQ-LF = international physical activity questionnaire-long form; PA = physical activity.

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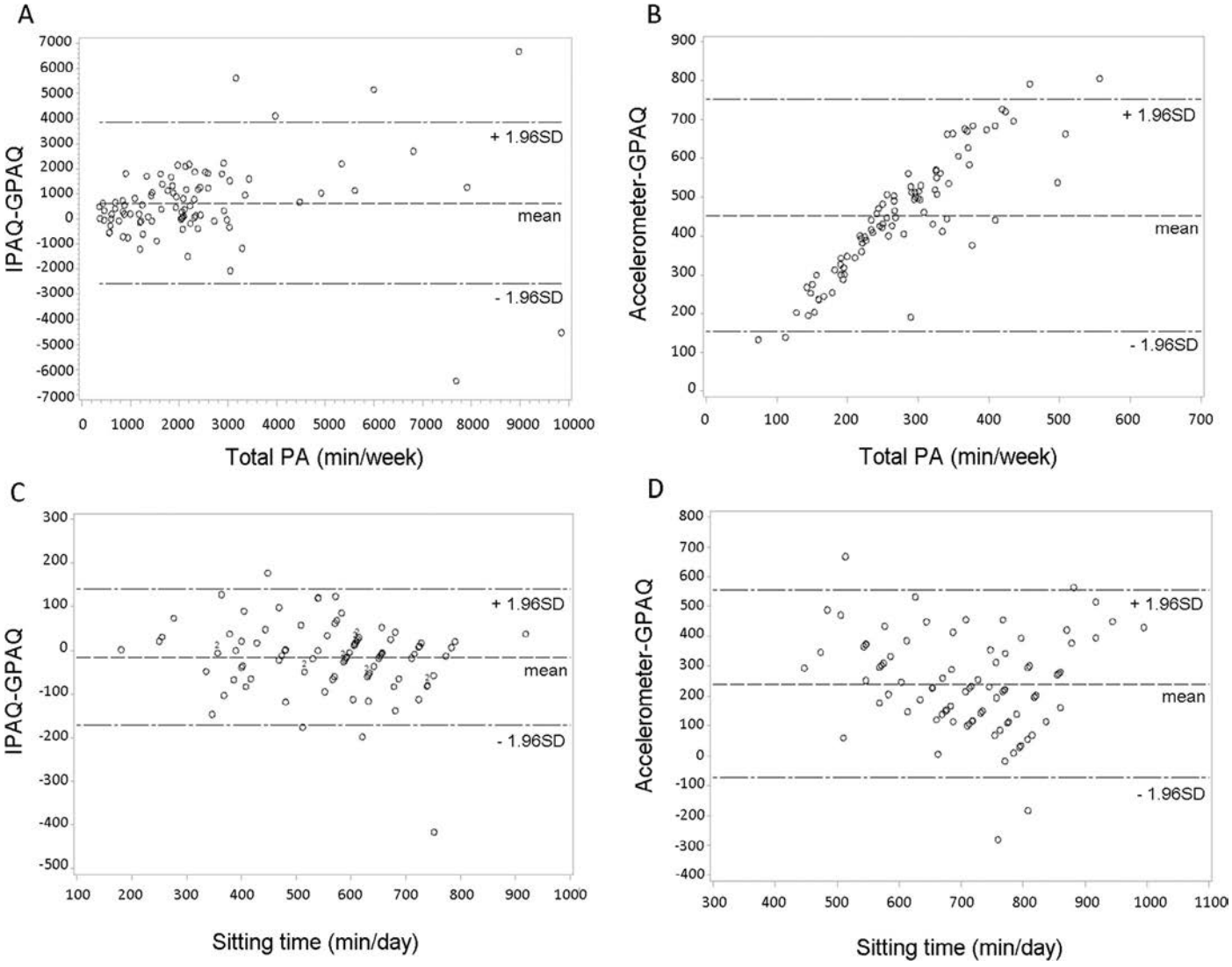

Fig. 1. Bland-Altman plots of the validity of the Global Physical Activity Questionnaire (GPAQ). A&C: Agreement of GPAQ with IPAQ for total PA(A), sitting time (B) at D0; B&D: Agreement of GPAQ with accelerometer for total PA (C), sitting time (D) at D8. IPAQ = international physical activity questionnaire; PA = physical activity.

correlation at both D0 ($r = 0.66$, 95%CI: 0.53–0.76) and D8 ($r = 0.67$, 95%CI: 0.54–0.77). Results of Bland-Altman analysis (Fig. 1A, C) for the GPAQ and IPAQ demonstrated a mean difference of 637.2 ± 1641.5 MET min/week. The limits of agreement for the 2 instruments were wide, with the difference between 1004.3 and 2580.1. For sedentary time, the mean difference of sedentary time was −15.5 ± 79.2 min/day. Overall, the classification by level of PA with the 2 questionnaires, at both times, was only poorly to moderately correlated, with a Phi coefficient ranged from 0.22 to 0.57.

3.5. Criterion validity

Accelerometer data were considered valid for 87 of the 92 participants (5 participants did not wear an accelerometer for at least 10 h per day over 7 days). Criterion validity was assessed by comparing total PA time spent in vigorous-intensity activity, or in moderate-intensity activity, or sitting per day reported with the GPAQ and derived from accelerometer counts. Poor but significant correlations for sedentary time ($r = 0.42$, $p < 0.01$) and total vigorous PA ($r = 0.38$, $p < 0.01$) were observed (Table 5).

Bland-Altman findings revealed that the GPAQ underreported total PA, with a mean difference between the GPAQ and accelerometer data of 443.95 ± 157.46 min/week (Fig. 1B, D). Limits of agreement for the 2 instruments were wide, with the difference between 286.5 and 601.3 min/week GPAQ underestimated sedentary time as compared with the accelerometer, with a mean difference between the 2 instruments of 251.2 ± 161.1 min/day. Limits of agreement for the 2 instruments ranged from 90.1 to 412.3 min/day.

4. Discussion

This study provides results, for the first time in a French population, for the reliability and validity of the GPAQ.

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Table 5
Criterion validity of the GPAQ: Spearman's correlation between the GPAQ and accelerometer data at day 8 (D8) ($n = 87$).

GPAQ	Accelerometer		
	Average sedentary counts/day	Average moderate counts/day	Average vigorous counts/day
Total vigorous PA (min)	0.02	0.19	0.38**
Total moderate PA (min)	−0.20	0.10	−0.10
Total PA across all domains (min)	−0.20	0.40**	0.24*
Time spent sitting (min)	0.42**	−0.22*	0.30**

* $p < 0.05$,** $p < 0.01$, compared GPAQ with accelerometer's values.
Abbreviations: GPAQ = global physical activity questionnaire; PA = physical activity.

For reliability, we found poor to good correlation, with highest value obtained for vigorous leisure PA, which indicates the stability of this type of PA. This result is consistent with the findings by Matthews et al.[30] who observed no significant variation in vigorous leisure time activity over 1 year in 580 healthy adults.[30] Overall, our results are comparable to other studies testing the psychometric properties of the GPAQ. Herrmann et al.[13] demonstrated short- and long-term reliability with ICC values from 0.54 to 0.92. Bull et al.[11] reported test–retest correlation coefficients from 0.67 to 0.81 and kappa coefficients from 0.67 to 0.73 for pooled data.

Whereas Bull et al.[11] and Herrmann et al.[13] showed a poor to moderate correlation between the GPAQ and IPAQ (with coefficients from 0.45 to 0.57 and 0.26 to 0.63, respectively), our results indicate a poor to good concurrent validity. A reason of this difference could be the use, by the former studies, of the IPAQ short-form (IPAQ-SF) as compared with our use of the long form. Unlike the GPAQ and IPAQ-LF, which measure PA in different domains, the IPAQ-SF measures overall PA duration and frequency, which may explain the differences. In measuring the concurrent validity of the GPAQ, the IPAQ-LF may be more relevant than the IPAQ-SF. However, despite an acceptable concurrent validity, the agreement between the GPAQ and the IPAQ-LF to classify participants by PA levels was only poor to moderate (Phi coefficients 0.22 to 0.57), with the highest agreement attributable to high PA level. In addition, the Bland-Altman analysis revealed wide discrepancies in total PA measured by the 2 questionnaires, with a mean difference of 637.2 ± 1641.5 MET min/week. A possible explanation could be that the IPAQ-LF contains detailed items dedicated to household activities, whereas in the GPAQ, household activities are included in work activities. Also, the IPAQ-LF measures time spent walking, which is not considered by the GPAQ if it is not brisk walking (considered moderate activity). These differences may explain the gap in total PA measured by the 2 questionnaires. These results indicate the difficulty in comparing different questionnaires and thus the need to use the same questionnaire in a population surveillance study to be able to interpret the pattern of PA over the years.

A poor criterion-related validity for the GPAQ as compared with accelerometer data was shown. These results are comparable to Cleland et al.[12] and Bull et al.,[11] who demonstrated correlations with accelerometer data ranging from 0.19 to 0.48 and −0.20 to 0.40, respectively, whereas results from Hoos et al.[14] showed correlations from 0.32 to 0.52. According to Bland-Altman analysis, the GPAQ seems to underestimate total PA as compared with the accelerometer. This finding can be explained by the GPAQ including only PA that lasts at least 10 min, whereas the accelerometer measures all activities regardless of duration. This result was already found in studies comparing questionnaires to objective measures of PA.[31] In this study and according to Bland-Altman analysis, the GPAQ seemed to underestimate sedentary time as measured by the accelerometer. This finding can be justified most likely by difficulty to accurately recall sitting time as well as by a response bias due to social desirability, which may affect the degree of reporting the time spent sitting by subjects.[31] Future research is needed to identify whether a bias does exist and if so, whether it differs by gender or socioprofessional status, and to what extent.

This study had several strengths, beginning with the adherence to standardized WHO protocols in administering questionnaires (GPAQ was always administered before the IPAQ) and the concordant measurement period (the same 7 days) for both questionnaires and the accelerometer. Also, we used Bland-Altman analysis, a useful and recommended approach to assess the level of agreement, as compared with usual correlation coefficients assessing only the strength of the relationship between the measures.[27] Finally, the use of the IPAQ-LF seems relevant because it induced better concurrent validity with the GPAQ than in previous studies.

The major limitation of this study was the use of accelerometer as an alternative to the gold standard. However, in the absence of a gold standard, accelerometer may be used to measure PA in daily life.[32,33]

5. Conclusion

This study adds important and new information in testing the psychometric properties of the GPAQ in France. The results suggest that the GPAQ is a reliable questionnaire for use in the French population. The overall validity was poor to good but remained acceptable and was similar to previous studies.[11,12] Another important highlight is the need to use the same questionnaire in surveillance studies to allow for comparison and follow-up of the PA level of the study population and for PA surveillance in general.

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All volunteers who participated in this study.

Authors' contributions

FZW, AV, ES, and FR participated in the design of the study. FZW and FR contributed to data collection. FZW and MLE contributed to data reduction/analysis. HE contributed to data analysis and interpretation of results. All authors contributed to the manuscript writing. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

References

1. World Health Organization. Global strategy on diet, physical activity and Realth. In: *Proceedings of the 57th World Health Assembly*. Geneva: World Health Organization; 2004.
2. O'Donovan G, Blazevich AJ, Boreham C, Cooper AR, Crank H, Ekelund U, et al. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci* 2010;**28**:573–91.
3. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity–a systematic review of longitudinal studies. *BMC Public Health* 2013;**13**:813. doi: 10.1186/1471-2458-13-813
4. Kujala UM. Evidence on the effects of exercise therapy in the treatment of chronic disease. *Br J Sports Med* 2009;**43**:550–5.
5. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scand J Med Sci Sports* 2006;**16**:3–63.
6. van Poppel MN, Chinapaw MJ, Mokkink LB, Van Mechelen W, Terwee CB. Physical activity questionnaires for adults. *Sports Med* 2010;**40**: 565–600.
7. Armstrong T, Bull F. Development of the world health organization global physical activity questionnaire (GPAQ). *J Public Health (Bangkok)* 2006; **14**:66–70.
8. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;**35**:1381–95.
9. World Health Organization. *WHO STEPS surveillance manual: the WHO STEPwise approach to chronic disease risk factor surveillance*. Geneva: World Health Organization; 2005.
10. Thuy AB, Blizzard L, Schmidt M, Hung Luc P, Magnussen C, Dwyer T. Reliability and validity of the global physical activity questionnaire in Vietnam. *J Phys Act Health* 2010;**7**:410.
11. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *J Phys Act Health* 2009;**6**:790.
12. Cleland CL, Hunter RF, Kee F, Cupples ME, Sallis JF, Tully MA. Validity of the Global Physical Activity Questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behaviour. *BMC Public Health* 2014;**14**:1255. doi: 10.1186/1471-2458-14-1255
13. Herrmann SD, Heumann KJ, Der Ananian CA, Ainsworth BE. Validity and reliability of the global physical activity questionnaire (GPAQ). *Meas Phys Educ Exerc Sci* 2013;**17**:221–35.
14. Hoos T, Espinoza N, Marshall S, Arredondo EM. Validity of the global physical activity questionnaire (GPAQ) in adult Latinas. *J Phys Act Health* 2012;**9**:698–705.
15. Soo K, Manan WWA, Suriati WW. The bahasa melayu version of the global physical activity questionnaire reliability and validity study in Malaysia. *Asia Pac J Public Health* 2015;**27**:NP184–93.
16. Trinh OT, Do Nguyen N, van der Ploeg HP, Dibley MJ, Bauman A. Test-retest repeatability and relative validity of the Global Physical Activity Questionnaire in a developing country context. *J Phys Act Health* 2009; **6**(Suppl 1):S46–53.
17. Escalon H, Bossard C, Beck F, Bachelot-Narquin R. *Baromètre santé nutrition 2008*. Saint-Denis: INPES; 2009.
18. Arredondo EM, Mendelson T, Holub C, Espinoza N, Marshall S. Cultural adaptation of physical activity self-report instruments. *J Phys Act Health* 2012;**9**(Suppl 1):S37–43.
19. Terwee CB, Mokkink LB, van Poppel MN, Chinapaw MJ, van Mechelen W, de Vet HC. Qualitative attributes and measurement properties of physical activity questionnaires. *Sports Med* 2010;**40**:525–37.
20. Anthoine E, Moret L, Regnault A, Sébille V, Hardouin J-B. Sample size used to validate a scale: a review of publications on newly-developed patient reported outcomes measures. *Health Qual Life Outcomes* 2014; **12**:176. doi: 10.1186/s12955-014-0176-2
21. World Health Organization. Global. *physical activity questionnaire (GPAQ) analysis guide*. Geneva: World Health Organization; 2012.
22. Crinière L, Lhommet C, Caille A, Giraudeau B, Lecomte P, Couet C, et al. Reproducibility and validity of the French version of the long International Physical Activity Questionnaire in patients with type 2 diabetes. *J Phys Act Health* 2011;**8**:858–65.
23. Wyatt J. *ActiLife 6 user's manual*. ActiGraph Software Department; 2012.
24. Pedišić Ž, Bauman A. Accelerometer-based measures in physical activity surveillance: current practices and issues. *Br J Sports Med* 2015;**49**:219–23.
25. Matthews CE, Ainsworth BE, Thompson RW, Bassett DR Jr. Sources of variance in daily physical activity levels as measured by an accelerometer. *Med Sci Sports Exerc* 2002;**34**:1376–81.
26. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Phys Ther* 2005;**85**:257–68.
27. Bland JM, Altman D. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;**327**:307–10.
28. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;159–74.
29. Portney LG, Watkins MP. *Foundations of clinical research: applications to practice (Vol. 2)*. Upper Saddle River, NJ: Prentice Hall; 2000.
30. Matthews CE, Freedson PS, Hebert JR, Stanek EJ, Merriam PA, Rosal MC, et al. Seasonal variation in household, occupational, and leisure time physical activity: longitudinal analyses from the seasonal variation of blood cholesterol study. *Am J Epidemiol* 2001;**153**:172–83.
31. Prince SA, Adamo KB, Hamel ME, Hardt J, Gorber SC, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act* 2008; **5**:56. doi: 10.1186/1479-5868-5-56
32. LaMonte MJ, Ainsworth BE. Quantifying energy expenditure and physical activity in the context of dose response. *Med Sci Sports Exerc* 2001; **33**(6 Suppl):S370–8.
33. Westerterp KR. Assessment of physical activity: a critical appraisal. *Eur J Appl Physiol* 2009;**105**:823–8.

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Study 4. Content comparison of sedentary behavior questionnaires: a systematic review

Abstract

Background: Health effects of sedentary behaviors may vary depending on their characteristics (type, purpose, duration, etc). While a growing number of questionnaires assesses sedentary behaviors, it is unclear which characteristics of SB are being measured. The aim of this review was to examine the content of self-report sedentary behaviors questionnaires.

Methods: Four databases were searched for sedentary behaviors questionnaires published before January 1st, 2016. Based on the inclusion criteria, 82 articles (out of 1369) were retrieved for a total of 60 different questionnaires. For each questionnaire, the sedentary behaviors characteristics identified were reported and analyzed.

Results: Most of the questionnaires assessed when the behavior take place (n=55), the Posture (n=54), Purpose (n=46) and Type (n=45) of the behavior, 20 enquired about Environment, only 11 asked about the Social context, 2 about the Status and 2 about the Associated Behaviors. All the questionnaires (except 2) assessed time spent in SB, 17 asked for frequency and 6 inquired about breaks. The most occurring characteristics were the categories "sitting", "of day", "TV" and "computer" identified in 90, 90, 65 and 55% of the questionnaires, respectively, but many characteristics of sedentary behaviors were often not measured.

Conclusion: By knowing the breadth of sedentary behaviors measures available, this review provides a support to shape the design of new questionnaires measuring the sedentary behaviors characteristics which are under measured to reduce the gaps in sedentary behaviors measurement.

Title: Taxonomy-based content analysis of sedentary behavior questionnaires: a systematic review

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Introduction

SB is defined as "as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" [1]. Health effects of sedentary time have been increasingly studied over the past decade with most studies showing negative associations between sedentary time and health outcomes in both adults and youths [2–4]. Much of the evidence has been provided by self-report [2] and the majority of the studies have used TV viewing or total sitting time derived from a single question [4,5] as a measure of sedentary behavior (SB). However, measuring total sedentary time may not provide enough information when investigating health effects of SB. Some studies have revealed that the associations between SB and health-related outcomes may change with the characteristics of the behavior measured and the manner in which sedentary time is accumulated [6–8]. For example, a systematic review of the effects of sedentary behaviors on health outcomes has shown that TV viewing has different impacts than reading on cognitive development in early childhood [9]. Statistically significant detrimental associations were observed between total duration/frequency of TV, videos, computers or overall screen time and cognitive development while significant beneficial associations were found between total duration/frequency of reading/being read to and cognitive development. However, these associations were complex and positive associations also were shown for some TV content (educational, ABS and PBS channel viewing) while negative for other content (cartoons). These findings are supported by another systematic review examining the relationships between SB and health indicators in children and youth [10] that showed negative associations between screen-related behaviors and body composition (TV viewing), cardio metabolic status (TV viewing), behavioral conduct/pro-social behavior (TV viewing and video game use), fitness (screen time), self-esteem (screen time and computer use). Conversely, higher durations of reading and doing homework were associated with higher academic achievement. Therefore, the relationship between SB and health is more complex than earlier thought and questionnaires assessing

several aspects of SB are needed to improve our understanding of the relationship between SB and health outcomes.

To better characterize SB, a taxonomy of SB has been developed in 2013 [13]. The taxonomy of SB is the result of the first round of an open science project called "SIT". Led by Chastin et al. [13], this formal consensus process offers a comprehensive frame of reference for SB developed through a Delphi method involving international experts. The taxonomy includes 9 complementary facets to describe SB: the posture(sitting or lying), the purpose of the behavior (ex: for work or for transportation), the time of the day or the year when one engage in SB, the types of behaviors engaged in while sedentary (such as watching TV or using computer), the environment and social context where SB occurred, the associated behaviors (such as eating while watching TV), the functional states of the individual, and the instrument measuring the behavior (see figures 1 and 2). Currently, there are a variety of questionnaires assessing SB that vary considerably in length and item content. While the questionnaire's measurement properties have been assessed in several reviews [11,12], to our knowledge, there is no recent study reporting the content of SB questionnaires in a detailed and standardized manner. Therefore, the aim of this study was to use the taxonomy of SB to systematically appraise and compare the content of SB questionnaires. The objectives were (1) to examine the content of questionnaires measuring SB and the indicators used to synthetize the information recorded, and (2) to compare the content of the questionnaires based on a well-defined and standardized classification of SB.

Methods

This systematic review aimed to identify all studies published by 31 December 2016 reporting the development and/or the psychometric properties of self-report questionnaires that assess SB. The PRISMA Statement was used to guide the report of this work [14].

Literature search

The following electronic bibliographic databases were searched: Medline (PubMed), PsycINFO/ARTICLE (EBSCOhost) and SportDiscus (EBSCOhost). The full search strategies in (A) PubMed and (B) PsycINFO/ARTICLE and SportDiscus were as follows:

(A) (sedentar*[TIAB] OR Sedentary Lifestyles[MeSH] OR sitting[TIAB]) AND (questionnaires[MeSH] OR questionnaire*[TIAB] OR report*[TIAB]) AND (valid*[TIAB] OR reliab*[TIAB] OR Reproducibility of Results[MeSH])

(B) (TI(sedentar* OR sitting) OR AB(sedentar* OR sitting)) AND (TI(questionnaire* OR report*) OR AB(questionnaire* OR report*)) AND (TI(valid* OR reliab*) OR AB(valid* OR reliab*))

In addition, existing reviews of SB questionnaires were hand-searched to identify potential missing questionnaires [11, 12].

Study inclusion/exclusion criteria

Studies meeting all of the following inclusion criteria were included: (i) the aim of the study was the development of a measurement instrument or the evaluation of one or more of its measurement properties; (ii) the instrument under study was self-reported; (iii) the instrument was a questionnaire (i.e. use-of-time tools, logs and diaries were excluded); (iv) the questionnaire measured SB; (v) the study was accepted as a full text original article in a peer-reviewed journal until the 31 December 2015; (vi) the article was published in English or French and the questionnaire was available in one of these languages.

Study selection

Two reviewers independently assessed titles/abstracts (AV, FR) and selected full-text articles (FR, SA) based upon the eligibility criteria. In case of disagreement between the two reviewers, a third reviewer (AO) made the final decision. Full text copies were obtained for all articles meeting initial

screening (but 3) by one of the reviewer (FR). Reviewers were not blinded to the authors or journals when extracting data.

Data extraction

Description of Questionnaires

General characteristics of the instruments were extracted from the included papers using a standardized data-extraction form. This information included: (i) name of the questionnaire; (ii) version; (iii) construct to be measured; (iv) targeted age group; (v) number of items; (vi) mode of administration; (vii) recall period; (viii) dimensions; and (ix) indicators. Two reviewers independently extracted all the data. In case of disagreement, this was resolved through discussion and consensus.

Content of Questionnaires

The content comparison aimed to identify the SB characteristics measured by each questionnaire for each item. To allow the comparison and analysis of the questionnaires the decision was made to link the SB characteristics measured to the taxonomy of SB [13]. The taxonomy served as a reference framework to identify and classify the different categories of SB. The taxonomy of SB is composed of 9 main facets (Fig 1) and each of these facets has sub-categories. For example, the level one facet "Purpose" and its 3 sublevel facets are presented in Fig 2. The content of each questionnaire was systematically linked to the corresponding categories of the taxonomy of SB following standardized linking rules (see Table 1). A short-hand version of the taxonomy of SB was used (by omitting "undetermined" and "others" categories) to reduce the ambiguity of the results of the linking process. To allow the linking process the taxonomy was used in a hierarchical structure. For each questionnaire, the following information was reported: (i) the number of items assessing SB characteristics; (ii) the number of SB characteristics identified; and (iii) the facets and categories of the taxonomy covered.

The linking process was inspired from the International Classification of Functioning, Disability and Health linking rules [15] and adapted to this purpose. The linking rules were first developed then refined after being tested with some questionnaires. The final linking rules were comprised of 8 rules listed in Table 1. The linking process was performed by two independent researchers who had been trained in applying the taxonomy as well as the linking rules. Disagreement was discussed until a consensus was reached.

Results

The literature search

The literature search produced a total of 1,369 hits: 946 in PubMed, 221 in PsycINFO/ARTICLES and 202 in SportDiscus. When selecting articles based on the inclusion criteria, 82 studies were retrieved and 3 additional articles were identified based on hand-searching of existing reviews for a total of 60 questionnaires. The retrieval process and the full list of questionnaire abbreviations and their corresponding definitions are presented in Fig 3 and S1 Appendix, respectively.

Description of questionnaires

A description of the selected questionnaires describing SB item-characteristics is presented in table 2. Some questionnaires including items on only SB and other included items about SB and PA. When the questionnaires measured PA, only the SB-related content was abstracted and reviewed. From the 60 questionnaires meeting the inclusion criteria, 24 specifically measured SB only and 36 measured both SB and PA. Questionnaires were developed or tested for use in the following populations: healthy adults (n=33), adults with specific health problems (n=11), adolescents (n=9), seniors (n=9), children (n=3), women (n=1), and students (n=1). The majority were self-administered (n= 49) vs interviewer administered (n=25). The recall period focused on a single day (n=23, ex: previous day, workday, or week-end day), week (n=28, ex: usual week or last week. past month (n= 7), or a longer

recall period (n=6). All the questionnaires (except two) assessed time spent in SB in hours or minutes. Seventeen measured the frequency of SB and 6 measured breaks in SB.

Taxonomy-based content analysis

Overall, 567 SB characteristics were identified and linked to the taxonomy. Questionnaires 'content is presented in Table 3 using a shortened taxonomy form and fully presented in S2 Appendix. Important differences were observed in the characteristics of SB measured: most of the questionnaires assessed the Time (n=55), Posture (n=54), Purpose (n=46) and Type (n=45) of the SB, 20 enquired about Environment, only 11 asked about the Social context, 2 about the Status and 2 about the Associated Behaviors. The mean number of items per questionnaire was 14.2 [min – max = 1 - 115], and the mean number of SB characteristics measured per questionnaire was 9.4 [min - max = 2 - 27]. For questionnaires measuring only SB, the mean number of SB characteristics per questionnaire was 11.5 [min – max = 2 – 27], while for questionnaires measuring both PA and SB the mean number was 8.1 [min – max = 2 – 23]. The most frequent SB characteristics in questionnaires were the posture "sitting" (90%), the time "of day" (90%), the type "TV" (65%), and "computer" (55%). Conversely, many SB characteristics were never measured such as the Associated Behavior "Smocking", and most of the sub-categories of the facets Environment and Status. Among the including questionnaires, the ASAQ, SIT-Q-12m, SIT-Q-7d and STAR-Q are some of the most comprehensive questionnaires. They comprised 55-115 items measuring 13-27 SB characteristics. In the opposite, the CSIST, IPAQ-SF and GPAQ are some of the least comprehensive questionnaires and are comprised of only 1 item measuring overall sitting time.

Table 3 presents a comprehensive evaluation of the taxonomy's facets contained in each SB questionnaire items reviewed. The first column presents all the main facets (bolded), with the exception of measurement as all instruments are self-report questionnaires, and the first level of their associated sub-facets as displayed in figure 2. In the remaining columns, facets measured by each

questionnaire have been identified with a X, or with a (X) when it was presented as an example (see fifth point in Table 1).

Discussion

The aim of this review was to examine and compare the content of questionnaires measuring SB using facets or characteristics of SB described in Chastin et al.'s Taxonomy of SB. Overall, our review reports wide differences in the questionnaires' content with the most comprehensive questionnaires measuring up to 27 SB characteristics while the least comprehensive questionnaires measured only overall sitting time. Most of the questionnaires measured sitting time spent watching TV or using a computer during a day. However, studies showed that screen-related SB may be differently associated with health-related outcomes than other types of SB [10, 11]. Thus, when selecting a questionnaire one should determine which characteristics of SB are of interest.

Questionnaires developed to obtain a more comprehensive measurement of SB purport to characterize patterns of SB during daily life by measuring sub-categories within most of the facets identified in the taxonomy. Such questionnaires allow consideration of the variety of SB when exploring its relationship to health. Many comprehensive questionnaires such as the SIT-Q, the MPAQ and the STAR-Q, are structured into different sections, where each section represents mostly a purpose, and within each section (i.e., for each purpose) ask for sedentary time or other characteristics of SB. As an example, the SIT-Q-7d is one of the more comprehensive SB questionnaires. It comprises 68 items and measures time spent in different sedentary activities for work, transportation, domestic, education, socializing, eating and care giving behaviors, during both a week day and a week-end day. This kind of structure may be of interest when trying to address the complexity of SB; however, we noticed the inconsistency in which SB is measured depending on the purpose. For example, the types of SB performed in leisure activities often is queried, yet for work activities, only the overall sitting time is measured in general terms. Furthermore, some categories of the facet purpose are barely

measured as compared to others; only 4 questionnaires asked for care giving SB and domestic activities while 21 enquired about work and 19 about leisure activities. So far little is known about why an individual engages in SB and to what extent the purpose of SB relates to health, and existing questionnaires may not allow to deeply investigate these questions.

Other facets of SB often are not measured by SB questionnaires such as associated behaviors (queried as "what else?"), the social context (with whom?) and the functional states of an individual. However, these characteristics are of interest and need to be more thoroughly investigated as they can induce biased in the relationship between SB and health-related outcomes. Associated behaviors, such as eating while watching TV have been shown to be associated with an increased risk of obesity [97]; possibly resulting from nutritionally bad food choices influenced by TV commercials, less feeling of satiety while distracted by TV viewing and the replacement of PA by a sedentary activity (i.e., watching TV) [98]. The social context is also sparsely considered when investigating SB and health. However, both the quantity (having many social relationships vs their relative absence) and quality (such as emotional support or conflict) of social relationships are associated with morbidity and mortality [99]. Thus, it can be expected that the social context when one individual engage in SB influences the strength of the association between SB and health-related outcomes. For relevance, at equal amounts of sedentary time, an individual engaging in sedentary activities alone may be at greater risk of health complications than another individual engaging in sedentary activities while having social relationships. Additionally, some facets such as environment that identifies where a SB occurred and time that identifies when a SB occurred are measured on a restricted basis with only a limited number of sub-categories measured. Almost exclusively the sub-categories of facets of environment "indoor" and time "day" are measured on many SB questionnaires. However, the facet time also encompasses the categories by day and year. While time of the year (seasons) is known to affect PA, little is known about how it influences SB. Similarly, the environment has been identified as one of the main determinants of SB [100] but little information is available about the natural and

built environment in which an individual engages in SB. This lack of information partially may be attributable to SB questionnaires that fail to assess many characteristics of SB (as shown in S2 Appendix).

Only 2 questionnaires asked about multi-tasking as associated behaviors. Individuals could engage in several tasks simultaneously such as watching TV and chatting via skype or Facebook. Perhaps watching television would be associated with negative cognitive outcomes while using screen-based devices to chat allows to connect with friends and impact on well-being and self-esteem [101] Little is known about whether sedentary multitasking might induce a greater health risk or has both distinct positive and negative health outcomes. It has been suggested that multitasking activities are associated with an increase in negative emotions, stress, psychological distress, and work-family conflict in women [102], and that media multitasking could be a unique risk factor for mental health problems [103]. The understanding of the association between media use and mental health needs to consider not only what types of media people are using, but how they are engaging with and what is the content of those media. All together these results support the need to consider multitasking when investigating health effects of SB.

The taxonomy-based content analysis also brings to light that some characteristics of SB measured in many questionnaires did not appear in the lower levels of the taxonomy (e.g. “doing arts”, “talking with acquaintances”, and “hobbies”); thus, they were linked to the upper levels of the taxonomy (for example, “doing arts” was linked to the facet “no screen”). While these characteristics are not in the taxonomy they may be important for some research settings. Thus, such items could be used to enrich the existing taxonomy. Conversely, while SB is defined as “as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture” [1], sleeping and having a nap are considered SB in the taxonomy. Similarly, a few characteristics of SB present in the taxonomy were measured by some questionnaires but were considered as physical activity. In

particular, “cooking” and “household chores” are considered to be a “no-screen” SB from the facet Type oin the taxonomy but are associated to an energy expenditure strictly greater than 1.5 METs in the 2011 Adult Compendium of Physical Activities [104]; considered to be light physical activity by some questionnaires. Also the sub-category“Making music” was considered to be either a SB or a light physical activity depending on the questionnaire and “yoga relaxation” was considered a SB by one questionnaire while it is associated to an energy expenditure of a minimum of 2.0 METs in the 2011 Adult Compendium. In addition, time spent in front of small screen devices such as phone or music player is considered sedentary in the taxonomy and most of studies, however the use of these devices can potentially occur while walking or standing (the use of the mobile application Pokemon Go is a prime example) thus asking for the posture is essential (yet far from being systematic). The boundary between SB and light physical activity is small and complex and may reflect changes in the definition of SB after development of questionnaires with items that may no longer be classified as SB. Epidemiology of SB is a recent research field and efforts must be pursued to harmonize and standardize the measurement of SB.

Finally, differences in the recall frame, duration and mode of administration were observed. The most common recall frames were a week and a day as short recall periods been shown to be fairly easy to recall [105]. Longer recall frames are more likely to measure usual patterns, however the potential for memory bias is also greater than for shorter recall periods [12]. All but 2 questionnaires measured time spend in SB. Depending on the questionnaire, duration was recalled either in hours and minutes per day as a continuous variable or in hours or minutes per day as a discrete variable. From the included questionnaires, 49 have been validated in a self-administered form (paper of computer) and 25 in an interview-administered form (face-to-face or telephone). The mode of administration of questionnaires is of importance as it may influence the answers of participants due to social desirability [106]. Furthermore, while in this paper we focused only on self-reported questionnaires, proxy-report may be more appropriate for use in population with limited cognitive capacity (children,

intellectual disabled persons, and older persons) as it may restrain the accuracy of the recall. In that case, parent-, relatives or professional health care- proxy report may be used to collect information on participant's SB [5].

Limitations

The use of the Taxonomy of Sedentary Behaviors to analyze the content of the questionnaires is a long and tedious work. Some SB characteristics appear twice in the taxonomy and others are similar (for examples, the category "at the workplace" and the category "for work) making difficult the linking process. The development of the linking rules was an essential step of this work to ensure that all questionnaires' content was linked following the same criteria. Despite the linking rules, some content was linked differently between the two reviewers, but a consensus was reached after discussion. Nevertheless, the use of the taxonomy as a reference framework allowed a standardized comparison of the questionnaires content. However, given that only articles written in English and in French were selected, and that no grey literature was search, we can't rule out the possibility for missing questionnaires.

Conclusions

This study presents a standardized content analysis of 60 SB questionnaires to show how many and which characteristics of SB are measured in each questionnaire. Considerable variability in the comprehensiveness of questionnaires was observed. Overall, the questionnaires included in this review are composed of 1-115 items measuring 2-27 SB characteristics. When selecting a questionnaire to measure SB, one should consider the measurement properties as well as the characteristics of SB included in a questionnaire and the nature of information for frequency, duration, interruptions, and recall frame. The taxonomy-based content analysis provides a useful tool to identify and compare the content of each questionnaire as it shows that a limited number of SB's characteristics are currently being measured through questionnaire. While recent work suggests that

different types of SB might have different effect on health, this review provides a support for the development of questionnaires measuring the SB characteristics that are under measured to reduce the gaps in SB measurement and further explore health effects of SB and their determinants. In particular, behaviors associated to sedentary time (such as eating, smocking, etc), multitasking, the physical and social environment, when the behavior takes place, and the physical and psychological state of the individual are rarely measured with the existing questionnaires. In the absence of questionnaire to measure these SB characteristics, other method, such as ecological momentary assessment or diary may be more appropriate.

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References

1. Sedentary Behaviour Research Network. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours." Appl Physiol Nutr Metab. 2012;37(3):540–2. http://dx.doi.org /10.1139/h2012-024.

2. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med. 2015;162(2):123-132. http://dx.doi.org/10.7326/M14-1651.

3. Chau JY, Grunseit AC, Chey T, Stamatakis E, Brown WJ, Matthews CE, et al. Daily sitting time and all-cause mortality: a meta-analysis. PLoS ONE. 2013;8(11):e80000. http://dx.doi.org/10.1371/journal.pone.0080000.

4. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act. 2011; 8(1):98. http://dx.doi.org/10.1186/1479-5868-8-98

5. Atkin AJ, Gorely T, Clemes SA, Yates T, Edwardson C, Brage S, et al. Methods of Measurement in epidemiology: sedentary Behaviour. Int J Epidemiol. 2012;41(5):1460-1471. http://dx.doi.org/10.1093/ije/dys118.

6. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Breaks in sedentary time beneficial associations with metabolic risk. Diabetes care. 2008;31(4):661–666. http://dx.doi.org/10.2337/dc07-2046.

7. Saunders TJ, Tremblay MS, Mathieu M-È, Henderson M, O'Loughlin J, Tremblay A, et al. Associations of sedentary behavior, sedentary bouts and breaks in sedentary time with cardiometabolic risk in children with a family history of obesity. PLoS ONE. 2013;8(11):e79143. http://dx.doi.org/10.1371/journal.pone.0079143.

8. Kikuchi H, Inoue S, Sugiyama T, Owen N, Oka K, Nakaya T, et al. Distinct associations of different sedentary behaviors with health-related attributes among older adults. Prev Med. 2014;67:335-339. http://dx.doi.org/10.1016/j.ypmed.2014.08.011.

9. Carson V, Kuzik N, Hunter S, Wiebe SA, Spence JC, Friedman A, et al. Systematic review of sedentary behavior and cognitive development in early childhood. Preventive Medicine. 2015;78:115-122. http://dx.doi.org/10.1016/j.ypmed.2015.07.016.

10. Carson V, Hunter S, Kuzik N, Gray CE, Poitras VJ, Chaput JP, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl Physiol Nutr Metab 2016; 41(6):S240-S265. http://dx.doi.org/10.1139/apnm-2015-0630

11. Clark BK, Sugiyama T, Healy GN, Salmon J, Dunstan DW, Owen N. Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review. Obesity Reviews. 2009;10(1):7-16. http://dx.doi.org/10.1111/j.1467-789X.2008.00508.x.

12. Healy GN, Clark BK, Winkler EAH, Gardiner PA, Brown WJ, Matthews CE. Measurement of Adults' Sedentary Time in Population-Based Studies. Amn J Preve Med. 2011;41(2):216-227. http://dx.doi.org/10.1016/j.amepre.2011.05.005.

13. Chastin SFM, Schwarz U, Skelton DA. Development of a Consensus Taxonomy of Sedentary Behaviors (SIT): Report of Delphi Round 1. PLoS ONE. 2013;8(12):e82313. http://dx.doi.org/10.1371/journal.pone.0082313.

14. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 2009;6(7):e1000097. http://dx.doi.org/10.1371/journal.pmed.1000097.

15. Cieza A, Geyh S, Chatterji S, Kostanjsek N, Ustün B, Stucki G. ICF linking rules: an update based on lessons learned. J Rehabil Med. 2005;37(4):212-218. doi:10.1080/16501970510040263.

16. Bonn SE, Bergman P, Trolle Lagerros Y, Sjolander A, Balter K. A Validation study of the Web-Based Physical Activity Questionnaire Active-Q Against the GENEA Accelerometer. JMIR Res Protoc 2015; 4(3):e86. http://dx.doi.org/10.2196/resprot.3896.

17. Clark BK, Lynch BM, Winkler EA, Gardiner PA, Healy GN, Dunstan DW et al. Validity of a multi-context sitting questionnaire across demographically diverse population groups: AusDiab3. Int J Behav Nutr Phys Act. 2015;12:148. http://dx.doi.org/10.1186/s12966-015-0309-y.

18. Aadahl M, Jorgensen T. Validation of a New Self-Report Instrument for Measuring Physical Activity: Medicine & Science in Sports & Exercise. 2003;35(7):1196-1202. http://dx.doi.org/10.1249/01.MSS.0000074446.02192.14.

19. de Fátima Guimarães R, Pereira da Silva M, Legnani E, Mazzardo O, de Campos W. Reproducibility of adolescent sedentary activity questionnaire (ASAQ) in Brazilian adolescents. Brazilian Journal of Kineanthropometry & Human Performance. 2013;15(3):276-285. http://dx.doi.org/10.5007/1980-0037.2013v15n3p276.

20. Hardy LL, Booth ML, Okely AD. The reliability of the Adolescent Sedentary Activity Questionnaire (ASAQ). Prev Med. 2007;45(1):71-74. http://dx.doi.org /10.1016/j.ypmed.2007.03.014.

21. Aguilar-Farías N, Brown WJ, Olds TS, (Geeske) Peeters GMEE. Validity of self-report methods for measuring sedentary behaviour in older adults. J Sci Med Sport. 2015;18(6):662-6. http://dx.doi.org /10.1016/j.jsams.2014.08.004.21.

22. Chinapaw MJ, Slootmaker SM, Schuit AJ, van Zuidam M, van Mechelen W. Reliability and validity of the Activity Questionnaire for Adults and Adolescents (AQuAA). BMC Med Res Methodol. 2009;9(1):58. http://dx.doi.org /10.1186/1471-2288-9-58.

23. Oostdam N, van Mechelen W, van Poppel M. Validation and responsiveness of the AQuAA for measuring physical activity in overweight and obese pregnant women. Journal of Science and Medicine in Sport. 2013;16(5):412-416. http://dx.doi.org /10.1016/j.jsams.2012.09.001.23.

24. Fjeldsoe B, Marshall A, Miller Y. Measurement properties of the Australian women's activity survey. Med Sci Sports Exerc. 2009;41(5):1020–1033. http://dx.doi.org /10.1249/MSS.0b013e31819461c2.

25. Strugnell C, Renzaho A, Ridley K, Burns C. Reliability of the modified child and adolescent physical activity and nutrition survey, physical activity (CAPANS-PA) questionnaire among chinese-australian youth. BMC Med Res Methodol. 2011;11(1):122. http://dx.doi.org /10.1186/1471-2288-11-122.

26. Gennuso KP, Matthews CE, Colbert LH. Reliability and Validity of Two Self-Report Measures to Assess Sedentary Behavior in Older Adults. J Phys Act Health. 2015;12(5):727-32. http://dx.doi.org /10.1123/jpah.2013-0546.

27. Clemes SA, David BM, Zhao Y, Han X, Brown W. Validity of two self-report measures of sitting time. J Phys Act Health. 2012;9(4):533-539.

28. Schmitz KH, Harnack L, Fulton JE, Jacobs DR, Gao S, Lytle LA, et al. Reliability and validity of a brief questionnaire to assess television viewing and computer use by middle school children. J Sch health. 2004;74(9):370–377.

29. Wareham NJ, Jakes RW, Rennie KL, Mitchell J, Hennings S, Day NE. Validity and repeatability of the EPIC-Norfolk Physical Activity Questionnaire. Int J Epidemiol. 2002;31(1):168-174.

30. Cleland CL, Hunter RF, Kee F, Cupples ME, Sallis JF, Tully MA. Validity of the Global Physical Activity Questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behaviour. BMC Public Health. 2014;14(1):1255. http://dx.doi.org /10.1186/1471-2458-14-1255.

31. Herrmann SD, Heumann KJ, Ananian CA Der, Ainsworth BE. Validity and Reliability of the Global Physical Activity Questionnaire (GPAQ). Meas Phys Educ Exerc Sci. 2013;17(3):221-235. http://dx.doi.org /10.1080/1091367X.2013.805139

32. Hoos T, Espinoza N, Marshall S, Arredondo EM. Validity of the global physical activity questionnaire (GPAQ) in adult Latinas. J Phys Act Health. 2012;9(5):698.

33. Cerin E, Sit CHP, Huang Y-J, Barnett A, Macfarlane DJ, Wong SSH. Repeatability of self-report measures of physical activity, sedentary and travel behaviour in Hong Kong adolescents for the iHealt(H) and IPEN - Adolescent studies. BMC Pediatr. 2014;14:142. http://dx.doi.org /10.1186/1471-2431-14-142.

34. Tran DV, Lee AH, Au TB, Nguyen CT, Hoang DV. Reliability and validity of the International Physical Activity Questionnaire–Short Form for older adults in Vietnam. Health Promot J Austr. 2013;24(2):126. http://dx.doi.org /10.1071/HE13012.

35. Cerin E, Barnett A, Cheung M, Sit CH, Macfarlane DJ, Chan W. Reliability and validity of the IPAQ-L in a sample of Hong Kong urban older adults: does neighborhood of residence matter? J Aging Phys Act. 2012;20(4):402–420.35.

36. Chastin SFM, Culhane B, Dall PM. Comparison of self-reported measure of sitting time (IPAQ) with objective measurement (activPAL). Physiol Meas. 2014;35(11):2319-2328. http://dx.doi.org /10.1088/0967-3334/35/11/2319.36.

37. Crinière L, Lhommet C, Caille A, Giraudeau B, Lecomte P, Couet C, et al. Reproducibility and validity of the French version of the long International Physical Activity Questionnaire in patients with type 2 diabetes. J Phys Act Health. 2011;8(6):858.

38. Hagstromer M, Ainsworth BE, Oja P, Sjostrom M. Comparison of a subjective and an objective measure of physical activity in a population sample. J Phys Act Health. 2010;7(4):541.38.

39. Hansen AW, Dahl-Petersen I, Helge JW, Brage S, Grønbæk M, Flensborg-Madsen T. Validation of an Internet-based long version of the International Physical Activity Questionnaire in Danish adults using combined accelerometry and heart rate monitoring. J Phys Act Health. 2014;11(3):654-664. http://dx.doi.org /10.1123/jpah.2012-0040.

40. Roman-Viñas B, Serra-Majem L, Hagströmer M, Ribas-Barba L, Sjöström M, Segura-Cardona R. International Physical Activity Questionnaire: Reliability and validity in a Spanish population. European Journal of Sport Science. 2010;10(5):297-304. http://dx.doi.org /10.1080/17461390903426667.

41. Rosenberg DE, Bull FC, Marshall AL, Sallis JF, Bauman AE. Assessment of sedentary behavior with the International Physical Activity Questionnaire. J Phys Act Health. 2008;5:S30.

42. Rosenberg DE, Norman GJ, Wagner N, Patrick K, Calfas KJ, Sallis JF. Reliability and validity of the Sedentary Behavior Questionnaire (SBQ) for adults. J Phys Act Health. 2010;7(6):697–705.

43. Van Dyck D, Cardon G, Deforche B, De Bourdeaudhuij I. IPAQ interview version: convergent validity with accelerometers and comparison of physical activity and sedentary time levels with the self-administered version. J Sports Med Phys Fitness. 2015; 55(7-8):776-86.

44. Oyeyemi AL, Bello UM, Philemon ST, Aliyu HN, Majidadi RW, Oyeyemi AY. Examining the reliability and validity of a modified version of the International Physical Activity Questionnaire, long form (IPAQ-LF) in Nigeria: a cross-sectional study. BMJ Open. 2014;4(12):e005820-e005820. http://dx.doi.org /10.1136/bmjopen-2014-005820.

45. Segura-Jimenez V, Munguia-Izquierdo D, Camiletti-Moiron D, Alvarez-Gallardo IC, Ortega FB, Ruiz JR, et al. Comparison of the International Physical Activity Questionnaire (IPAQ) with a multi-sensor armband accelerometer in women with fibromyalgia: The al-Andalus project. Clin Exp Rheumatol. 2013;31(6 Suppl 79):2.

46. Dahl-Petersen IK, Hansen AW, Bjerregaard P, JøRgensen ME, Brage S. Validity of the International Physical Activity Questionnaire in the Arctic: Med Sci Sports Exerc. 2013;45(4):728-736. http://dx.doi.org /10.1249/MSS.0b013e31827a6b40.

47. Brown WJ, Trost SG, Bauman A, Mummery K, Owen N. Test-retest reliability of four physical activity measures used in population surveys. J Sci Med Sport. 2004;7(2):205-215.

48. Curry WB, Thompson JL. Comparability of accelerometer- and IPAQ-derived physical activity and sedentary time in South Asian women: A cross-sectional study. Eur J Sport Sci. 2014:1-8. http://dx.doi.org /10.1080/17461391.2014.957728.

49. Dyrstad SM, Hansen BH, Holme IM, Anderssen SA. Comparison of Self-reported versus Accelerometer-Measured Physical Activity: Med Sci Sports Exerc. 2014;46(1):99-106. http://dx.doi.org /10.1249/MSS.0b013e3182a0595f.

50. Ekelund U, Sepp H, Brage S, Becker W, Jakes R, Hennings, M, et al. Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults. Public Health Nutr. 2006;9(2). http://dx.doi.org /10.1079/PHN2005840.

51. Kolbe-Alexander TL, Lambert EV, Harkins JB, Ekelund U. Comparison of two methods of measuring physical activity in South African older adults. J Aging Phys Act. 2006;14(1):98.

52. Kurtze N, Rangul V, Hustvedt B-E. Reliability and validity of the international physical activity questionnaire in the Nord-Trondelag health study (HUNT) population of men. BMC Med Res Methodol. 2008;8(1):63. http://dx.doi.org /10.1186/1471-2288-8-63.

53. Marmeleira J, Laranjo L, Marques O, Batalha N. Criterion related validity of the short form of the International Physical Activity Questionnaire in adults who are blind. J Vis Impair Blind. 2013;107(5):375–381.

54. Oyeyemi AL, Oyeyemi AY, Adegoke BO, Oyetoke FO, Aliyu HN, Aliyu SU, et al. The Short International Physical Activity Questionnaire: cross-cultural adaptation, validation and reliability of the Hausa language version in Nigeria. BMC Med Res Methodol. 2011;11(1):156.

55. Oyeyemi AL, Umar M, Oguche F, Aliyu SU, Oyeyemi AY. Accelerometer-Determined Physical Activity and Its Comparison with the International Physical Activity Questionnaire in a Sample of Nigerian Adults. PLoS ONE. 2014;9(1):e87233. http://dx.doi.org /10.1371/journal.pone.0087233.

56. Papathanasiou G, Georgoudis G, Papandreou M, Spyropoulos P, Georgakopoulos D, Kalfakakou V, et al. Reliability measures of the short International Physical Activity Questionnaire (IPAQ) in Greek young adults. Hellenic J Cardiol. 2009;50(4):283–294.

57. Wang C, Chen P, Zhuang J. Validity and Reliability of International Physical Activity Questionnaire–Short Form in Chinese Youth. Res Q Exerc Sport. 2013;84(sup2):S80-S86. http://dx.doi.org /10.1080/02701367.2013.850991.

58. Visser M, Koster A. Development of a questionnaire to assess sedentary time in older persons--a comparative study using accelerometry. BMC Geriatr. 2013;13:80. http://dx.doi.org /10.1186/1471-2318-13-80.

59. Johansen KL, Painter P, Delgado C, Doyle J. Characterization of Physical Activity and Sitting Time Among Patients on Hemodialysis Using a New Physical Activity Instrument. J Ren Nutr. 2015;25(1):25-30. http://dx.doi.org /10.1053/j.jrn.2014.06.012.

60. Lagersted-Olsen J, Korshøj M, Skotte J, Carneiro I, Søgaard K, Holtermann A. Comparison of Objectively Measured and Self-reported Time Spent Sitting. Int J Sports Med. 2013;35(6):534-540. http://dx.doi.org /10.1055/s-0033-1358467.

61. Marshall AL, Miller YD, Burton NW, Brown WJ. Measuring Total and Domain-Specific Sitting A Study of Reliability and Validity. Med Sci Sports Exerc. 2010;42(6):1094-1102.

62. Chau JY, Van Der Ploeg HP, Dunn S, Kurko J, Bauman AE. Validity of the Occupational Sitting and Physical Activity Questionnaire. Med Sci Sports Exer. 2012;44(1):118-125. http://dx.doi.org /10.1249/MSS.0b013e3182251060.

63. Anjana RM, Sudha V, Lakshmipriya N, Subhashini S, Pradeepa R, Geetha L, et al. Reliability and validity of a new physical activity questionnaire for India. Int J Behav Nutr Phys Act. 2015;12(1):40. http://dx.doi.org /10.1186/s12966-015-0196-2.

64. Whitfield GP, Pettee Gabriel KK, Kohl HW. Assessing Sitting Across Contexts: Development of the Multi-Context Sitting Time Questionnaire. Res Q Exerc Sport. 2013;84(3):323-328.

65. Jancey J, Tye M, McGann S, Blackford K, Lee AH. Application of the Occupational Sitting and Physical Activity Questionnaire (OSPAQ) to office based workers. BMC Public Health. 2014;14:762. http://dx.doi.org /10.1186/1471-2458-14-762.

66. James F. Sallis PKS. Validation of interviewer- and self-administered physical activity checklists for fifth grade students. Med Sci Sports Exer. 1996;28(7):840-851. http://dx.doi.org /10.1097/00005768-199607000-00011.

67. Adami F, Bergamaschi DP, Hinnig P de F, Oliveira NS. Validity study of the "Physical Activity Checklist" in children. Revista de Saúde Pública. 2013;47(3):488-496. http://dx.doi.org /10.1590/S0034-8910.2013047004018.

68. Adami F, Cruciani F, Douek M, Sewell CD, Mariath AB, Hinnig PD, et al. Reliability of the Brazilian version of the Physical Activity Checklist Interview in children. Revista de Saúde Pública. 2011;45(2):321-333. http://dx.doi.org /10.1590/S0034-89102011000200011.

69. Simpson K, Parker B, Capizzi J, Thompson P, Clarkson P, Freedson P, et al. Validity and reliability question 8 of the Paffenbarger Physical Activity Questionnaire among healthy adults. J Phys Act Health. 2015;12(1):116-123. http://dx.doi.org /10.1123/jpah.2013-0013.

70. Buchowski MS, Matthews CE, Cohen SS, Signorello LB, Fowke JH, Hargreaves MK, et al. Evaluation of a questionnaire to assess sedentary and active behaviors in the southern community cohort study. J Phy Act Health. 2012;9(6):765.

71. Scholes S, Coombs N, Pedisic Z, Mindell JS, Bauman A, Rowlands AV, et al. Age- and Sex-Specific Criterion Validity of the Health Survey for England Physical Activity and Sedentary Behavior Assessment Questionnaire as Compared With Accelerometry. Am J Epidemiol. 2014;179(12):1493-1502. http://dx.doi.org /10.1093/aje/kwu087.

72. Clark BK, Winkler E, Healy GN, Gardiner PG, Dunstan DW, Owen N, et al. Adults' past-day recall of sedentary time: reliability, validity, and responsiveness. Med Sci Sports Exerc. 2013;45(6):1198-1207. http://dx.doi.org /10.1249/MSS.0b013e3182837f57.

73. Clark BK, Pavey TG, Lim RF, Gomersall SR, Brown WJ. Past-day recall of sedentary time: Validity of a self-reported measure of sedentary time in a university population. J Sci Med Sport. 2016;19(3):237-241. http://dx.doi.org /10.1016/j.jsams.2015.02.001.

74. Ota E, Haruna M, Yanai H, Suzuki M, Anh DD, Matsuzaki M, et al. Reliability and validity of the Vietnamese version of the Pregnancy Physical Activity Questionnaire (PPAQ). Southeast Asian J Trop Med Public Health. 2008;39(3):562-70.

75. Tessier S, Vuillemin A, Briançon S. Propriétés psychométriques d'un questionnaire de mesure de l'activité physique chez l'enfant scolarisé âgé de six à dix ans: QAPE-semaine. Sci & Sports. 2007;22(5):224-231. http://dx.doi.org /10.1016/j.scispo.2007.07.002.

76. Shuval K, Kohl HW, Bernstein I, Cheng D, Gabriel KP, Barlow CE, et al. Sedentary behaviour and physical inactivity assessment in primary care: the Rapid Assessment Disuse Index (RADI) study. Br J Sports Med. 2014;48(3):250-255. http://dx.doi.org /10.1136/bjsports-2013-092901.

77. Golubic R, May AM, Borch KB, Overvad K, Charles MA, Diaz MJ, et al. Validity of electronically administered Recent Physical Activity Questionnaire (RPAQ) in ten European countries. PLoS ONE. 2014;9(3):e92829. http://dx.doi.org /10.1371/journal.pone.0092829.

78. Besson H, Brage S, Jakes RW, Ekelund U, Wareham NJ. Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. Am J Clin Nutr. 2010;91(1):106-114. http://dx.doi.org /10.3945/ajcn.2009.28432.

79. Brown TD, Holland BV. Test-retest reliability of the self-assessed physical activity checklist. Percept Mot Skills. 2004;99(3 Pt 2):1099-1102. http://dx.doi.org /10.2466/pms.99.3f.1099-1102.

80. Dollman J, Pontt JL, Rowlands AV. Validity of self-reported sedentary time differs between Australian rural men engaged in office and farming occupations. J Sports Sci. 2016;34(12):1154-1158. http://dx.doi.org /10.1080/02640414.2015.1094185.

81. Munguia-Izquierdo D, Segura-Jiménez V, Camiletti-Moirón D, et al. Spanish adaptation and psychometric properties of the Sedentary Behaviour Questionnaire for fibromyalgia patients: the al-Andalus study. Clin Exp Rheumatol. 2013;31(6 Suppl 79):S22-33.

82. Pedisic Z, Bennie JA, Timperio AF, Crawford DA, Dunstan DW, Bauman AE, et al. Workplace Sitting Breaks Questionnaire (SITBRQ): an assessment of concurrent validity and test-retest reliability. BMC Public Health. 2014;14(1):1249.

83. Lynch BM, Friedenreich CM, Khandwala F, Liu A, Nicholas J, Csizmadi I. Development and testing of a past year measure of sedentary behavior: the SIT-Q. BMC Public Health. 2014;14(1):899.

84. Wijndaele K, De Bourdeaudhuij I, Godino JG, Lynch BM, Griffin SJ, Westgate K, et al. Reliability and Validity of a Domain-Specific Last 7-d Sedentary Time Questionnaire. Med Sci Sports Exerc. 2014;46(6):1248-1260. http://dx.doi.org /10.1249/MSS.0000000000000214.

85. Orsini N, Bellocco R, Bottai M, Pagano M, Wolk A. Reproducibility of the past year and historical self-administered total physical activity questionnaire among older women. Eur J Epidemiol. 2007;22(6):363-368. http://dx.doi.org /10.1007/s10654-006-9102-1.

86. Pettee KK, Ham SA, Macera CA, Ainsworth BE. The reliability of a survey question on television viewing and associations with health risk factors in US adults. Obesity (Silver Spring). 2009;17(3):487-493. http://dx.doi.org /10.1038/oby.2008.554.

87. Csizmadi I, Neilson HK, Kopciuk KA, Khandwala F, Liu A, Friedenreich CM, et al. The Sedentary Time and Activity Reporting Questionnaire (STAR-Q): Reliability and Validity Against Doubly Labeled Water and 7-Day Activity Diaries. Am J Epidemiol. 2014;180(4):424-435. http://dx.doi.org /10.1093/aje/kwu150.

88. Neilson HK, Ullman R, Robson PJ, Friedenreich CM, Csizmadi I. Cognitive testing of the STAR-Q: insights in activity and sedentary time reporting. J Phys Act Health. 2013;10(3):379-389.

89. Rey-Lopez JP, Ruiz JR, Ortega FB, Verloigne M, Vicente-Rodriguez G, Gracia-Marco L, et al. Reliability and validity of a screen time-based sedentary behaviour questionnaire for adolescents: The HELENA study. Eur J Public Health. 2012;22(3):373-377. http://dx.doi.org /10.1093/eurpub/ckr040.

90. Clark B, Thorp A, Winkler E, Gardiner PA, Healy GN, Owen N, et al. Validity of Self-Report Measures of Workplace Sitting Time and Breaks in Sitting Time. Med Sci Sports Exerc. 2011:1. http://dx.doi.org /10.1249/MSS.0b013e31821820a2.

91. Gardiner PA, Clark BK, Healy GN, Eakin EG, Winkler EAH, Owen N. Measuring older adults' sedentary time: reliability, validity, and responsiveness. Med Sci Sports Exerc. 2011;43(11):2127-2133. http://dx.doi.org /10.1249/MSS.0b013e31821b94f7.

92. Van Cauwenberg J, Van Holle V, De Bourdeaudhuij I, Owen N, Deforche B. Older adults' reporting of specific sedentary behaviors: validity and reliability. BMC Public Health. 2014;14(1):734.

93. McCormack G, Giles-Corti B, Milligan R. The test-retest reliability of habitual incidental physical activity. Aust N Z J Public Health. 2003;27(4):428–433.

94. Chau JY, van der Ploeg HP, Dunn S, Kurko J, Bauman AE. A tool for measuring workers' sitting time by domain: the Workforce Sitting Questionnaire. Br J Sports Med. 2011;45(15):1216-1222. http://dx.doi.org /10.1136/bjsports-2011-090214.

95. De Abajo S, Larriba R, Marquez S. Validity and reliability of the Yale Physical Activity Survey in Spanish elderly. J Sports Med Phys Fitness. 2001;41(4):479-485.

96. Lindamer LA, McKibbin C, Norman GJ, Jordan L, Harrison K, Abeyesinhe S, et al. Assessment of physical activity in middle-aged and older adults with schizophrenia. Schizophr Res. 2008;104(1-3):294-301. http://dx.doi.org /10.1016/j.schres.2008.04.040.

97. Pearson N, Biddle SJ. Sedentary behavior and dietary intake in children, adolescents, and adults: a systematic review. Am J Prev Med. 2011;41(2),178-188. http://dx.doi.org / 10.1016/j.amepre.2011.05.002.

98. Boulos R, Vikre EK, Oppenheimer S, Chang H, Kanarek RB. ObesiTV: how television is influencing the obesity epidemic. Physiol Behav. 2012;107(1),146-153. http://dx.doi.org / 10.1016/j.physbeh.2012.05.022.

99. Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D. Loneliness and social isolation as risk factors for mortality a meta-analytic review. Perspect Psychol Sci. 2015;10(2),227-237. http://dx.doi.org /10.1177/1745691614568352.

100. Sallis JF, Owen N, & Fotheringham MJ. Behavioral epidemiology: a systematic framework to classify phases of research on health promotion and disease prevention. Ann Behav Med. 2000;22(4), 294-298.

101. Valkenburg PM, Peter J, & Schouten AP. Friend networking sites and their relationship to adolescents' well-being and social self-esteem. CyberPsycholBehav. 2006;9(5):584-590.

102. Offer S, & Schneider B. Revisiting the gender gap in time-use patterns multitasking and well-being among mothers and fathers in dual-earner families. ASR. 2011;76(6):809-833. http://dx.doi.org /10.1177/0003122411425170.

103. Becker MW, Alzahabi R, & Hopwood CJ. Media multitasking is associated with symptoms of depression and social anxiety. Cyberpsychol Behav Soc Netw. 2013;16(2):132-135. http://dx.doi.org /10.1089/cyber.2012.0291

104. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011;43(8):1575-81. http://dx.doi.org /10.1249/MSS.0b013e31821ece12.

105. Ainsworth BE, Caspersen CJ, Matthews CE, Mâsse LC, Baranowski T, Zhu W. Recommendations to improve the accuracy of estimates of physical activity derived from self report. J Phys Act Health. 2012;9(0 1):S76.

106. Chang L, Krosnick JA. Comparing Oral Interviewing with Self-Administered Computerized QuestionnairesAn Experiment. Public Opin Q. 2010. http://dx.doi.org /10.1093/poq/nfp090.

Figure

Fig 1. Taxonomy level one facets and coding labels [13]

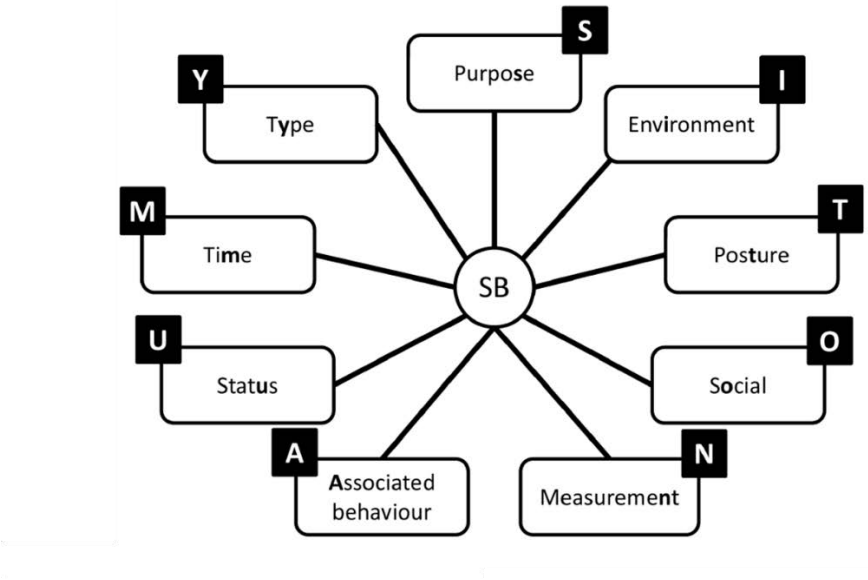


Fig 2. Purpose facet substructure and labels [13]

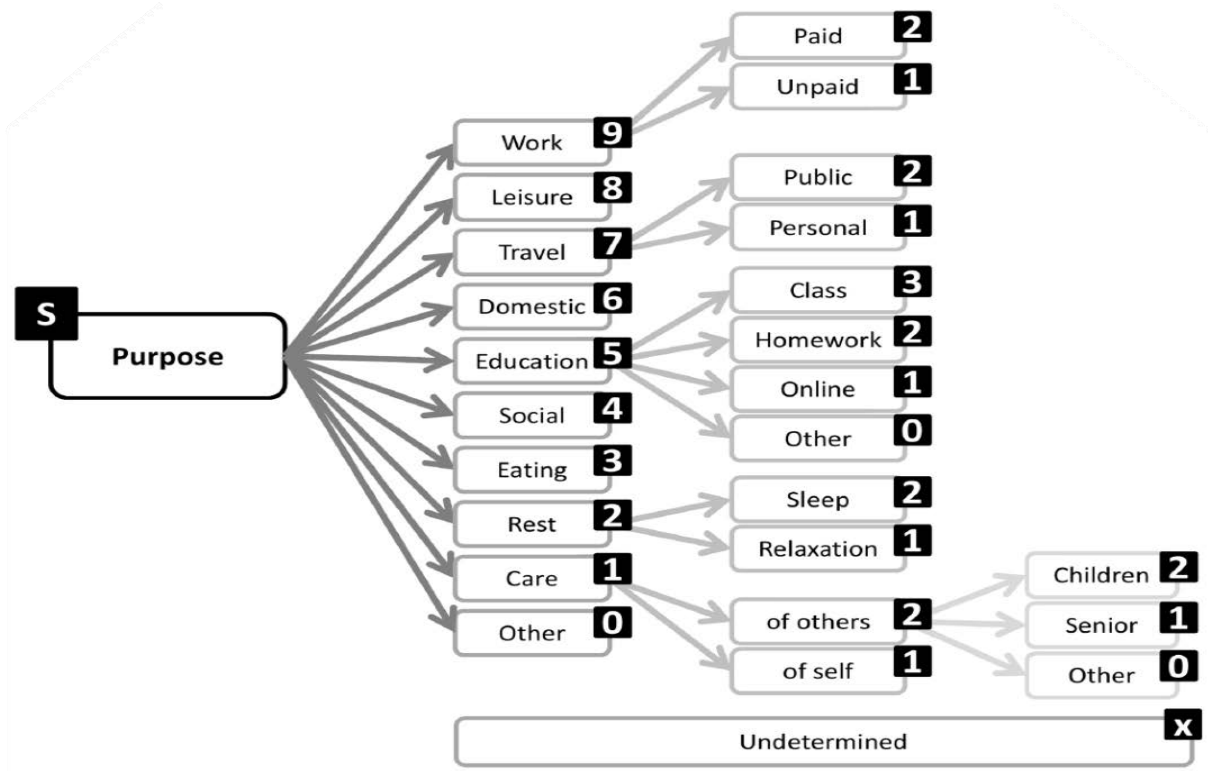
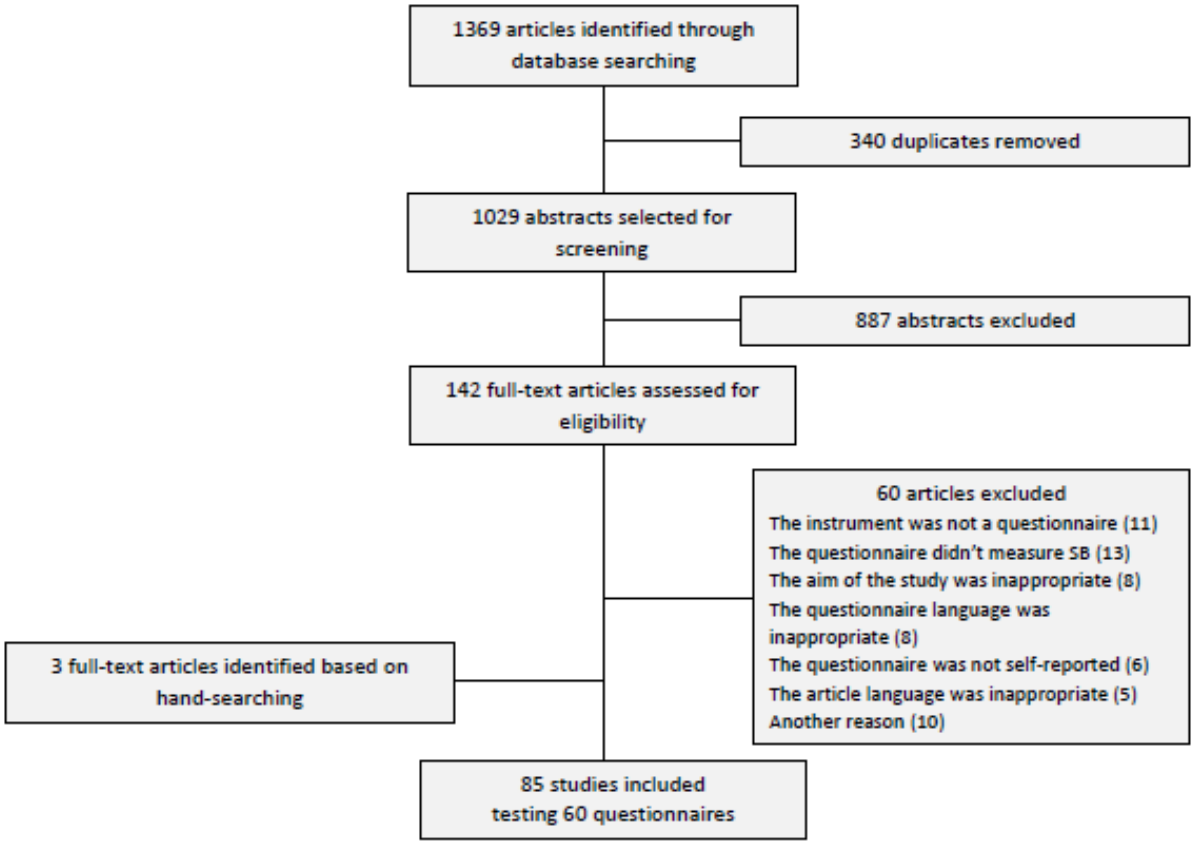


Fig 3. Flow chart



Tables

Table 1.

Number	Rule
1	Before starting the process of linking SB questionnaires to the taxonomy categories, good knowledge of the taxonomy should be acquired and all meaningful sedentary behaviour (SB) characteristics within each item of the questionnaire under consideration should be identify.
2	Only SB characteristics should be linked (for example "How many times a week did you travel from home to your main work?" does not assess any sedentary behaviours)
3	Each meaningful SB characteristic within items is linked to the most precise taxonomy category. Example: Item 6a of the STAR-Q "Driving a car or light truck" should be linked to the subcategory S71 *personal* from the category *travel* within the domain p*urpose*.
4	If a single item encompasses different SB characteristics, they should all be linked. Example: In item 7a of the SIT-Q "How much time per day did you spend sitting for job?" *day, sitting and job* should be linked.
5	If a SB characteristic within an item is explained by examples both the SB characteristic and the examples should be linked. However, the taxonomy categories to which the examples have been linked should be put within parentheses. Examples are often introduced using "such as", "for examples", "e.g." and/or appear in parentheses.

Example: In item 1a of the WSQ "for transport (e.g. in car, bus, train, etc)" *car* should be linked to the subcategory S71 *personal* from the category *travel*.

6 The response options of an item are linked if they contain SB characteristics

Example: In item 3 of the PASBAQ "Which of these did you do whilst working?
sitting down or standing up
Walking at work
Climbing stairs or ladders*"*
Sitting down should be linked to the appropriate taxonomy category.

7 If a SB characteristic in an item is more general than the corresponding taxonomy substructure category, the higher level of category should be linked.

8 The recall period (the interval of time to which the item refers) is not linked to the taxonomy as well as the time (the duration of the SB), the frequency (number of bouts of a certain duration) and the interruption (breaking up sedentary behaviours.

Table 2. Description of sedentary behaviors items from published questionnaires.

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
Active-Q [16]	SB, PA	Adults	SA	Past month	16	# days/week	h/day or m/day	/	MET-Time, Duration
AD3STQ [17]	SB	Adults	I	Last week	10	/	h-m/week, h-m/week-end	/	Duration
AJPAS [18]	SB, PA	Adults	SA	Average weekday	3	/	h-m/day	/	MET-Time, Duration
ASAQ [19,20]	SB	Adolescents	SA, I	Each day of a normal school week	79	# days/week	h-m/day	/	Duration
ASTSQ [21]	SB	Older adults	I	Usual weekday, usual weekend day and previous day	3	/	h/day	/	Duration
AQuAA [22,23]	SB, PA	Adolescents, Adults, Obese and overweight pregnant women	SA	Average/day during the last 7 days	11	# days/week	h-m/day	/	Duration
AWAS [24]	SB, PA	Women	I	Average day during a typical week and weekend	27	# days/week, # days/weekend	h-m/day	/	Duration
CAPANS-PA-M [25]	SB, PA	Adolescent	SA	Normal day in the past 7 days	44	/	h-m/day	/	Duration
CHAMPS [26]	SB, PA	Older adults	SA	Typical wk during the last 4 weeks	18	# times/week	h/week	/	Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
CSIST [27]	SB	Adults	SA	Today	1	/	h-m/day	/	Duration
DSSTQ [27]	SB	Adults	SA	Usual weekday and weekend day	10	/	h-m/day	/	Duration
EAST-Q [	SB	Adolescents	SA	Average weekday and weekend day during the current school year/past year/summer	5	/	h/day	/	Duration
EPAQ2 [29]	SB, PA	Adults	SA	Average weekday and weekend day during the past 12 months	23	Frequency of mode of transportation (always to never)	h/week or h/day	/	Duration
GPAQ [30–32]	SB, PA	Adults	SA, I	Typical day on a typical week	1	/	h-m/day	/	Duration
HBSC [22]	SB, PA	Adolescents	I	Usual weekday and weekend day	6	/	h/day		Duration
iHSQ [33]	SB, PA	Adolescents	SA	Typical school day, average school week	14	Modes of transportation: # days/week	Minutes or hours / day	/	Duration
IPAQ-E [34]	SB, PA	Older adults	SA	Average/day during the last 7 days	1	/	h-m/day	/	Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	*Time*	*Breaks*	
IPAQ-LF [35–43]	SB, PA	Adults, Older adults, Patients with T2DM, Overweight adults	SA, I	Average/weekdays and weekend days during the last 7 days	4	# days/week in a motor vehicle	h-m/day	/	Duration
IPAQ-LF-Hausa [44]	SB, PA	Adults	SA	Average/weekdays and weekend days during the last 7 days	4	# days/week in a motor vehicle	h-m/day	/	Duration
IPAQ-LF-Fibromyalgia [45]	SB, PA	Women with fibromyalgia	SA	Average/weekdays and weekend days during the last 7 days	6	# days/week in a motor vehicle	h-m/day	/	Duration
IPAQ-LF-Inuit [46]	SB, PA	Adults	I	Average/weekdays and weekend days during the last 7days	4	# days/week in a motor vehicle	h-m/day	/	Duration
IPAQ-SF [34,41,47–57]	SB, PA	Adolescents, Adults, Older adults, Blind adults	SA, I	Average/day during the last 7 days	1	/	h-m/day	/	Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
IPAQ-SF-Hausa [54]	SB, PA	Adults	SA	Average day during the last 7 days	1	/	h-m/day	/	Duration
LASA-SBQ [58]	SB	Older adults	SA	Average weekday and weekend day	20	/	h-m/day	/	Duration
LoPAQ [59]	SB, PA	Patients on hemodialysis	I	Average/day during the last 7 days	5	# naps/week	h/day	/	Duration
LOSTQ [60]	SB	Adults	SA	Average working and leisure day during the measuring period (7d)	8	/	h-m/day	/	Duration
MDSSTQ [61]	SB	Adults	SA	Usual weekday and weekend day	10	/	h-m/day	/	Duration
MOSPA-Q-M [62]	SB, PA	Adults	SA	Typical workday in the last 7 days	1	/	h-m/day	/	Duration
MPAQ [63]	SB, PA	Adults	I	Typical workday, weekday and week-end day	44	Frequency (daily, weekly, monthly, yearly, never)	h-m/day	/	Duration
MSTQ [64]	SB	Adults	SA	Average work day and non-work day during an usual week	14	/	h-m/day	/	Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	*Time*	*Breaks*	
OSPAQ [65]	SB, PA	Adults	SA	Typical workday in the last 7 days	3	/	%, h-m/day	/	Duration
PACI [66–68]	SB, PA	Children	I	Yesterday before and after school	4	/	h-m/day	/	Duration
Paffenbarger PAQ – Q8 [69]	SB, PA	Adults	I	Usual weekday and weekend day	4	/	h/day	/	Duration
PAQ [70]	SB, PA	Adults	I	Typical day	7	/	h-m/day	/	Duration
PASBAQ [71]	SB, PA	Adults	I	Average weekday and weekend day in the last 4 weeks	4	/	h-m/day	/	Duration
PAST [72]	SB	Women with breast cancer	I	Previous day	9	/	h-m/day	/	Duration
PAST-U [73]	SB	Adults (students)	I	Previous day	9	/	h-m/day	/	Duration
PPAQ [74]	SB, PA	Pregnant women	I	Usual day in this trimester	5	/	h/day	/	MET-Time, Duration
QAPE – S [75]	SB, PA	Children	SA	Each day of the last week	41	# days/week	/	/	Score
RADI [76]	SB, PA	Patients in primary care	SA	Typical day during the past wk, month, year	3	/	h/day	/	Score, Duration
RPAQ [77,78]	SB, PA	Adults	SA	Average/weekday and weekend day over the last 4 weeks	12	/	h-m/day	/	MET-Time, Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
SAPAC [66]	SB, PA	Children	SA	Before and after school yesterday	4	/	h-m/day	/	Duration
SAPAC-M [79]	SB, PA	Preadolescent	I	Previous day before and after school	4	/	h-m/day	/	Duration
SAPAS [80]	SB	Adults	I	Typical day	2	/	h-m/day	Frequency (from always to never)	Duration, Frequency of breaks
SBQ [42]	SB	Overweight adults	SA	Typical weekday and weekend day	18	/	h/day	/	Duration
SBQ-Spanish [81]	SB	Patients with fibromyalgia	SA	Typical weekday and weekend day	22	/	m/day or h/day	/	Duration
SITBRQ [82]	SB	Adults	SA	Typical work day	2	/	/	# breaks/h, total time of break during the day at work	# of breaks
SIT-Q-12m [83]	SB	Adults	SA	Usual weekday and weekend day during the last 12 months	55	Frequency of eating while watching tv (always to never)	h-m/day	Frequency of breaks during work and tv viewing for leisure	# of breaks, Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
SIT-Q-7d [84]	SB	Adults	SA	Average weekday and weekend day during the last 7 days	68	/	m/day or h/day	# breaks/day during sitting while doing occupation and watching TV	Duration
SMCPAQ [85]	SB, PA	Adults	SA	Average/day during the past year and ages 15, 30 and 50.	8	/	h/day	/	Duration
SQTV [86]	SB	Adults	SA	Usual week	1	/	h-m/day	/	Duration
STAR-Q [87,88]	SB, PA	Adults	SA	Average/day during the last 4 weeks	115	# days/past 4 weeks	h-m/day	/	Duration
STSBQ [89]	SB	Adolescents	SA	Usual weekday and usual weekend	12	/	h/day	/	Duration
SUASQ [90]	SB	Adults	I	Average work day during last week	2	/	h-m/day	# of breaks/h during sitting at work	# of breaks, Duration
SUHSQ [91]	SB	Older adults	I	Last week	7	/	h-m/week	/	Duration
VCSBQ [92]	SB	Older adults	I	Usual day during the last 7 days	21	# days/week	h-m/day	/	Duration

Questionnaire	Construct to be measured	Target population	Mode	Recall period	# of items	Dimensions			Indicators
						Frequency	***Time***	***Breaks***	
WAIPAQ [93]	SB, PA	Adults	I	Typical weekday, Saturday, Sunday or on average per day	5	/	h-m/day	/	Duration
WSQ [94]	SB	Adults	SA	Average working, non-working day during the last 7 days	10	/	h-m/day	/	Duration
YPAS [26,51,95,96]	SB, PA	Older adults, Adults with Schizophrenia, or schizoaffective disorders	I	Average day over the last month, last week	2	/	h/day, h-m/week	/	Score, Duration
YRBS [29]	SB, PA	Adolescents	SA	Average school day	1	/	h/day	/	Duration

SA: Self-Administered; I: Interview; #: Number; h: hours; m: minutes; %: Percentage; /: not listed

Table 3. Questionnaires 'content linked to the taxonomy

Taxonomy		Active-Q	AD3STQ	AJPAS	AQuAA	ASAQ	ASTSQ	AWAS	CAPANS-PA (Modified)	CHAMPS	CSIST	DSSTQ	EAST-Q
S	**Purpose**												
S9	Work	X (X)	X	X			(X)	X (X)					
S8	Leisure		(X)		X			X				X	
S7	Travel	X	X		X (X)	X (X)		X (X)	X			X	
S6	Domestic							X					
S5	Education	(X)				X		X	X	X			X
S4	Social		(X)	X	(X)	(X)	(X)			X		(X)	
S3	Eating			X								(X)	
S2	Rest	X		X		(X)							
S1	Care							X					
I	**Environment**												
Ic	Community												
Ip	Physical												
II	Location		X		(X)	X			X	X		X	X
T	Posture												
T2	Sitting	X	X	X	(X)	X	X	X	X		X	X	X
T1	Lying												
O	**Social**												
O2	With others		(X)	X	(X)	(X)	(X)			X		(X)	
O1	Alone												
A	**Associated behaviours**												
As	Smoking												
Ae	Eating		(X)										
Ad	Drinking												
An	None												
U	**Status**												
Uf	Functional												
Up	Psychology												
M	**Time**												
Md	Of day	X	X	X	X	X	X	X	X		X	X	X
My	Of year												X
Y	**Type**												
Yn	No screen	X	(X)	X	X (X)	X (X)	(X)	X (X)	X	X		(X)	
Ys	Screen	X	X (X)	X	X (X)	X	(X)	(X)	X	X		X (X)	X

Taxonomy		EPAQ2	GPAQ	HBSC	iHSQ	IPAQ-E	IPAQ-LF	IPAQ-LF (Hausa)	IPAQ-LF (Fibromyalgia)	PAQ-LF (Inuit)	IPAQ-SF	IPAQ-SF (Hausa)	LASA-SBQ
S	**Purpose**												
S9	Work	X (X)											X
S8	Leisure				X	X	X	X	X	X	X	X	X
S7	Travel	X	X (X)	(X)	X (X)		X (X)	X (X)	X (X)	X (X)			X
S6	Domestic											X	
S5	Education			(X)	X	X	X		X	X	X		
S4	Social		X (X)	(X)		(X)	(X)	(X)	(X)	(X)	(X)	(X)	X
S3	Eating			(X)									
S2	Rest	X											X
S1	Care												
I	**Environment**												
Ic	Community												
Ip	Physical												
II	Location		X			X	X	X	X	X	X	X	X
T	**Posture**												
T2	Sitting	X	X	X	X	X (X)	X (X)	X (X)	X (X)	X (X)	X (X)	X (X)	X
T1	Lying		X			(X)	(X)	(X)	X (X)	(X)	(X)	(X)	X
O	**Social**			(X)									
O2	With others		X (X)			(X)	(X)	(X)	(X)	(X)	(X)	(X)	X (X)
O1	Alone												
A	**Associated behaviours**												
As	Smoking												
Ae	Eating												
Ad	Drinking												
An	None												
U	**Status**												
Uf	Functional												
Up	Psychology												
M	**Time**			X									
Md	Of day	X	X	X	X	X	X	X	X	X	X	X	X
My	Of year												
Y	**Type**												
Yn	No screen	(X)	(X)	(X)	X (X)	(X)	(X)	(X)	(X)	(X)	(X)	X (X)	X (X)
	Screen	X	(X)	X (X)	X (X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	X

Taxonomy		LoPAQ	LOSTQ	MDSSTQ	MOSPA-Q (Modified)	MPAQ	MSTQ	OSPAQ	PACI	Paffenbarger PAQ-Q8	PAQ	PASBAQ	PAST
S	**Purpose**												
S9	Work		X		X	(X)	X	X		X (X)			X
S8	Leisure		X	X									X
S7	Travel			X		X	X				X		X (X)
S6	Domestic												
S5	Education						X					(X)	
S4	Social			(X)			X						(X)
S3	Eating			(X)		X				(X)	(X)	(X)	X (X)
S2	Rest	X				X	X			X	X		
S1	Care												
I	**Environment**												
Ic	Community												
Ip	Physical												
II	Location			X				X			X		X
T	**Posture**												
T2	Sitting	X	X	X	X	X	X	X	X	X	X	X	X
T1	Lying												X
O	**Social**						X						
O2	With others			(X)									(X)
O1	Alone												
A	**Associated behaviours**												
As	Smoking												
Ae	Eating												
Ad	Drinking												
An	None												
U	**Status**												
Uf	Functional						X						
Up	Psychology												
M	**Time**												
Md	Of day	X	X	X	X	X		X	X	X	X	X	X
My	Of year												
Y	**Type**					X							
Yn	No screen	X		(X)		X (X)	X	(X)		(X)	(X)	(X)	X (X)
Ys	Screen	X		X (X)		X (X)	X	(X)	X	(X)	X (X)	X (X)	X (X)

Taxonomy		PAST-U	PPAQ	QAPE - Semaine	RADI	RPAQ	SAPAC (Modified)	SAPAC	SAPAS	SBQ	SBQ (Spanish)	SITBRQ	SIT-Q-12m
S	**Purpose**												
S9	Work	X				X				X	X		X
S8	Leisure												X
S7	Travel	X	X			X			X	X	X		X
S6	Domestic												
S5	Education	X (X)											X
S4	Social	X	X						X				
S3	Eating	X			(X)						X		X
S2	Rest										X		X
S1	Care												X
I	**Environment**												
Ic	Community												
Ip	Physical												
II	Location	X (X)	X		(X)	X			X			X	
T	**Posture**												
T2	Sitting	X	X		X	X			X	X	X	X	X
T1	Lying	X							X		X		X
O	**Social**		X										
O2	With others	X (X)							X				
O1	Alone												
A	**Associated behaviours**												
As	Smoking												
Ae	Eating												X
Ad	Drinking												
An	None												
U	**Status**												
Uf	Functional												
Up	Psychology												
M	**Time**												
Md	Of day	X	X	X	X	X	X	X	X		X	X	X
My	Of year												
Y	**Type**												
Yn	No screen	X (X)	X		(X)				X	X (X)	X	X	X
Ys	Screen	X	X	X (X)	(X)	X (X)	X (X)	X	X	X (X)	X		X

Taxonomy		SIT-Q-7d	SMCPAQ	SQTV	STAR-Q	STSBQ	SUASQ	SUHSQ	VCSBQ	WAIPAQ	WSQ	YPAS	YRBS
S	**Purpose**												
S9	Work	X	X		X		X						
S8	Leisure		X						X		X		
S7	Travel	X			X			X	X		X (X)		
S6	Domestic	X							X				
S5	Education	X			X	X			X				
S4	Social	X			(X)			X	X		(X)		
S3	Eating	X			X				X				
S2	Rest	X			X								
S1	Care	X			X								
I	**Environment**												
Ic	Community												
Ip	Physical												
II	Location				X		X		X	X	X		
T	**Posture**												
T2	Sitting	X	X	X	X		X	X	X	X	X (X)	X	X
T1	Lying	X		X	X			X					
O	**Social**	X			(X)						(X)		
O2	With others	X						X	X				
O1	Alone												
A	**Associated behaviours**												
As	Smoking												
Ae	Eating	X											
Ad	Drinking	X											
An	None												
U	**Status**												
Uf	Functional				X								
Up	Psychology												
M	**Time**												
Md	Of day	X			X	X	X		X	X	X	X	X
My	Of year												
Y	**Type**												
Yn	No screen	X (X)	X		X (X)		X	X	X (X)				
Ys	Screen	X (X)	X	X	X (X)	X		X	X	X	X (X)		X

Supporting information

S1 Appendix. Full list of questionnaire abbreviations and their corresponding definitions

This file presents the entire list of SB questionnaires analyzed in this review, their abbreviations, and the references for each of them.

Active-Q	Web-Based Physical Activity Questionnaire Active-Q
AD3STQ	AusDiab3 Sitting Time Questionnaire
AJPAS	Aadahl & Jorgensen Physical Activity Scale
AQuAA	Activity Questionnaire for Adults and Adolescents
ASAQ	Adolescent Sedentary Activities Questionnaire
ASTSQ	Aguilar Sitting Time Single Question
AWAS	Australian Women Activity Survey
CAPANS-PA-M	Child and Adolescent Physical Activity and Nutrition Survey, Physical Activity (Modified)
CHAMPS	Community Health Activities Model Program for Seniors
CSIST	Clemes Single Item Sitting Time
DSSTQ	Domain-Specific Sitting Time Questionnaire
EAST-Q	Project EAST Questionnaire
EPAQ2	EPIC-Norfolk Physical Activity Questionnaire
GPAQ	Global Physical Activity Questionnaire (version 2)
HBSC	Health Behaviour in School aged Children
iHSQ	iHealth Study Questionnaire
IPAQ-E	International Physical Activity Questionnaire - Short Form (Modified for elderly)
IPAQ-LF	International Physical Activity Questionnaire - Long Form

IPAQ-LF-Hausa	International Physical Activity Questionnaire - Long Form (Modified in Hausa)
IPAQ-LF-F	International Physical Activity Questionnaire - Long form (Modified for people with fibromyalgia)
IPAQ-LF-Inuit	International Physical Activity Questionnaire - Long form (Modified in Inuit)
IPAQ-SF	International Physical Activity Questionnaire - Short form
IPAQ-SF-Hausa	International Physical Activity Questionnaire - Short Form (Modified in Hausa)
LASA-SBQ	Longitudinal Aging Study Amsterdam Sedentary Behavior Questionnaire
LoPAQ	Low Physical Activity Questionnaire
LOSTQ	Lagersted-Olsen Sitting Time Questionnaire
MDSSTQ	Marshall Domain-Specific Sitting Time Questionnaire
MPAQ	MDRF Physical Activity Questionnaire
MOSPA-Q-M	MONICA Optional Study on Physical Activity Questionnaire (Modified)
MSTQ	Multicontext Sitting Time Questionnaire
OSPAQ	Occupational Sitting and Physical Activity Questionnaire
PACI	Physical Activity Checklist Interview
Paffenbarger PAQ – Q8	Paffenbarger Physical Activity Questionnaire - Question 8
PAQ	Physical Activity Questionnaire
PASBAQ	Physical Activity and Sedentary Behavior Assessment Questionnaire
PAST	Past-day Adults' Sedentary Time questionnaire
PAST-U	Past-day Adults' Sedentary Time – University
PPAQ	Pregnancy Physical Activity Questionnaire
QAPE – S	Children Physical Activity Questionnaire - week
RADI	Rapid Assessment Disuse Index
RPAQ	Recent Physical Activity Questionnaire
SAPAC	Self-administered Physical Activity Checklist
SAPAC-M	Self-administered Physical Activity Checklist (Modified form)

SAPAS	South Australian Physical Activity Survey
SBQ	Sedentary Behavior Questionnaire
SBQ-Spanish	Sedentary Behavior Questionnaire (Modified in Spanish)
SITBRQ	Workplace Sitting Breaks Questionnaire
SIT-Q-12m	Last 12-month Sedentary Time Questionnaire
SIT-Q-7d	Last 7-day Sedentary Time Questionnaire
SMCPAQ	Swedish Mammography Cohort Physical Activity Questionnaire
SQTV	Survey Question on Television Viewing
STAR-Q	Sedentary Time and Activity Reporting Questionnaire
STSBQ	Screen Time-based Sedentary Behaviour Questionnaire
SUASQ	Stand Up Australia Study Questionnare
SUHSQ	Stand Up for your Health Sedentary Questionnaire
VCSBQ	Van Cauwenberg Sedentary Behaviors Questionnaire
WAIPAQ	Western Australian Incidental Physical Activity Questionnaire
WSQ	Workforce Sitting Questionnaire
YPAS	Yale Physical Activity Survey
YRBS	Youth Risk Behviorur Questionnaire 1999

Chapter 4

General discussion

This dissertation was composed of 4 different studies, with the overall purpose to contribute to the surveillance and measurement of physical activity and sedentary behaviors. These studies were designed to answer the following research questions:

- What is the current state of physical activity and sedentary behavior surveillance in France?
- What are the psychometric properties of the French Global Physical Activity Questionnaire?
- What do sedentary behaviors questionnaires measure?

This general discussion discusses findings relating to these questions, first summarizing the main results of each study, then discussing its implications and perspectives.

1 Study 1. Surveillance of physical activity and sedentary behaviors: case-study using French surveillance data.

1.1 Main results

Study 1 aimed to investigate the measuring instrument used to measure physical activity and sedentary behaviors in French national surveillance studies. National experts of physical activity and public health gathered to report findings on prevalence of physical activity and sedentary behaviors, and discuss measurement issues. Six national health studies enabling an estimate of physical activity prevalence have been implemented, from 2005 to nowadays. All studies have used questionnaires to measure physical activity and sedentary behaviors. For adults, the IPAQ-SF, GPAQ and a modified version of RPAQ have been used. For adolescents aged 15-17 years the IPAQ-SF, GPAQ, and modified questions from the United States Youth Risk Behavior Survey (YRBS) have been used. For adolescent aged 11-14 years original and modified questions from the YRBS have been used, and for children aged 10 years and younger a French questionnaire developed by the French Nutritional

Epidemiological and Surveillance Unit have been used, both in its original and modified form. From 62.8% to 79.4% of adults and 29.8% to 43.2% of adolescents 15-17 years old reported a level of physical activity meeting the recommended target. All studies focused on aerobic physical activity, and none measured muscle-strengthening and joint mobility exercises.

1.2 Discussion

In France, surveillance of physical activity and sedentary behaviors has been developed mainly as a result of the introduction of the PNNS. Over the last 15 years, a series of well-designed large-scale surveys have been implemented to collect data among representative sample. The work undertaken during this thesis reported two main issues related to these surveys. The first issue is the lack of consistency over time, which impairs between-study comparability. The second issue is related to the indicators assessed.

Consistency is a key element of public health surveillance. The PNNS sets goals related to the proportion of youth and adults meeting the national recommendation (PNNS 2011-2005, 2006-2010, 2011-2015). To evaluate the achievement of these goals, surveys must be implemented and repeated over time. However, the lack of stability in the measuring tools prevents the ability to compare the results over time. In France the IPAQ-SF has been used for surveillance from 2005 to 2007, in 2008 the Health Barometer used the GPAQ, and in 2014-2015 the last French surveys have used the RPAQ. There is no evidence that the RPAQ provides more accurate estimates than the GPAQ as they have not been compared. Further, the use of the RPAQ makes it complicated to compare the results between the previous surveys using the IPAQ-SF (2005 Health Barometer, ENNS and INCA 2 in 2006-2007) and GPAQ (2008 Health Barometer) and the last surveys using the RPAQ (INCA 3 and ESTEBAN in 2014-2015). As the use of different items to derive physical activity indicator values is likely to produce differences in estimates, the same questionnaire should be used is to compare results over time and between surveys. This concern is seen in different surveillance systems. This concern is seen in different surveillance systems. In the United States National Health and Nutrition Examination Survey, a single question indicating the usual amount of time spent sitting is used to track the prevalence of sedentary time since 2007 (CDC, 2017/). Physical activity levels are estimated by asking the time spent in moderate- and vigorous-intensity physical activity for work, leisure and transport to determine the proportion of participants meeting the physical activity guidelines (NAHNES 2007-2008, 2009-2010, 2011-2012, 2013-2014, 2015-2016). In Canada, the Canadian Health Measures

Survey uses objective monitoring (i.e. accelerometers) to measure physical activity since its first implementation in 2007.This enables an accurate tracking of Canadian physical activity levels and sedentary time (Statistics Canada, 2015).

The second main issue identified in study 1 is related to the indicators of physical activity and sedentary behaviors. The report from the evaluation of the PNNS suggested the need to develop a relevant matrix of indicators that measure physical activity and sedentary behaviors, the monitoring of which will be prioritized and will enable the evaluation of the efficiency of the PNNS (General Inspectorate of Social Affairs, 2016). The work realized during this thesis led to the same conclusion. The objectives of the PNNS is to increase by 20% the proportion of adults with a moderate level of physical activity (as determined with the IPAQ and GPAQ), and by 20 and 25% the proportion of men and women with a high level of physical activity, respectively, over 5 years (PNNS 2011-2015). The IPAQ and GPAQ are used to assess physical activity. Yet, a questionnaire different from the IPAQ or GPAQ, with a different scoring, protocols has been used in the most recent French surveys (Esteban and Inca 3), which make it unclear how to evaluate the achievement of these targets. For youth aged between 3 and 17 years, the PNNS 2011-2015 aimed to have50% of youth engaging in at least 60 minutes of vigorous physical activity 3 days or more per week and to reduce by 10% daily screen time within five years. However, the questionnaires used in the most recent surveys asks about vigorous-intensity physical activity lasting at least 40 minutes. Therefore, these questionnaires do not allow to determine whether the objectives for physical activity are met.

The PNNS envisioned physical activity as a nutritional behavior, meaning as a way to prevent obesity and other diet-related diseases. This may explain why no other indicators for physical activity have been used in the surveillance system. As part of the recommendations from Anses for the PNNS 2016-2021, it is now recommended that adutls engage in muscle-strengthening and joint mobility exercises. Thus, it is expected that the next PNNS will include indicators related to these physical activities. National physical activity strengthening goals are assessed in the United States Behavioral Risk Factor Surveillance System with participants asked to report the number of time they engage in physical activities to strengthen their muscles (CDC, 2017). Furthermore, other indicators could be measured that relate to physical activity. For example, the environment (including the social environment and the physical environment such as outdoor playground) and policies and programs are of importance in understanding physical activity and sedentary behaviors and for the planning of

effective interventions (Sallis et al., 2015). Yet, in the U.S., since none of the questions about the environment and policies are being measured, it is hard to interpret the responses. Therefore, the development of a comprehensive framework of indicators for physical activity and sedentary behaviors should be given careful consideration to include measures that are meaningful to national goals.

1.3 Strengths and limitations

The main strength of this study was in gathering French national experts of physical activity and sedentary behaviors surveillance to review the current French surveillance system. By doing so, the conclusions and recommendations made by the experts are more likely to influence the future of physical activity and sedentary behaviors surveillance in France.

Study 1 have limitations. Study 1 included only national surveys implemented in metropolitan France, thus excluded the surveys implemented in French overseas departments and territories. Furthermore, it focused exclusively on surveys that aimed to determine the prevalence of physical activity levels, resulting in the inclusion of health surveys only. However, surveys on transportation or work can collect valuable information regarding active transportation and physical activity at work, respectively.

2 Study 2. Results from the first French Report Card on physical activity for children and adolescents (2016).

2.1 Main results

Study 2 aimed to report the first French Report Card on the physical activity of children and adolescents. The Report Card assessed eight indicators of physical activity: 1) Overall Physical Activity Levels, 2) Organized Sport Participation, 3) Active Transportation, 4) Sedentary Behaviors, 5) Family and Peers, 6) School setting, 7) Community and the Built Environment, and 8) Government Strategies and Investment Grades were assigned following the framework and benchmarks used by the Active Healthy Kids Global Alliance: A: 81% to 100%, B: 61% to 80%, C: 41% to 60%, D: 21% to 40%, F: 0% to 20%. An incomplete (INC) grade was assigned where insufficient data were available or due to the absence of a suitable benchmark. In 2016, 38 countries joined the Active Health Kids Global Alliance and produced a Report Card on the physical activity of children and youth following the same framework (Tremblay et al., 2016). In study 2, the following grades were reported: Overall Physical Activity: INC; Organized Sport Participation: D; Active Transportation: D; Sedentary

Behaviors: D; Family and Peers: INC; School: B; Community and the Built Environment: INC; Government Strategies and Investment: INC.

2.2 Discussion

The grades reveal that efforts must be done to improve youth's physical activity and that several gaps in the literature still need to be addressed. Four indicators could not be graded: overall physical activity, community and environment, family and peers, and government and institutions. In comparison, from the 38 countries who reported a Report Card, only 5 countries did not report the grade for at least 4 indicators (i.e. Brazil, England, India, Qatar and Venezuela) (Tremblay et al., 2016). There is a clear need for stronger evidence based data at a national level regarding the physical activity level in children and adolescents in France, the built environment, family and peers' physical activity, and the implication of the government in promoting physical activity in youth.

Among the 4 grades that had been graded, three received the grade D: organized sport participation, active transportation, and sedentary behaviors. In comparison, 61%, 79% and 29% of the 38 countries who produced a report card reported a grade A, B or C for: organized sport participation, active transportation, and sedentary behaviors, respectively. In regards to the low proportion of children using active transportation and engaging in organized sport, there is a need to implement and strengthen policies to promote active transportation and organized sport. Initiatives could include designing and building cycle routes that allow cycling in good conditions of effort and safety, in a time-efficient way to schools, and building bicycle parking near or within schools. Financial incentive could be used to help parents registering their children in organized sport activities. Regarding sedentary behaviors, the low proportions of countries awarded a grade A, B or C indicate that children and adolescents sedentary lifestyle is an issue of global concern.

A positive note was the B grade attributed to school-based physical activity, which indicates that school fulfills its role of providing access to sports and physical activity to most children.

2.3 Strengths and limitations

The strength of study 2 was to comply with the framework used by the Active Healthy Kids Global Alliance (Tremblay et al., 2016). Another strength of this study was to realize the Report Card in collaboration with the national observatory on physical activity and sedentary behaviors, who launched the release of the report card giving a greater visibility to this work. Within about one month, the long form of the report card had been downloaded 600 times, and the short form 400 times, which illustrates the interest of the French scientific and public health community in this work.

The main limitation of study was the quality and availability of the data which impaired the assignment of grades. For example, organized sports participation was assigned a grade D in France. Organized sports participation was assessed by identifying the number of sports licenses delivered by French sports federations. However, organized sport participation can occur in different settings, such as organized sport participation in private club. Therefore, it could not be ruled out that the grade for organized sport participation will be higher if more data sources were available.

3 Study 3. Reliability and validity of the French version of the global physical activity questionnaire.

3.1 Main results

Study 3 aimed to assess the test-retest reliability as well as criterion and concurrent validity of the French version of the GPAQ by comparison with the French IPAQ-LF and use of an accelerometer. Participants were invited to participate in a face-to-face interview where they completed the GPAQ and IPAQ-LF. Participants were asked to wear an ActiGraph GT3X+ for 7 consecutive days. Eight days after the first interview, participants returned the ActiGraph and completed the GPAQ and IPAQ-LF a second time. The GPAQv2 showed poor-to-good 1-week test-retest reliability (ICC = 0.37–0.94; Kappa = 0.50–0.62) and concurrent validity against the IPAQ-LF (Spearman r = 0.41–0.86), but only poor criterion validity against ActiGraph GT3X+ minutes for sedentary time (Spearman's r = 0,42, p<0,01), total vigorous physical activity (r=0.38, p<0.05), and total moderate physical activity (r=0.10). Estimates of the participants who did not meet the WHO recommendations for physical activity ranged between 22.8 and 29.4% using the GPAQ, and between 8.7 and 15.2% using the IPAQ-LF. Limits of agreement for the GPAQ and accelerometer were wide, with differences between 286.5 min/day and 601.3 min/day. Overall, the French GPAQ provided limited but acceptable reliability and validity for the measurement of physical activity and sedentary time. Psychometric properties of the GPAQ in France are similar to what is commonly observed among GPAQ administered in other countries. Other studies tested the psychometric properties of the GPAQ in different countries, including Ethiopia, Indonesia, India, South Africa, China, Bangladesh, Brazil, Japan, Portugal, and US, for a total of about 1,600 adults (Bull et al., 2009, Hermann et al., 2013). These studies reported poor-to-moderate correlations between the GPAQ and the short form of IPAQ, with Spearman's coefficients ranging from r = 0.45 to 0.57 (Bull et al., 2009), and r = 0.26 to 0.63 (Hermann et

al., 2013). When compared with accelerometers, GPAQ in France showed poor validity coefficients, comparable to those observed in the scientific literature. For instance, Cleland et al. (2014) reported Spearman's correlations ranging from r = 0.19 for sedentary time to 0.48 for moderate-to-vigorous physical activity, when tested among 95 adults in Ireland. In general, accuracy of questionnaires in quantifying physical and sedentary time remains low, and the French GPAQ is no exception.

3.2 Discussion

Research showed that different instruments used to measure the same construct can produce different results (Bauman, 1987; Ainsworth et al., 2006; Bull et al., 2009). Such findings were observed in study 3, when comparing estimates between GPAQ and IPAQ-LF in the percentage of participants who did not meet the WHO recommendations for physical activity. GPAQ and IPAQ-LF are different, yet very similar. The main differences are: the GPAQ asks about physical activity performed during a usual week and merges physical activity performed at work and in the household setting together while the IPAQ-LF asks about physical activity performed during the last seven days and makes a distinction between work- and household related physical activity. While study 1 reported the use of different questionnaires as well as questionnaires modified from the original version, results from study 3 underline the need for surveillance system to rely on standardized, repeated measures.

The GPAQ is one of the few questionnaires that has been tested against accelerometry in France. Because there is no gold standard for physical activity, many different criteria have been used, including pedometer, estimated maximal oxygen uptake and other questionnaires (Shephard, 2003). Therefore, it makes it difficult to determine whether one questionnaire perform better than the others to assess physical activity levels. To address the lack of consistency when testing the psychometric properties of physical activity questionnaires, Terwee et al. have proposed a set of best practices (Terwee et la., 2010). They recommended using other instruments measuring closely related constructs for criterion validity: doubly labelled water for total energy expenditure, accelerometry for total, vigorous- and moderate-intensity physical activity, and pedometers for walking. In addition, they recommended using correlations to investigate the validity of questionnaires, as it shows the degree to which 2 variables are related (Terwee et al., 2010). However, a high correlation does not necessary imply that there is a good agreement. Therefore, Bland-Altman plots have been used in study

3 to assess the agreement for total physical activity and sedentary time between GPAQ and accelerometers.

Differences in estimates of physical activity and sedentary time in minutes reported by Bland-Altman plots in study 3 were striking. Bland Altman Plot showed that the more participants engaged in physical activity, the more the accelerometers over-estimated physical activity when total physical activity in minutes per week from derived from accelerometers was compared with GPAQ; and inversely, physical activity was under-estimated when comparing the accelerometer with GPAQ among participants with low levels of physical activity. Research showed that low fit and sedentary individuals tend to rate their perception of effort at a given relative intensity as more intense or harder than trained individuals at the same relative intensity (Demello et al., 1987; Sylva et al., 1990; Hassmen, 1990). Thus, one possible consequence is that individuals with low physical activity levels might over-report time performing moderate-to-vigorous physical activity, which could explain Bland Altman results. Another explanation could lie in the fact that questionnaires ask about subjective intensity of physical activity while accelerometers estimate absolute intensity (the cut-points to define physical activity intensity are the same for all participants, whatever their physical fitness). It has been shown than individuals with low levels of physical activity have lower cardiorespiratory fitness, and individuals with high levels of physical activity, especially high vigorous physical activity, have higher cardiorespiratory fitness (Dencker et al., 2006; Després, 2016). Because cardiorespiratory fitness influences an individuals' perception of physical activity intensity, it may likely that participants with lower physical activity and fitness levels may over-estimate physical activity intensity, while individuals with higher physical activity and fitness levels may under-estimate their physical activity intensity (Milanez et al., 2011). As a consequence, physical activity measured by an accelerometer as light intensity could be perceived as moderate intensity by individuals with lower physical activity and fitness levels, and conversely, physical activity measured by an accelerometer measured as moderate intensity as could be perceived as light intensity by individuals with higher physical activity and fitness levels. Because the GPAQ does not ask about light intensity physical activity, individuals with higher fitness levels might under-report the time they spend in total physical activity.

3.3 Strengths and limitations

This study had several strengths, including the adherence to standardized WHO protocols in administering questionnaires, the concordant measurement period for both questionnaires and the accelerometer, and the use of Bland Altman plots to explore the agreement between GPAQ and accelerometers. This study had some limitations that may influence the results. First, the population was not representative of the French population, which may limit the generalizability of the findings. The second main limitation was the use of accelerometers as a reference instrument; the GPAQ and accelerometers do not measure the same construct. Three points highlight this limitation. First, the GPAQ has respondents recall physical activity that lasts at least 10 minutes, whereas accelerometers measure all activities regardless of duration. Second, the GPAQ has respondents recall their perceived intensity (for example vigorous-intensity activity is defined by a large increase in breathing or heart rate), while the accelerometer estimates absolute intensity from its primary output (counts per unit of time) by using intensity-related cut points. Third, accelerometers cannot measure some activities, such as aquatic activities, cycling and weight lifting. Therefore, it is not surprising to observe a poor criterion validity for the GPAQ as compared with accelerometer. These limitations could have been improved by calibrating the accelerometers for the physiological capacity of the participants to estimate relative intensity by using individualized activity count cut-points, analyze accelerometer counts to included activities lasting at least 10 minutes only, and giving a diary to participants to indicate the time and intensity of activities that cannot be accurately measured by accelerometers such as swimming and cycling.

4 Study 4. Content comparison of sedentary behaviors questionnaires: a systematic review.

4.1 Main results

Study 3 aimed to report the content of sedentary behaviors questionnaires in a detailed and standardized manner. The content of 60 questionnaires was linked to the taxonomy of sedentary behaviors (Chastin et al., 2013). The following information were reported: (i) the number of items assessing sedentary behaviors characteristics; (ii) the number of SB characteristics identified; and (iii) the facets and categories of the taxonomy covered. The mean number of items per questionnaire was 14.2 [min – max = 1 - 115], and the mean number of sedentary behaviors characteristics measured per questionnaire was 9.4 [min - max = 2 - 27]. Most of the questionnaires assessed the facets Time (n=55), Posture (n=54),

Purpose (n=46) and Type (n=45) of the taxonomy of sedentary behaviors, 20 enquired about Environment, only 11 asked about the Social context, 2 about the Status and 2 about the Associated Behaviors. Differences in questionnaires' content were observed, with the most comprehensive questionnaires measuring up to 27 sedentary behaviors characteristics while the least comprehensive questionnaires measured only sitting time. Important discrepancy in the characteristics of sedentary behaviors measured was noticed, with "TV" and "computer" measured by 65 and 55% of the questionnaires, respectively, while many characteristics of sedentary behaviors were often not measured. These observations have implications as depending of the type, purpose, environment, associated behaviors, and other facets of the behavior, sedentary behaviors might be differently associated with various health outcomes, and might have different correlates and determinants. Therefore, all facets of sedentary behaviors need to be investigated; but study 3 showed that many facets are not, or rarely, measured with questionnaires, including behaviors associated to sedentary time (such as eating and smoking), multitasking, the physical and social environment, when the behavior takes place, and the physical and psychological state of the individual. This finding has implication as qualitative information can be collected using self-report methods only. As a consequence, either new questionnaire need to be developed, or other self-report method, such as ecological momentary assessment (EMA), need to be used, to assess the facets of sedentary behaviors that current questionnaire misses to measure.

4.2 Discussion

The taxonomy-based content analysis provides a useful tool to identify and compare the content of questionnaires. In addition, information on the construct to be measured (sedentary behaviors and physical activity or sedentary behaviors only), the target population, mode of administration, recall period, number of items, and the quantitative components measured (frequency, time and breaks) were reported in study 4. The results observed in study 4 may help researchers to select the most appropriate questionnaire based on the purpose of their study and the information they seek to collect.

One of the main challenges of surveillance system is to rely on consistent methodology to allow comparison over time, while being sufficiently flexible to adapt to changing needs. For example, the surveillance system has to be able to adapt to changes in guideline definitions. However, because questionnaires are used as a whole to measure physical activity and sedentary behaviors, changing needs often result in changing wording or questionnaire, as

observed in study 1. Therefore, a solution could be to test the psychometric properties at item levels and to create a bank of item where each item could be used individually or in association with others. By doing so, it would allow investigators to add or remove a few items depending on the objectives of the survey. Study 3 identified 846 items, out of 60 questionnaires, and reported the diversity in the characteristics of sedentary behaviors being measured.

Such item banks are already being developed to improve the measurement of patient reported outcomes (Cella et al., 2007; Tucker et al., 2014a). For example, the Patient-Reported Outcomes Measurement Information System (PROMIS) provides item banks that offer the potential for patient reported outcomes measurement that is efficient (minimizes item number without compromising reliability), flexible (enables optional use of interchangeable items), and precise (has minimal error in estimate) (Cella et al., 2010). PROMIS aims to develop a set of efficient and flexible measures that evaluates and monitors physical, mental, and social health in adults and children (http://www.healthmeasures.net/explore-measurement-systems/promis). As part of the PROMIS project, Tucker and colleagues initiated the development of item pools measuring physical activity and sedentary behaviors among child aged between 8 and 18 years (Tucker et al., 2014a; Tucker et al., 2014b). Tucker and colleagues performed literature review, semi-structured interviews (with expert and child) and cognitive interviews to generate and improve items for sedentary behaviors and physical activity measurement. As a result, 80 items for physical activity and 23 items for sedentary behaviors were generated. While the psychometric properties have not been tested yet, Tucker et al. aim to administer the items to a large sample in a near future. Therefore, it can be expected that the accuracy of these items will be investigated.

4.3 Strengths and limitations

The main strength of study 4 was to analyze the content of sedentary behaviors questionnaires using a standardized method proposed by Chastin et al. (Chastin et al., 2013). However, this method had several limitations. First, despite the development of linking rules, disagreement was observed during the linking process, and the degree of agreement between the two investigators was not assessed. Disagreements were discussed and a consensus was obtained. In addition, only articles written in English and in French were selected, and no grey literature was search, thus some questionnaires may have been missed. Finally, the psychometric properties of the questionnaires reviewed were not reported, which would have added to the informative value of this work.

5 Perspectives

Collectively, the studies completed during this thesis provide valuable information regarding the surveillance and measurement of physical activity and sedentary behaviors. This thesis also raises questions as for the future of the French surveillance system and the measurement of physical activity and sedentary behaviors. These questions are inter-connected as an improvement in measurement accuracy will directly improve the quality of data collected in surveillance studies. The following sections discuss public health and research perspectives related to these questions.

5.1 Public health perspectives

How to improve measurement and surveillance of physical activity and sedentary behaviors?

Use standardized and repeated measures for physical activity and sedentary behaviors surveillance

One issue observed in the French surveillance of physical activity and sedentary behaviors is the lack of standardization in the measuring instrument. As reported in study 3, two different questionnaires, even though fairly similar, produce different results. Therefore, French surveillance studies should aim to use repeatedly the same instrument in order to allow tracking of physical activity levels and sedentary time.

Assess the psychometric properties of questionnaires for physical activity and sedentary behaviors surveillance

One issue with the use of questionnaires to measure physical activity and sedentary behaviors in surveillance studies is the lack of evidence for the psychometric properties of the questionnaires. As reported in study 1, questionnaires have been used in a version different from the original version, while only the psychometric properties of the original version had been investigated. Further, the French GPAQ has been used in the 2008 Health Barometer but its psychometric properties of the French version of the GPAQ had not been investigated yet. Assessing the psychometric properties of the questionnaire can provide insights about

accuracy and misclassification in estimates of physical activity and sedentary behaviors. Testing the psychometric properties of a given questionnaire is essential to properly interpret physical activity and sedentary behaviors reported using this questionnaire.

Develop a conceptual framework of indicators for French physical activity and sedentary behaviors monitoring system.

The lack of standardized continuous measurement might be partially explained by the lack of standardized framework of indicators. In France, the surveillance of physical activity and sedentary has grown in uneven ways, with different studies funded and implemented by different institutions. The lack of adequate coordination between these institutions may be responsible of some limitations identified by this thesis, for instance the existence of multiple, overlapping data sources in some years (for example INCA 3 and Esteban provide information regarding the same indicators, over the same years), while other years no survey was implemented. A framework of indicators could help in structuring the surveillance of physical activity and sedentary behaviors. Public health actors in France should aim to develop a standardized framework of indicators that would guide the implementation of survey and the identification of the best measure and data source for each indicator. The objective of such framework would be to support a more comprehensive surveillance of physical activity and sedentary behavior in France, and should become the foundation for surveillance reporting and data development in these areas.

As an example, Canada has developed a list of key indicators that highlight the different components of daily activity and organized them in a framework called the Physical Activity, Sedentary behavior and Sleep (PASS) indicator framework (Public Health Agency of Canada, 2017). The PASS indicator list relies on a knowledge-based conceptual model. The conceptual model is based on a socio-ecological approach of behavioral determinants, and includes sleep, sedentary behaviors, light-, moderate-, and vigorous-intensity physical activity, and helped guiding the selection of indicators. Indicators were selected based on the following criteria: a strong body of evidence linked the indicator to the behavior/outcome of interest, the indicator provided information that was considered to be highly salient and relevant to the target population and the user, the indicator provided information that could inform, influence, or change public health policy, data collection, and/or practice, and the indicator was scientifically sound, valid, reliable, sensitive to change, interpretable, and

complete. The PASS indicator framework identified 55 unique indicators, with 30 indicators overlapping the two age groups, in such a way that there are 44 indicators for children and youth (aged 5 to 17), and 41 indicators for adults (aged 18 or more). The PASS indicator framework is available online, at https://infobase.phac-aspc.gc.ca/pass-apcss/. Based on the conceptual model, the list of indicators provides a comprehensive set of information to collect, and help in guiding the surveillance of movement behaviors in Canada.

The development of a framework of indicators, and the selection of measurement tools, must be the results of a collective reflection. Examples of surveillance systems from other countries could be examined, including Canada, USA and Australia. Overall, the framework of indicators should aim at providing a comprehensive understanding of physical activity participation and sedentary lifestyle to guide policy planning, resource allocation, setting and tracking national goals, assessing changes in physical activity and sedentary behaviors determinants, and evaluating national campaigns. The framework of indicators could include a variety of indicators, including levels of physical activity and sedentary time, context (work, school, home) and type (endurance or resistance exercises, TV viewing or driving a car) of physical activity and sedentary behaviors, and influencers at the intrapersonal (for example enjoyment levels and perceived benefits and risks), interpersonal (for example social support), social and physical environment (for example the numbers of TV at home and neighborhood walkability), and policy and program levels (including public health, urban planning, and transport policies).

Such framework of indicators could help in coordinating the surveillance system by identifying the data source for each indicator. The framework might also facilitate the integration of data sources other than health surveys. For example, active transportation is measured in detail in French National Survey on Transport. Finally, it allows to determine which indicators cannot be assessed with existing data sources, and might guide the development of future surveys.

5.2 Research perspectives

Should a shift towards objectively measured physical activity and sedentary behaviors be prioritized in order to improve data quality, and comparability of data collected between studies and over-time?

In general, accuracy of questionnaires in quantifying physical activity and sedentary behaviors remains low, and the French GPAQ is no exception. As observed by Shephard in 2003, physical activity questionnaires show limited validity despite extensive research., Physical activity and sedentary behaviors have many dimensions that may be differently associated with various health outcomes, and different correlates and determinants; and objective measures cannot assess all of these dimensions. Therefore, there is no doubt that the future of physical activity and sedentary behavior measurement will rely on the combination of both subjective and objective methods.

Such combinations have been implemented in surveillance systems in the United States, Canada, and recently in France, where both self-reported and device-based methods are used simultaneously to provide independent measure. Self-eported information can provide contextual information on participants' physical and sedentary time, which may help explain variability in device-based data (e.g. by examining domain-specific contribution to overall physical and sedentary time). Troiano et al. (2012) suggested the use of linked or integrated assessment techniques for a more comprehensive measurement of physical and sedentary behaviors (see Figure 8). Current approaches to measure physical and sedentary behaviors in surveillance systems correspond to panels A, B, and C. Panels D and E could provide a more comprehensive measurement of these behaviors. Panel D corresponds to simultaneous measurement using reports and devices, linked together. As an example, self-reported logs and diaries provide detailed information of an individual's behavior, at the time it occurred. By linking such information with device-based data it is possible to accurately estimate intensity and duration of a large range of everyday activities (Bringolf-Isler et al., 2009). Linked data also make it possible to determine the relative (i.e. perceived) intensity of device-based physical activity; and may also help to identify non-wear time more accurately

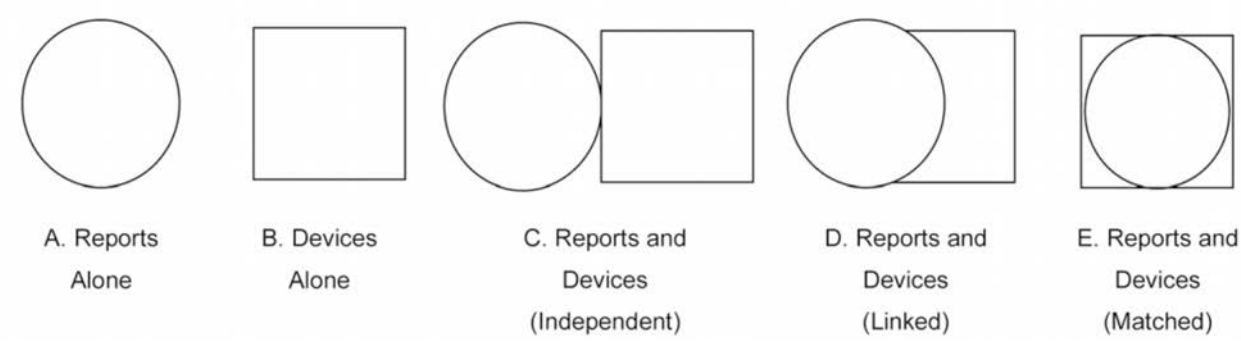


Figure 8. Approaches to measuring physical and sedentary behaviors by report and devices (from Troiano et al., 2012).

Measurement of physical activity and sedentary behaviors must tend toward the integration of reported and device-based methods, corresponding to Figure 8, panel E. Technological advancement enables combination of device-based measurement with EMA, to simultaneously collect qualitative and quantitative information of the behaviors. For example, Dunton et al. have used the smartphone internal sensors to trigger momentary assessments when at least one of the following conditions was met: 1. 15+ minutes of high intensity activity followed by 10+ minutes of low-intensity activity, 2. 60+ minutes of low-intensity activity followed by 1+ minutes of moderate intensity activity or greater, and 3. 10+ minutes of no activity data followed by 1+ minutes of some activity data (Dunton et al., 2014). A mobile app identifies the sensor-informed movement transition cues to trigger a real-time EMA self-report survey measuring the type and purpose of physical and sedentary activities, enjoyment of these activities, and social and physical features of the activity setting. Smartphones with built-in inclinometers, GPS and accelerometers that are worn all day can provide multiple sources of information about posture, movement-intensity, and travel patterns. Combined with EMA the additional sources of information may allow assessments all facets of physical activity and sedentary behaviors. Smartphone also can be connected with other devices such as watches that are able to measure heart rate and movement. Therefore, smartphones are likely to be at the core of future sedentary behaviors and physical activity measurement methods.

6 Conclusion

To conclude, the work realized during this thesis allows the formulation of recommendations to improve the surveillance of physical activity and sedentary behaviors in France:

- Surveillance of physical activity and sedentary behaviors should rely on standardized, repeated measurements;
- Key elements of data collection and processing protocols, such as physical activity and sedentary behaviors questionnaires, survey administration modes, survey time frames, and definitions of indicators, should be standardized;

- The psychometric properties of the instrument used should have been tested in the population of interest;
- The selection of the measuring tool should be made in adequacy with the indicators needed;
- A conceptual framework of indicators for comprehensive physical activity and sedentary behaviors surveillance should be developed to guide the implementation of surveys;

The surveillance system should not only provide trends information on physical activity and sedentary behaviors, but also collect information on other influencing factors such as programs and policies, and social and physical environment. This thesis is timely. At the national level, Public Health France must soon release the PNNS 2017-2021 with updated recommendations and indicators for physical activity and sedentary behaviors. This thesis might help in identifying indicators and choosing the best measuring instrument(s) to report on these indicators. In 2024, France will organize the 2024 Olympic games. One of the objective of the French organizing committee is to use the Olympic games to foster physical activity promotion. This event is an opportunity to obtain new funding to implement physical activity survey to measure the impact of the games on the physical activity level of the population.

At the European level, the EUPASMOS project (European Union Physical Activity and Sport Monitoring System) aims to implement Physical Activity and Sport Monitoring System, through the development of an integrated and shared methodological process that will provide comparable, valid and reliable sedentary behaviors patterns, physical activity and sport participation data across European Union Member States. The project, funded within the frame of Erasmus+ Sport, is led by Instituto Portugues do Desporto e Juventude I.P. (Lisboa) and involves 8 additional partners organization, including France.

This thesis fits within the WHO European region physical activity strategy 2016–2025 and the WHO global action plan on physical activity 2018-2030 which draft is under development (WHO, 2017). In its current form, the draft of WHO global action plan on physical activity 2018-2030 and the WHO European region physical activity strategy encourage member states to strengthen population surveillance of physical activity across all ages and domains, to track trends, and to ensure timely reporting; and to assess policies and national action. As part of its 2018-2030 action plan, WHO will provide support to help member states in their actions,

which might represent an opportunity for the public health institutions in France to improve the physical activity and sedentary behaviors surveillance system.

References

ACSM. (1978). Position statement on the recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. Med. Sci. Sports Exerc., 10, vii-x.

Ainsworth, B. E., Macera, C. A., Jones, D. A., Reis, J. P., Addy, C. L., Bowles, H. R., & Kohl 3rd, H. W. (2006). Comparison of the 2001 BRFSS and the IPAQ Physical Activity Questionnaires. Medicine and science in sports and exercise, 38(9), 1584-1592.

Allemani, C., Weir, H. K., Carreira, H., Harewood, R., Spika, D., Wang, X. S., ... & Marcos-Gragera, R. (2015). Global surveillance of cancer survival 1995–2009: analysis of individual data for 25 676 887 patients from 279 population-based registries in 67 countries (CONCORD-2). The Lancet, 385(9972), 977-1010.

Altenburg, T. M., & Chinapaw, M. J. (2015). Bouts and breaks in children's sedentary time: currently used operational definitions and recommendations for future research. Preventive medicine, 77, 1-3.

Anses. (2016). OPINION of ANSES on the "Updating of the PNNS guidelines: Revision of the guidelines relating to physical activity and sedentarity". Retrieved October 15, 2017, from https://www.anses.fr/en/content/opinion-anses-updating-pnns-guidelinesrevision-guidelines-relating-physical-activity-and

Aquatias, S., Arnal, J. F., Rivière, D., Bilard, J., Callède, J. P., Casillas, J. M., ... & Duché, P. (2008). Activité physique: Contextes et effets sur la santé. INSERM.

Armstrong, T., & Bull, F. (2006). Development of the world health organization global physical activity questionnaire (GPAQ). Journal of Public Health, 14(2), 66-70.

Australian Bureau of Statistics. 4153.0–How Australians Use Their Time, 2006. Retrieved October 15, 2017, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4153.0

Australian Government Department of Health. n.d. National Monitoring in Public Health Nutrition. Retrieved October 15, 2017, from http://www.health.gov.au/nutritionmonitoring

Bauman, A., Ainsworth, B. E., Sallis, J. F., Hagströmer, M., Craig, C. L., Bull, F. C., ... & IPS Group. (2011). The descriptive epidemiology of sitting: a 20-country comparison using the

International Physical Activity Questionnaire (IPAQ). American journal of preventive medicine, 41(2), 228-235.

Baumeister, S. E., Ricci, C., Kohler, S., Fischer, B., Töpfer, C., Finger, J. D., & Leitzmann, M. F. (2016). Physical activity surveillance in the european union: reliability and validity of the european health interview survey-physical activity questionnaire (EHIS-PAQ). International Journal of Behavioral Nutrition and Physical Activity, 13(1), 61.

Beck F, Gautier A, Guignard R. Méthode d'enquête du Baromètre santé nutrition 2008: une évolution dans la continuité. Baromètre santé nutrition. 2008;39–63.

Beck F, Guilbert P. Baromètres santé: un éclairage sur leur méthode et leur évolution. Baromètre santé. 2005;27–43.

Belgian Scientific Institute of Public Health. n.d. Health Interview Survey. Retrieved October 15, 2017, from https://his.wiv-isp.be/SitePages/Home.aspx

Bel-Serrat, S., Huybrechts, I., Thumann, B. F., Hebestreit, A., Abuja, P. M., de Henauw, S., ... & van Rossum, C. (2017). Inventory of surveillance systems assessing dietary, physical activity and sedentary behaviours in Europe: a DEDIPAC study. The European Journal of Public Health, 27(4), 747-755.

Berkelman, R. L., Sullivan, P. S., & Buehler, J. W. (2009). Public health surveillance. Oxford textbook of public health, Volume 2: the methods of public health, (Ed. 5), 699-715.

Besson, H., Brage, S., Jakes, R. W., Ekelund, U., & Wareham, N. J. (2010). Estimating physical activity energy expenditure, sedentary time, and physical activity intensity by self-report in adults. The American journal of clinical nutrition, 91(1), 106-114.

Birkhead, G. S., & Maylahn, C. M. (2000). State and local public health surveillance. Principles and practice of public health surveillance, 253-86.

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adultsa systematic review and meta-analysissedentary time and disease incidence, mortality, and hospitalization. Annals of internal medicine, 162(2), 123-132.

Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

Bringolf-Isler, B., Grize, L., Mäder, U., Ruch, N., Sennhauser, F. H., & Braun-Fahrländer, C. (2009). Assessment of intensity, prevalence and duration of everyday activities in Swiss school children: a cross-sectional analysis of accelerometer and diary data. International Journal of Behavioral Nutrition and Physical Activity, 6(1), 50.

Brown, W. J., Burton, N. W., Marshall, A. L., & Miller, Y. D. (2008). Reliability and validity of a modified self-administered version of the Active Australia physical activity survey in a sample of mid-age women. Australian and New Zealand journal of public health, 32(6), 535-541.

Brown, W. J., Trost, S. G., Bauman, A., Mummery, K., & Owen, N. (2004). Test-retest reliability of four physical activity measures used in population surveys. Journal of Science and Medicine in Sport, 7(2), 205-215.

Bull, F. C., Gauvin, L., Bauman, A., Shilton, T., Kohl III, H. W., & Salmon, A. (2010). The Toronto Charter for Physical Activity: a global call for action. Journal of Physical Activity and health, 7(4), 421-422.

Bull, F. C., Maslin, T. S., & Armstrong, T. (2009). Global physical activity questionnaire (GPAQ): nine country reliability and validity study. Journal of Physical Activity and health, 6(6), 790-804.

Bureau of Labor Statistics. n.d. American Time Use Survey. Retrieved October 15, 2017, from www.bls.gov/tus/

Canadian Fitness and Lifestyle Research Institute. 2017a. Physical Activity and Sport Monitor. Retrieved October 15, 2017, from http://www.cflri.ca/physical-activity-and-sport-monitors-population-studies

Canadian Fitness and Lifestyle Research Institute. 2017b. Physical Activity Longitudinal Study. Retrieved October 15, 2017, from http://www.cflri.ca/physical-activity-longitudinal-study-pals

Canadian Fitness and Lifestyle Research Institute. 2017c. Canada's Physical Activity Levels Among Youth (CANPLAY) Survey. Retrieved October 15, 2017, from http://www.cflri.ca/canplay

Canadian Fitness and Lifestyle Research Institute. 2017d. Survey of Settings. Retrived October 15, 2017, from http://www.cflri.ca/survey-settings

Canadian Research Data Center Network. N.d. Canadian Community Health Sruvey. Retrieved October 15, 2017, from https://crdcn.org/datasets/cchs-canadian-community-health-survey

Carson, V., & Janssen, I. (2011). Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC public health, 11(1), 274.

Carson, V., Stone, M., Faulkner, G., 2014. Patterns of sedentary behavior and weight status among children. Pediatr. Exerc. Sci. 26, 95–102.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public health reports, 100(2), 126.

Cella, D., Gershon, R., Lai, J. S., & Choi, S. (2007). The future of outcomes measurement: item banking, tailored short-forms, and computerized adaptive assessment. Quality of Life Research, 16(1), 133-141.

Cella, D., Riley, W., Stone, A., Rothrock, N., Reeve, B., Yount, S., ... & Cook, K. (2010). Initial adult health item banks and first wave testing of the patient-reported outcomes measurement information system (PROMIS™) network: 2005–2008. Journal of Clinical Epidemiology, 63(11), 1179.

Centers for Disease Control and Prevention. 2017. Behavioral Risk Factor Surveillance System. Retrieved October 15, 2017, from www.cdc.gov/brfss/index.html

Centers for Disease Control and Prevention. 2017. National Health and Nutrition Examination Survey. Retrieved October 15, 2017, from www.cdc.gov/nchs/nhanes/index.htm

Centers for Disease Control and Prevention. 2017. National Health Interview Survey. Retrieved from October 15, 2017 from www.cdc.gov/nchs/nhis/index.htm

Chastin SF, Helbostad JL, Tremblay MS, Ainsworth B, Mork PJ, Rochester L, et al. AlPHABET: Development of A Physical Behaviour Taxonomy with an international open consensus. (2016). Retrieved October 15, 2017, from https://osf.io/2wuv9/

Chastin, S. F. M., Schwarz, U., & Skelton, D. A. (2013). Development of a consensus taxonomy of sedentary behaviors (SIT): report of Delphi Round 1.PloS one, 8(12), e82313.

Chau, J. Y., Grunseit, A. C., Chey, T., Stamatakis, E., Brown, W. J., Matthews, C. E., ... & van der Ploeg, H. P. (2013). Daily sitting time and all-cause mortality: a meta-analysis. PLoS One, 8(11), e80000.

Chaud, P. (2014). De la surveillance en santé publique à la veille sanitaire: historique, principes et organisation. Réanimation, 23(5), 529-532.

Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. Journal of sports sciences, 20(11), 873-899.

Clark, B. K., Thorp, A. A., Winkler, E. A., Gardiner, P. A., Healy, G. N., Owen, N., & Dunstan, D. W. (2011). Validity of self-reported measures of workplace sitting time and breaks in sitting time. Medicine and science in sports and exercise, 43(10), 1907-1912.

Cleland, C. L., Hunter, R. F., Kee, F., Cupples, M. E., Sallis, J. F., & Tully, M. A. (2014). Validity of the Global Physical Activity Questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behaviour. BMC public health, 14(1), 1255.

Colley, R. C., Garriguet, D., Janssen, I., Craig, C. L., Clarke, J., & Tremblay, M. S. (2011). Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Health reports, 22(1), 7.

Colley, R. C., Garriguet, D., Janssen, I., Wong, S. L., Saunders, T. J., Carson, V., & Tremblay, M. S. (2013). The association between accelerometer-measured patterns of sedentary time and health risk in children and youth: results from the Canadian Health Measures Survey. BMC public health, 13(1), 200.

Cooper, A. R., Sebire, S., Montgomery, A. A., Peters, T. J., Sharp, D. J., Jackson, N., ... & Andrews, R. C. (2012). Sedentary time, breaks in sedentary time and metabolic variables in people with newly diagnosed type 2 diabetes. Diabetologia, 55(3), 589-599.

Craig, C. L., Cameron, C. A., & Bauman, A. (2017). Utility of Surveillance Research to Inform Physical Activity Policy: An Exemplar From Canada. Journal of Physical Activity and Health, 14(3), 229-239.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., ... & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. Medicine & Science in Sports & Exercise, 35(8), 1381-1395.

Dall, P. M., Coulter, E. H., Fitzsimons, C. F., Skelton, D. A., & Chastin, S. F. M. (2017). TAxonomy of Self-reported Sedentary behaviour Tools (TASST) framework for development, comparison and evaluation of self-report tools: content analysis and systematic review. BMJ open, 7(4), e013844.

Declich, S., & Carter, A. O. (1994). Public health surveillance: historical origins, methods and evaluation. Bulletin of the World Health Organization, 72(2), 285.

Demello, J. J., Cureton, K. J., Boineau, R. E., & Singh, M. M. (1987). Ratings of perceived exertion at the lactate threshold in trained and untrained men and women. Medicine & Science in Sports & Exercise, 19, 354–362.

Dencker, M., Thorsson, O., Karlsson, M. K., Lindén, C., Svensson, J., Wollmer, P., & Andersen, L. B. (2006). Daily physical activity and its relation to aerobic fitness in children aged 8–11 years. European journal of applied physiology, 96(5), 587-592.

Després, J. P. (2016). Physical activity, sedentary behaviours, and cardiovascular health: when will cardiorespiratory fitness become a vital sign?. Canadian Journal of Cardiology, 32(4), 505-513.

Dietz, W. H. (1996). The role of lifestyle in health: the epidemiology and consequences of inactivity. Proceedings of the Nutrition Society, 55(3), 829-840.

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., ... & Lancet Physical Activity Series 2 Executive Committee. (2016). The

economic burden of physical inactivity: a global analysis of major non-communicable diseases. The Lancet, 388(10051), 1311-1324.

Dolan, S. H., Williams, D. P., Ainsworth, B. E., & Shaw, J. M. (2006). Development and reproducibility of the bone loading history questionnaire. Medicine and science in sports and exercise, 38(6), 1121-1131.

Dunstan, D. W., Salmon, J., Owen, N., Armstrong, T., Zimmet, P. Z., Welborn, T. A., ... & AusDiab Steering Committee. (2005). Associations of TV viewing and physical activity with the metabolic syndrome in Australian adults. Diabetologia, 48(11), 2254-2261.

Dunstan, D., Healy, G. N., Sugiyama, T., & Owen, N. (2010). Too Much Sitting and Metabolic Risk - Has Modern Technology Caught Up with Us. European Endocrinology. 2010;6(1):19-23.

Dunton, G. F., Dzubur, E., Kawabata, K., Yanez, B., Bo, B., & Intille, S. (2014). Development of a smartphone application to measure physical activity using sensor-assisted self-report. Emerging Technologies to Promote and Evaluate Physical Activity, 88-100.

Ekelund, U., Steene-Johannessen, J., Brown, W. J., Fagerland, M. W., Owen, N., Powell, K. E., ... & Lancet Sedentary Behaviour Working Group. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. The Lancet, 388(10051), 1302-1310.

Erlichman, J., Kerbey, A. L., & James, W. P. T. (2002). Physical activity and its impact on health outcomes. Paper 1: the impact of physical activity on cardiovascular disease and all-cause mortality: an historical perspective. obesity reviews, 3(4), 257-271.

Esen (Équipe de surveillance et d'épidémiologie nutritionnelle). (2017) Étude de santé sur l'environnement, la biosurveillance, l'activité physique et la nutrition (Esteban) 2014-2016. Volet nutrition. Chapitre Activité physique et sédentarité. Saint-Maurice : Santé publique France.

Eurobarometer, E. S. (2014). 412-Sport and Physical Activity. Belgium: European Comission.

European Commission. n.d. Piublic Opinion. Retrieved October 15, 2017, from http://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/General/index

Finger, J. D., Tafforeau, J., Gisle, L., Oja, L., Ziese, T., Thelen, J., ... & Lange, C. (2015). Development of the European Health Interview Survey-Physical Activity Questionnaire (EHIS-PAQ) to monitor physical activity in the European Union. Archives of Public Health, 73(1), 59.

Friedenreich, C. M., Courneya, K. S., Neilson, H. K., Matthews, C. E., Willis, G., Irwin, M., ... & Ballard-Barbash, R. (2006). Reliability and validity of the past year total physical activity questionnaire. American journal of epidemiology, 163(10), 959-970.

Fulton, J. E., Carlson, S. A., Ainsworth, B. E., Berrigan, D., Carlson, C., Dorn, J. M., ... & Mâsse, L. C. (2016). Strategic priorities for physical activity surveillance in the United States. Translational Journal of the American College of Sports Medicine, 1(13), 111-123.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., ... & Swain, D. P. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Medicine and science in sports and exercise, 43(7), 1334-1359.

General Inspectoral of Social Affaires (2016) Evaluation of the National Nutrition and health Programme PNNS2 2006-2010. Retrieved October 15, 2017, from http://agriculture.gouv.fr/telecharger/69308?token=e8a101ee8112c84564241f029e6f614d

German, R. R., Lee, L. M., Horan, J., Milstein, R., Pertowski, C., & Waller, M. (2001). Updated guidelines for evaluating public health surveillance systems. MMWR Recomm Rep, 50(1-35).

Gerovasili, V., Agaku, I. T., Vardavas, C. I., & Filippidis, F. T. (2015). Levels of physical activity among adults 18–64 years old in 28 European countries. Preventive medicine, 81, 87-91.

Government of South Australia. 2017. South Australian Monitoring and Surveillance System (SAMSS). Retrieved October 15, 2017, from http://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/about+us

/health+statistics/risk+factors+for+health+statistics/south+australian+monitoring+and+surveillance+system+samss

Guthold, R., Ono, T., Strong, K. L., Chatterji, S., & Morabia, A. (2008). Worldwide variability in physical inactivity: a 51-country survey. American journal of preventive medicine, 34(6), 486-494.

Hagströmer, M., Troiano, R. P., Sjöström, M., & Berrigan, D. (2010). Levels and patterns of objectively assessed physical activity—a comparison between Sweden and the United States. American journal of epidemiology, 171(10), 1055-1064.

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., & Lancet Physical Activity Series Working Group. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. The lancet, 380(9838), 247-257.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. Diabetes, 56(11), 2655-2667.

Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007 ; 39 : 1423 – 34

Hassmen, P. (1990). Perceptual and physiological responses to cycling and running in groups of trained and untrained subjects. European Journal of Applied Physiology, 60, 445–451.

Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmit PZ, et al. (2008) Breaks in sedentary time: beneficial associations with metabolic risk. Diabetes Care 31: 661–666. pmid:18252901

Healy, G. N., Clark, B. K., Winkler, E. A., Gardiner, P. A., Brown, W. J., & Matthews, C. E. (2011). Measurement of adults' sedentary time in population-based studies. American journal of preventive medicine, 41(2), 216-227.

Helmerhorst, H. H. J., Brage, S., Warren, J., Besson, H., & Ekelund, U. (2012). A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. International Journal of Behavioral Nutrition and Physical Activity, 9(1), 103.

Herrmann, S. D., Heumann, K. J., Der Ananian, C. A., & Ainsworth, B. E. (2013). Validity and reliability of the global physical activity questionnaire (GPAQ). Measurement in Physical Education and Exercise Science, 17(3), 221-235.

Hetzel, A. M. (1997). US vital statistics system. US Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Hidding, L. M., Altenburg, T. M., Mokkink, L. B., Terwee, C. B., & Chinapaw, M. J. (2017). Systematic review of childhood sedentary behavior questionnaires: What do we know and what is next?. Sports Medicine, 47(4), 677-699.

High Committee on Public Health. 2000. Pour une politique nutritionnelle de santé publique. [For a public health nutritional policy].

Hills, A. P., Mokhtar, N., & Byrne, N. M. (2014). Assessment of physical activity and energy expenditure: an overview of objective measures. Frontiers in nutrition, 1.

Hoos, T., Espinoza, N., Marshall, S., & Arredondo, E. M. (2012). Validity of the global physical activity questionnaire (GPAQ) in adult Latinas. Journal of Physical Activity and Health, 9(5), 698-705.

International Society for Physical Activity and Health (ISPAH). (2017). The Bangkok declaration on physical activity for global health and sustainable development. Br J Sports Med.

IPAQ Research Committee. (2005). Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ)–short and long forms.

Jeffery RW, French SA. Epidemic obesity in the U.S.: are fast foods and television viewing contributing? Am J Public Health 1998;88(2): 277– 80.

Kahlmeier, S., Wijnhoven, T. M., Alpiger, P., Schweizer, C., Breda, J., & Martin, B. W. (2015). National physical activity recommendations: systematic overview and analysis of the situation in European countries. BMC Public Health, 15(1), 133.

Keadle, S. K., Lyden, K., Hickey, A., Ray, E. L., Fowke, J. H., Freedson, P. S., & Matthews, C. E. (2014). Validation of a previous day recall for measuring the location and purpose of

active and sedentary behaviors compared to direct observation. International Journal of Behavioral Nutrition and Physical Activity, 11(1), 12.

Khan, K. M., Thompson, A. M., Blair, S. N., Sallis, J. F., Powell, K. E., Bull, F. C., & Bauman, A. E. (2012). Sport and exercise as contributors to the health of nations. The Lancet, 380(9836), 59-64.

Konstabel, K., Veidebaum, T., Verbestel, V., Moreno, L. A., Bammann, K., Tornaritis, M., ... & Wirsik, N. (2014). Objectively measured physical activity in European children: the IDEFICS study. International Journal of Obesity, 38(S2), S135.

Kruger, J., Ham, S. A., & Kohl III, H. W. (2005). Trends in leisure-time physical inactivity by age, sex, and race/ethnicity-United States, 1994-2004. Morbidity and Mortality Weekly Report, 54(39), 991-994.

Lafay L, Dufour A, Calamassi G, others. Étude individuelle nationale des consommations alimentaires 2 (INCA 2) 2006–2007. Rapport Afssa, Maisons Alfort 2009.

LaMonte, M. J., & Ainsworth, B. E. (2001). Quantifying energy expenditure and physical activity in the context of dose response. Medicine and Science in Sports and Exercise, 33(6 Suppl), S370-8.

Laporte, R. E., Adams, L. L., Savage, D. D., Brenes, G., Dearwater, & Cook, T. (1984). The spectrum of physical actvity, cardiovascular disease and health: an epidemiologic perspective. American Journal of Epidemiology, 120(4), 507-517.

Lear, S. A., Hu, W., Rangarajan, S., Gasevic, D., Leong, D., Iqbal, R., ... & Rosengren, A. (2017). The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. The Lancet.

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working Group. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. The lancet, 380(9838), 219-229.

Lee, L. M. (2010). Principles and practice of public health surveillance. Oxford University Press, USA.

Liu, Y., Wang, M., Tynjälä, J., Lv, Y., Villberg, J., Zhang, Z., & Kannas, L. (2010). Test-retest reliability of selected items of Health Behaviour in School-aged Children (HBSC) survey questionnaire in Beijing, China. BMC medical research methodology, 10(1), 73.

Lowry, R., Wechsler, H., Galuska, D. A., Fulton, J. E., & Kann, L. (2002). Television viewing and its associations with overweight, sedentary lifestyle, and insufficient consumption of fruits and vegetables among US high school students: differences by race, ethnicity, and gender. Journal of school health, 72(10), 413-421.

Loyen, A., Clarke-Cornwell, A. M., Anderssen, S. A., Hagströmer, M., Sardinha, L. B., Sundquist, K., ... & Wijndaele, K. (2016). Sedentary time and physical activity surveillance through accelerometer pooling in four European countries. Sports Medicine, 1-15.

Macera, C. A., & Pratt, M. (2000). Public health surveillance of physical activity. Research Quarterly for Exercise and Sport, 71(sup2), 97-103.

Marshall, A. L., Miller, Y. D., Burton, N. W., & Brown, W. J. (2010). Measuring total and domain-specific sitting: a study of reliability and validity. Medicine and Science in Sports and Exercise, 42(6), 1094-1102.

Milanez, V. F., Pedro, R. E., Moreira, A., Boullosa, D. A., Salle-Neto, F., & Nakamura, F. Y. (2011). The role of aerobic fitness on session rating of perceived exertion in futsal players. International journal of sports physiology and performance, 6(3), 358-366.

Milton, K., Gale, J., Stamatakis, E., & Bauman, A. (2015). Trends in prolonged sitting time among European adults: 27 country analysis. Preventive medicine, 77, 11-16.

Morris, J. N., Heady, J. A., Raffle, P. A. B., Roberts, C. G., & Parks, J. W. (1953a). Coronary heart-disease and physical activity of work. The Lancet, 265, 1053-1057.

Mumu, S. J., Ali, L., Barnett, A., & Merom, D. (2017). Validity of the global physical activity questionnaire (GPAQ) in Bangladesh. BMC public health, 17(1), 650.

Neilson, H. K., Ullman, R., Robson, P. J., Friedenreich, C. M., & Csizmadi, I. (2013). Cognitive testing of the STAR-Q: insights in activity and sedentary time reporting. Journal of Physical Activity and Health, 10(3), 379-389.

Nsubuga, P., White, M. E., Thacker, S. B., Anderson, M. A., Blount, S. B., Broome, C. V., ... & Stroup, D. F. (2006). Public health surveillance: a tool for targeting and monitoring interventions. Disease control priorities in developing countries, 2, 997-1018.

Office for National Statistics. The Time Use Survey, 2005. Retrieved October 15, 2017, from http://www.statistics.gov.uk/articles/nojournal/time_use_2005.pdf

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population-health science of sedentary behavior. Exercise and sport sciences reviews, 38(3), 105.

Paffenbarger RS Jr , Hyde RT, Wing AL, et al. Physical activity, all-cause mortality, and longevity of college alumni. N Engl J Med 1986 ; 314 : 605 – 13 .

Parrish, X. J., Brown, M., Emmel, J., & Marino, N. (2013). A systematic review to inform the Australian Sedentary Behaviour Guidelines for Children and Young People. Australian government department of health.

Pate, R. R., O'neill, J. R., & Lobelo, F. (2008). The evolving definition of" sedentary". Exercise and sport sciences reviews, 36(4), 173-178.

Pate, R. R., Pratt, M., Blair, S. N., Haskell, W. L., Macera, C. A., Bouchard, C., ... & Kriska, A. (1995). Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. Jama, 273(5), 402-407.

Pettee-Gabriel, K. K. , Morrow Jr, J. R. (2010). A framework for physical activity as a complex and multidimensional behavior. In: Proceedings of Measurement of Active and Sedentary Behaviors: Closing the Gaps in Self-Report Methods. United States, Bethesda.

Pettee-Gabriel, K. K. , Morrow Jr, J. R., & Woolsey, A. L. T. (2012). Framework for physical activity as a complex and multidimensional behavior. Journal of Physical Activity and Health, 9(s1), S11-S18.

Portney, L. G., & Watkins, M. P. (2000). Foundations of clinical research: applications to practice. Prentice Hall.

Powell, K. E., Paluch, A. E., & Blair, S. N. (2011). Physical activity for health: What kind? How much? How intense? On top of what?. Annual review of public health, 32.

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Gorber, S. C., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. International Journal of Behavioral Nutrition and Physical Activity, 5(1), 56.

Public Health Agency of Canada. 2017. Physical Activity, Sedentary Behaviour and Sleep (PASS) Indicators: Quick Stats, adults (18 years of age and older), Canada, 2017 edition. Ottawa (ON): Public Health Agency of Canada.

Rangul, V., Holmen, T. L., Kurtze, N., Cuypers, K., & Midthjell, K. (2008). Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. BMC medical research methodology, 8(1), 47.

Rosenberg, D. E., Bull, F. C., Marshall, A. L., Sallis, J. F., & Bauman, A. E. (2008). Assessment of sedentary behavior with the International Physical Activity Questionnaire. Journal of Physical Activity and Health, 5(s1), S30-S44.

Sallis, J. F., Bull, F., Guthold, R., Heath, G. W., Inoue, S., Kelly, P., ... & Lancet Physical Activity Series 2 Executive Committee. (2016). Progress in physical activity over the Olympic quadrennium. The Lancet, 388(10051), 1325-1336.

Sallis, J. F., Owen, N., & Fisher, E. (2015). Ecological models of health behavior. Health behavior: theory, research, and practice. 5th ed. San Francisco: Jossey-Bass, 43-64.

Saunders, T. J., Tremblay, M. S., Mathieu, M. È., Henderson, M., O'Loughlin, J., Tremblay, A., ... & Quality Cohort Research Group. (2013). Associations of sedentary behavior, sedentary bouts and breaks in sedentary time with cardiometabolic risk in children with a family history of obesity. PloS one, 8(11), e79143.

SBRN. (2012). Standardized use of the terms "sedentary" and "sedentary behaviours". Appl Physiol Nutr Metab, 37, 540–542.

Schneider, P. L., Crouter, S. E., Lukajic, O., & Bassett, D. R. (2003). Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk. Medicine and science in sports and exercise, 35(10), 1779-1784.

Schoeller, D. A. (1999). Recent advances from application of doubly labeled water to measurement of human energy expenditure. The Journal of nutrition, 129(10), 1765-1768.

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. British journal of sports medicine, 37(3), 197-206.

Sjöström, M., Oja, P., Hagströmer, M., Smith, B. J., & Bauman, A. (2006). Health-enhancing physical activity across European Union countries: the Eurobarometer study. Journal of Public Health, 14(5), 291-300.

Soo, K. L., Wan Abdul Manan, W. M., & Wan Suriati, W. N. (2015). The Bahasa Melayu Version of the Global Physical Activity Questionnaire: reliability and validity study in malaysia. Asia Pacific Journal of Public Health, 27(2), NP184-NP193.

Statistics Canada. 2015. Canadian Health Measures Survey. Retrived October 15, 2017 from http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5071

Stephens, T. (1987). Secular trends in adult physical activity: Exercise boom or bust?. Research Quarterly for Exercise and Sport, 58(2), 94-105.

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., ... & Swartz, A. M. (2013). Guide to the assessment of physical activity: clinical and research applications. Circulation, 128(20), 2259-2279.

Sugiyama, T., Healy, G. N., Dunstan, D. W., Salmon, J., & Owen, N. (2008). Is television viewing time a marker of a broader pattern of sedentary behavior?. Annals of Behavioral Medicine, 35(2), 245-250.

Sylva, M., Byrd, R., & Magnum, M. (1990). Effects of social influence and sex on rating of perceived exertion in exercising elite athletes. Perceptual Motor Skills, 70, 591–594.

Taylor, H. L., Jacobs, D. R., Schucker, B., Knudsen, J., Leon, A. S., & Debacker, G. (1978). A questionnaire for the assessment of leisure time physical activities. Journal of chronic diseases, 31(12), 741-755.

Terwee, C. B., Mokkink, L. B., van Poppel, M. N., Chinapaw, M. J., van Mechelen, W., & de Vet, H. C. (2010). Qualitative attributes and measurement properties of physical activity questionnaires. Sports Medicine, 40(7), 525-537.

Thuy, A. B., Blizzard, L., Schmidt, M., Luc, P. H., Magnussen, C., & Dwyer, T. (2010). Reliability and validity of the global physical activity questionnaire in Vietnam. Journal of Physical Activity and Health, 7(3), 410-418.

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., ... & Chinapaw, M. J. (2017). Sedentary Behavior Research Network (SBRN)–Terminology Consensus Project process and outcome. International Journal of Behavioral Nutrition and Physical Activity, 14(1), 75.

Tremblay, M. S., Barnes, J. D., González, S. A., Katzmarzyk, P. T., Onywera, V. O., Reilly, J. J., ... & Global Matrix 2.0 Research Team. (2016). Global Matrix 2.0: report card grades on the physical activity of children and youth comparing 38 countries. Journal of physical activity and health, 13(11 Suppl 2), S343-S366.

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. Applied Physiology, Nutrition, and Metabolism, 35(6), 725-740.

Tremblay, M. S., LeBlanc, A. G., Janssen, I., Kho, M. E., Hicks, A., Murumets, K., ... & Duggan, M. (2011a). Canadian sedentary behaviour guidelines for children and youth. Applied Physiology, Nutrition, and Metabolism, 36(1), 59-64.

Trinh, O. T., Nguyen, N. D., van der Ploeg, H. P., Dibley, M. J., & Bauman, A. (2009). Test-retest repeatability and relative validity of the Global Physical Activity Questionnaire in a developing country context. Journal of Physical Activity and Health, 6(s1), S46-S53.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. Medicine and science in sports and exercise, 40(1), 181.

Troiano, R. P., Gabriel, K. K. P., Welk, G. J., Owen, N., & Sternfeld, B. (2012). Reported physical activity and sedentary behavior: why do you ask?. Journal of Physical Activity and Health, 9(s1), S68-S75.

Troiano, R. P., McClain, J. J., Brychta, R. J., & Chen, K. Y. (2014). Evolution of accelerometer methods for physical activity research. Br J Sports Med, bjsports-2014.

Tucker, C. A., Bevans, K. B., Teneralli, R. E., Smith, A. W., Bowles, H. R., & Forrest, C. B. (2014a). Self-reported pediatric measures of physical activity, sedentary behavior and strength impact for PROMIS®: conceptual framework. Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association, 26(4), 376.

Tucker, C. A., Bevans, K. B., Teneralli, R. E., Smith, A. W., Bowles, H. R., & Forrest, C. B. (2014b). Self-reported pediatric measures of physical activity, sedentary behavior and strength impact for PROMIS®: item development. Pediatric physical therapy: the official publication of the Section on Pediatrics of the American Physical Therapy Association, 26(4), 385.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: a systematic review. Public health, 121(12), 909-922.

Tudor-Locke, C. (2001). A preliminary study to determine instrument responsiveness to change with a walking program: physical activity logs versus pedometers. Research quarterly for exercise and sport, 72(3), 288-292.

Unité de surveillance et d'épidémiologie nutritionnelle (Usen). Situation nutritionnelle en France en 2006 selon les indicateurs d'objectif et les reperes du Programme National Nutrition Santé (PNNS)(Nutritional Situation in France in 2006 Relative to the Objectives and Markers of the National Programme on Nutrition and Health (PNNS)). Paris: Institut de Veille Sanitaire INVS. 2006;

United Nations General Assembly. (2011). Political declaration of the high-level meeting of the general assembly on the prevention and control of non-communicable diseases. New York: United Nations.

United States Census Bureau. n.d. American Community Survey.Retrieved October 15, 2017, from www.census.gov/acs/

United States Department of LaborAmerican Time Use Survey–2007 Results. Retrieved October 15, 2017, from http://www.bls.gov/tus/

United States Department of Transportation. n.d. National Household Travel Survey. Retrieved October 15, 2017, from http://nhts.ornl.gov/

Van der Ploeg, H. P., Chey, T., Korda, R. J., Banks, E., & Bauman, A. (2012). Sitting time and all-cause mortality risk in 222 497 Australian adults. Archives of internal medicine, 172(6), 494-500.

Van Dyck, D., Cerin, E., De Bourdeaudhuij, I., Hinckson, E., Reis, R. S., Davey, R., ... & Salvo, D. (2015). International study of objectively-measured physical activity and sedentary time with body mass index and obesity: Ipen adult study. International journal of obesity (2005), 39(2), 199.

van Poppel, M. N., Chinapaw, M. J., Mokkink, L. B., Van Mechelen, W., & Terwee, C. B. (2010). Physical activity questionnaires for adults. Sports medicine, 40(7), 565-600.

Varela, A. R., Pratt, M., Powell, K., Lee, I. M., Bauman, A., Heath, G., ... & Hallal, P. C. (2017). Worldwide Surveillance, Policy and Research on Physical Activity and Health: The Global Observatory for Physical Activity–GoPA!. Journal of Physical Activity and Health, 1-28.

Verloigne, M., Ridgers, N. D., Chinapaw, M., Altenburg, T. M., Bere, E., Van Lippevelde, W., ... & De Bourdeaudhuij, I. (2017). Patterns of objectively measured sedentary time in 10- to 12-year-old Belgian children: an observational study within the ENERGY-project. BMC pediatrics, 17(1), 147.

Vogt, R. L., LaRue, D., Klaucke, D. N., & Jillson, D. A. (1983). Comparison of an active and passive surveillance system of primary care providers for hepatitis, measles, rubella, and salmonellosis in Vermont. American Journal of Public Health, 73(7), 795-797.

Vuillemin, A., Speyer, E., Simon, C., Ainsworth, B., & Paineau, D. (2012). Revue critique des questionnaires d'activité physique administrés en population française et perspectives de développement. Cahiers de nutrition et de diététique, 47(5), 234-241.

Wanner, M., Hartmann, C., Pestoni, G., Martin, B. W., Siegrist, M., & Martin-Diener, E. (2017). Validation of the Global Physical Activity Questionnaire for self-administration in a European context. BMJ Open Sport & Exercise Medicine, 3(1), e000206.

Wijndaele, K., De Bourdeaudhuij, I., Godino, J. G., Lynch, B. M., Griffin, S. J., Westgate, K., & Brage, S. (2014). Reliability and validity of a domain-specific last 7-d sedentary time questionnaire. Medicine and science in sports and exercise, 46(6), 1248-1260.

World Health Organization (2005). WHO STEPS Surveillance Manual: The WHO STEPwise approach to chronic disease risk factor surveillance. Geneva, World Health Organization

World Health Organization (2008). World Health Organization. (2008). Training for mid-level managers. Making disease surveillance work.

World Health Organization (2017). WHO guidelines on ethical public health surveillance.

World Health Organization. (2004). Global strategy on diet, physical activity and health.

World Health Organization. (2009). Global health risks: mortality and burden of disease attributable to selected major risks. World Health Organization.

World Health Organization. (2010). Global recommendations on physical activity for health.

World Health Organization. (2011). Global status report on noncommunicable diseases 2010. Geneva: World Health Organization.

World Health Organization. (2013a). Global action plan for the prevention and control of noncommunicable diseases 2013-2020.

World Health Organization. (2013b). Vienna declaration on nutrition and noncommunicable diseases in the context of health 2020. In WHO Ministerial Conference on Nutrition and Noncommunicable Diseases in the Context of Health (Vol. 2020).

World Health Organization. (2015). Physical activity strategy for the WHO European Region 2016–2025.

World Health Organization. 2017. Draft WHO global action plan on physical activity 2018 - 2030. Retrieved October 15, 2017, from http://www.who.int/ncds/governance/gappa_version_4August2017.pdf?ua=1

World Health Organization. 2017. WHO World Health Survey. Retrieved October 15, 2017, from http://www.who.int/healthinfo/survey/en

Yore, M. M., Ham, S. A., Ainsworth, B. E., Kruger, J., Reis, J. P., Kohl 3rd, H. W., & Macera, C. A. (2007). Reliability and validity of the instrument used in BRFSS to assess physical activity. Medicine and science in sports and exercise, 39(8), 1267-1274.

Appendix

Appendix 1: French version of GPAQ

Activité physique

Je vais maintenant vous poser quelques questions sur le temps que vous consacrez à différents types d'activité physique lors d'une semaine typique. Veuillez répondre à ces questions même si vous ne vous considérez pas comme quelqu'un d'actif.

Pensez tout d'abord au temps que vous y consacrez au travail, qu'il s'agisse d'un travail rémunéré ou non, de tâches ménagères, de cueillir ou récolter des aliments, de pêcher ou chasser, de chercher un emploi. *[Ajouter d'autres exemples si nécessaire].* Dans les questions suivantes, les activités physiques de forte intensité sont des activités nécessitant un effort physique important et causant une augmentation conséquente de la respiration ou du rythme cardiaque, et les activités physiques d'intensité modérée sont des activités qui demandent un effort physique modéré et causant une petite augmentation de la respiration ou du rythme cardiaque.

Question		Réponse		Code
Activités au travail				
1	Est-ce que votre travail implique des activités physiques de forte intensité qui nécessitent une augmentation conséquente de la respiration ou du rythme cardiaque, comme [soulever des charges lourdes, travailler sur un chantier, effectuer du travail de maçonnerie] pendant au moins 10 minutes d'affilée ? [INSÉRER DES EXEMPLES LOCAUX ET MONTRER LES CARTES]	Oui Non	1 2 *Si Non, aller à P4*	P1
2	Habituellement, combien de jours par semaine effectuez-vous des activités physiques de forte intensité dans le cadre de votre travail ?	Nombre de jours	⌊__⌋	P2
3	Lors d'une journée habituelle durant laquelle vous effectuez des activités physiques de forte intensité, combien de temps consacrez-vous à ces activités ?	Heures : minutes	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P3 (a-b)
4	Est-ce que votre travail implique des activités physiques d'intensité modérée, comme une marche rapide ou [soulever une charge légère] durant au moins 10 minutes d'affilée ? [INSÉRER DES EXEMPLES LOCAUX ET MONTRER LES CARTES]	Oui Non	1 2 *Si Non, aller à P 7*	P4
5	Habituellement, combien de jours par semaine effectuez-vous des activités physiques d'intensité modérée dans le cadre de votre travail ?	Nombre de jours	⌊__⌋	P5
6	Lors d'une journée habituelle durant laquelle vous effectuez des activités physiques d'intensité modérée, combien de temps consacrez-vous à ces activités ?	Heures : minutes	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P6 (a-b)
Se déplacer d'un endroit à l'autre				
Les questions suivantes excluent les activités physiques dans le cadre de votre travail, que vous avez déjà mentionnées. Maintenant, je voudrais connaître votre façon habituelle de vous déplacer d'un endroit à l'autre ; par exemple pour aller au travail, faire des courses, aller au marché, aller à votre lieu consacré au culte. [*Ajouter d'autres exemples si nécessaire*]				
7	Est-ce que vous effectuez des trajets d'au moins 10 minutes à pied ou à vélo ?	Oui Non	1 2 *Si Non, aller à P 10*	P7
8	Habituellement, combien de jours par semaine effectuez-vous des trajets d'au moins 10 minutes à pied ou à vélo ?	Nombre de jours	⌊__⌋	P8
9	Lors d'une journée habituelle, combien de temps consacrez-vous à vos déplacements à pied ou à vélo ?	Heures : minutes	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P9 (a-b)

Question		Réponse		Code
Activités de loisirs				
10	Est-ce que vous pratiquez des sports, du fitness ou des activités de loisirs de forte intensité qui nécessitent une augmentation importante de la respiration ou du rythme cardiaque comme [courir ou jouer au football] pendant au moins dix minutes d'affilée ? [INSÉRER DES EXEMPLES LOCAUX ET MONTRER LES CARTES]	Oui Non	1 2 *Si Non, aller à P 13*	P10
11	Habituellement, combien de jours par semaine pratiquez-vous une activité sportive, du fitness ou d'autres activités de loisirs de forte intensité ?	Nombre de jours	⌊__⌋	P11
12	Lors d'une journée habituelle, combien de temps y consacrez-vous ?	Heures : minutes	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P12 (a-b)
13	Est-ce que vous pratiquez des sports, du fitness ou des activités de loisirs d'intensité modérée qui nécessitent une petite augmentation de la respiration ou du rythme cardiaque comme la marche rapide [faire du vélo, nager, jouer au volley] pendant au moins dix minutes d'affilée ? [INSÉRER DES EXEMPLES LOCAUX ET MONTRER LES CARTES]	Oui Non	1 2 *Si Non, aller à P16*	P13
14	Habituellement, combien de jours par semaine pratiquez-vous une activité sportive, du fitness ou d'autres activités de loisirs d'intensité modérée ?	Nombre de jours	⌊__⌋	P14
15	Lors d'une journée habituelle, combien de temps y consacrez-vous ?	Heures : minutes	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P15 (a-b)
Comportement sédentaire				
La question suivante concerne le temps passé en position assise ou couchée, au travail, à la maison, en déplacement, à rendre visite à des amis, et inclut le temps passé [assis devant un bureau, se déplacer en voiture, en bus, en train, à lire, jouer aux cartes ou à regarder la télévision] mais n'inclut pas le temps passé à dormir. [INSÉRER DES EXEMPLES LOCAUX ET MONTRER LES CARTES]				
16	Combien de temps passez-vous en position assise ou couchée lors d'une journée habituelle ?	Heures : minutes Non	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins 2 *Si Non, aller à P 10*	P16 (a-b)

Appendix 2: French version of IPAQ-LFQ

Format Téléphonique Long 7 Derniers Jours

LIRE : Je vais vous interroger sur le temps que vous avez passé à être actif physiquement ces 7 derniers jours. Merci de répondre à chaque question même si vous ne vous considérez pas comme une personne physiquement active. Pensez aux activités que vous faites au travail, à domicile et dans votre jardin, pour vos déplacements d'un endroit à l'autre et pendant votre temps libre pour les loisirs, l'exercice ou le sport.

1ERE PARTIE : ACTIVITE PHYSIQUE LIEE AU TRAVAIL

LIRE : Les premières questions portent sur votre travail. Par travail on entend les emplois payés, le travail agricole, le travail bénévole, les études, les stages et tout autre type de travail non payé que vous avez effectué en dehors du domicile. Ne tenez pas compte du travail non payé que vous effectuez à domicile, comme faire le ménage, le jardinage, entretenir la maison ou vous occuper de votre famille. Je vous interrogerai sur ces activités plus tard.

1. Avez-vous actuellement un emploi ou faites-vous un travail payé ou non payé en dehors de votre domicile ? [Travail ; Oui = 1, Non = 0 ; 8,9]

____ Oui

____ Non *[Passez à la 2ème Partie]*

8. Ne sait pas / Pas sûr *[Passez à la 2ème Partie]*

9. N'a pas répondu

[**Clarification de l'enquêteur** : Cela comprend aussi les cours, les études et les stages. Cela comprend aussi le travail bénévole et le temps passé à chercher un emploi. Cela ne comprend pas le travail non payé fait à la maison ou dans votre jardin, ni le temps passé à s'occuper d'une personne à charge. Ceci fera l'objet de questions plus tard.]

LIRE : Les questions suivantes portent sur toutes les activités physiques que vous avez faites au travail qu'il soit payé ou non. Cela ne comprend pas les trajets entre votre domicile et votre travail.

LIRE : Tout d'abord, pensez aux activités *intenses* qui vous ont demandé un gros effort physique au travail. Les activités intenses font respirer beaucoup plus fort que d'habitude. Il peut s'agir d'activités comme porter des charges lourdes, creuser, faire de la maçonnerie ou monter des escaliers. Pensez seulement aux activités physiques intenses qui ont duré au moins dix minutes d'affilée.

2. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités physiques **intenses au travail** ? [De 0 à 7, 8, 9]

____ Jours par semaine *[Si la personne répond 0, passez à la question 4]*

8. Ne sait pas/pas sûr *[Passez à la question 4]*
9. N'a pas répondu *[Passez à la question 4]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Clarification de l'enquêteur** : Le travail comprend le travail payé et non payé ainsi que les études et les stages. Tenez compte de tous les emplois et du travail bénévole.]

3. Quand vous avez fait des activités physiques **intenses** au travail au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?

___ ___ Heures par jour [De 0 à 16]

___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / Pas sûr
999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre ou bien parce qu'il y a une grande variété de travaux payés ou non, demandez : « Quelle a été la durée totale de vos activités physiques intenses au travail **ces 7 derniers jours** ? »

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas/pas sûr

9999. N'a pas répondu

LIRE : Maintenant pensez aux activités qui vous ont demandé un effort physique modéré au travail. Les activités physiques modérées font respirer un peu plus fort que d'habitude et peuvent comprendre des activités comme porter des charges légères. N'incluez pas la marche. Là encore, pensez seulement aux activités physiques modérées qui ont duré au moins 10 minutes d'affilé.

4. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités physiques **modérées au travail** ? [De 0 à 7, 8, 9]
   ____ Jours par semaine *[Si la personne répond 0, passez à la Question 6]*

   8. Ne sait pas / pas sûr *[Passez à la question 6]*
   9. N'a pas répondu *[Passez à la question 6]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Clarification de l'enquêteur** : Le travail comprend le travail payé et non payé ainsi que les études et les stages. Tenez compte de tous les emplois et du travail bénévole.]

5. Quand vous avez fait des activités physiques **modérées** au travail au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
   ___ ___ Heures par jour [De 0 à 16]

   ___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

   998. Ne sait pas / pas sûr
   999. N'a pas répondu à la question

   [**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

   [**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre ou bien parce qu'il y a une grande variété de travaux payés ou non, demandez : « Quelle a été la durée totale de vos activités physiques modérées au travail **ces 7 derniers jours** ? »

   ___ ___ Heures par semaine [De 0 à 112]

   ___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

   9998. Ne sait pas/Pas sûr

9999. N’a pas répondu

LIRE : Maintenant, pensez au temps que vous passez à marcher pendant au moins 10 minutes au travail. Ne tenez pas compte de la marche entre votre domicile et votre lieu de travail.

6. Ces 7 **derniers jours**, pendant combien de jours avez-vous **marché au travail ?** [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la 2ème partie]*

8. Ne sait pas/Pas sûr *[Passez à la 2ème partie]*

9. N’a pas répondu *[Passez à la 2ème partie]*

[**Clarification de l’enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d’affilée.]

[**Clarification de l’enquêteur** : Tenez compte de tous les types de travail.]

7. Quand vous avez **marché** au travail au cours d’un de ces jours, combien de temps y avez-vous consacré en moyenne?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N’a pas répondu

[**Clarification de l’enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d’affilée.]

[**Précision pour l’enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d’un jour à l’autre ou bien parce qu’il y a une grande variété de travaux payés ou non, demandez : « Quelle a été la durée totale de votre marche au travail **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas/Pas sûr

9999. N’a pas répondu

2ème PARTIE : ACTIVITE PHYSIQUE LIEE AUX DEPLACEMENTS

LIRE : Maintenant, pensez à la manière dont vous vous êtes déplacé d'un endroit à un autre, notamment pour vous rendre au travail, dans des magasins, au cinéma, etc.

8. Ces 7 **derniers jours**, pendant combien de jours vous êtes-vous **déplacé en véhicule motorisé** comme le train, le bus, la voiture ou le tramway ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne interrogée répond 0, passez à la question 10]*

Ne sait pas / Pas sûr *[Passez à la question 10]*

N'a pas répondu *[Passez à la question 10]*

9. Quand vous vous êtes **déplacé** dans un véhicule à moteur (comme un train, un autobus, une voiture ou un tram) au cours d'un de ces jours, combien de temps cela a-t'il duré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / Pas sûr

999. N'a pas répondu

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos déplacements en véhicule motorisé **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

LIRE : Maintenant, pensez à vos déplacements *à vélo* entre votre domicile et votre travail, pour faire des courses ou pour aller d'un endroit à un autre. Ne tenez compte que des trajets à vélo qui ont duré au moins 10 minutes d'affilée.

10. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait du vélo pour aller d'un endroit à un autre ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la question 12]*

8. Ne sait pas/Pas sûr *[Passez à la question 12]*
9. N'a pas répondu *[Passez à la question 12]*

[**Clarification de l'enquêteur** : Pensez à vos déplacements à vélo qui ont duré au moins 10 minutes d'affilée.]

11. Quand vous avez fait du **vélo** au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez à vos déplacements à vélo qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos déplacements à vélo pour aller d'un endroit à un autre **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas/Pas sûr

9999. N'a pas répondu

LIRE : Maintenant, pensez au temps que vous avez passé à *marcher* pour vous déplacer entre votre domicile et votre travail, pour faire des courses ou pour aller d'un endroit à un autre. Incluez seulement la marche qui a duré au moins 10 minutes d'affilée. Ne tenez pas compte de la marche de loisir qui n'avait pas pour but le déplacement d'un endroit à un autre.

12. Ces 7 **derniers jours**, pendant combien de jours vous êtes-vous **déplacé à pied** ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la 3ème partie]*

8. Ne sait pas/Pas sûr *[Passez à la 3ème partie]*
9. N'a pas répondu *[Passez à la 3ème partie]*

[**Clarification de l'enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d'affilée.]

13. Quand vous avez marché **pour vos déplacements** au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos déplacements à pied pour aller d'un endroit à un autre **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas/Pas sûr

9999. N'a pas répondu

3ème PARTIE : MENAGE, ENTRETIEN DE LA MAISON, TEMPS PASSE A S'OCCUPER DE SA FAMILLE

LIRE : Maintenant pensez aux activités physiques que vous avez faites ces 7 derniers jours à l'intérieur et à l'extérieur de votre domicile comme faire le ménage, le jardinage, faire des travaux d'entretien et vous occuper de votre famille.

LIRE : Pensez d'abord aux activités *intenses* qui demandent *un gros effort physique* et que vous avez faites dans votre jardin ou votre cour. Les activités intenses font respirer beaucoup plus fort que d'habitude et comprennent des activités comme soulever des charges lourdes, couper du bois, déblayer la neige ou bêcher. Encore une fois, pensez seulement aux activités physiques intenses qui ont duré au moins 10 minutes d'affilée.

14. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités physiques **intenses dans votre jardin ou votre cour** ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la question 16.]*

8. Ne sait pas / pas sûr *[Passez à la question 16]*
9. N'a pas répondu *[Passez à la question 16]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

15. Quand vous avez fait des activités physiques **intenses** dans votre jardin ou votre cour au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne?

___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / pas sûr

999. N'a pas répondu

[Clarification de l'enquêteur : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos activités physiques intenses dans votre jardin ou votre cour **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

LIRE : Maintenant pensez aux activités dans votre jardin ou votre cour qui vous ont demandé un effort physique *modéré*. Les activités physiques modérées font respirer un peu plus fort que d'habitude et comprennent des activités comme soulever des charges légères, balayer, nettoyer les vitres et ratisser. Encore une fois, ne tenez compte que des activités physiques modérées qui ont duré au moins 10 minutes d'affilée.

16. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités **modérées dans votre jardin ou votre cour** ? [De 0 à 7, 8, 9]

___ Jours par semaine *[Si la personne interrogée répond 0, passez à la question 18]*

8. Ne sait pas / Pas sûr *[Passez à la question 18]*

9. N'a pas répondu *[Passez à la question 18]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée]

17. Quand vous avez fait de l'activité physique **modérée** dans votre jardin ou votre cour au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne?

___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos activités physiques modérées dans votre jardin ou votre cour **ces 7 derniers jours** ? »]

___ ___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ Minutes par semaine [De 0 à 960, 998, 999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

LIRE : Maintenant pensez aux activités *à l'intérieur de votre domicile* qui vous ont demandé au moins un effort physique *modéré*. Cela comprend des activités comme soulever des charges légères, nettoyer le sol ou les vitres et balayer. Ne tenez compte que des activités physiques modérées qui ont duré au moins 10 minutes d'affilée.

[**Clarification de l'enquêteur** : Les activités modérées font respirer un peu plus fort que d'habitude.]

18. Ces **7 derniers jours**, pendant combien de jours avez-vous fait des activités **modérées à l'intérieur de votre domicile** ? [De 0 à 7, 8, 9]

___ Jours par semaine *[Si la personne interrogée répond 0, passez à la 4ème partie]*

8. Ne sait pas / pas sûr *[Passez à la 4ème partie]*

9. N'a pas répondu *[Passez à la 4ème partie]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Clarification de l'enquêteur** : Ces **7 derniers jours**, combien de jours avez-vous fait des activités qui demandent **au moins un effort modéré** à l'intérieur de votre domicile ?]

19. Quand vous avez fait de l'activité physique **modérée** à l'intérieur votre maison au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos activités physiques modérées à l'intérieur de votre domicile **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

4ème PARTIE : ACTIVITE PHYSIQUE LIEE AUX LOISIRS, AU SPORT ET AU TEMPS LIBRE

LIRE : Maintenant, pensez à toutes les activités physiques que vous avez faites ces 7 derniers jours seulement dans le cadre de votre temps libre, de vos activités sportives ou de vos loisirs. Ne tenez pas compte des activités que vous avez déjà mentionnées.

20. Sans compter la marche que vous avez déjà mentionnée, ces **7 derniers jours**, combien de jours avez-vous **marché** pendant au moins 10 minutes **pendant votre temps libre** ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la question 22]*

8. Ne sait pas / pas sûr *[Passez à la question 22]*

9. N'a pas répondu *[Passez à la question 22]*

[**Clarification de l'enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d'affilée.]

21. Quand vous avez marché au cours de votre temps libre au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement à la marche qui a duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de votre marche pendant votre temps libre **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

LIRE : Maintenant, pensez aux autres activités physiques que vous avez faites pendant votre temps libre pendant au moins 10 minutes d'affilée.

LIRE : Tout d'abord, pensez aux activités *intenses* qui demandent un gros effort physique et que vous avez faites pendant votre temps libre. Il peut s'agir d'activités comme courir, faire du vélo ou nager vite ou faire de la gym type aérobic.

[**Clarification de l'enquêteur** : Les activités intenses font respirer plus fort que d'habitude.]

22. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités physiques **intenses pendant votre temps libre** ? [De 0 à 7, 8, 9]

___ Jours par semaine *[Si la réponse est 0, passez à la question 24]*

8. Ne sait pas / pas sûr *[Passez à la question 24]*

9. N'a pas répondu *[Passez à la question 24]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques **intenses** qui ont duré au moins 10 minutes d'affilée.]

23. Quand vous avez fait des activités physiques **intenses** au cours de votre temps libre au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos activités physiques intenses pendant votre temps libre **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas / Pas sûr

9999. N'a pas répondu

LIRE : Maintenant, pensez aux activités qui demandent un effort physique *modéré* et que vous avez faites pendant votre temps libre. Il peut s'agir d'activités comme faire du vélo ou nager à un rythme tranquille ou jouer au tennis en double. Encore une fois, ne tenez compte que des activités modérées qui ont duré au moins 10 minutes d'affilée.

[**Clarification de l'enquêteur** : les activités physiques modérées font respirer un peu plus fort que d'habitude.]

24. Ces 7 **derniers jours**, pendant combien de jours avez-vous fait des activités physiques **modérées pendant votre temps libre** ? [De 0 à 7, 8, 9]
___ Jours par semaine *[Si la personne répond 0, passez à la 5ème partie]*

8. Ne sait pas / pas sûr *[Passez à la 5ème partie]*
9. N'a pas répondu *[Passez à la 5ème partie]*

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

25. Quand vous avez fait des activités physiques modérées pendant votre temps libre au cours d'un de ces jours, combien de temps y avez-vous consacré en moyenne ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Pensez seulement aux activités physiques de ce type qui ont duré au moins 10 minutes d'affilée.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Quelle a été la durée totale de vos activités physiques modérées pendant votre temps libre **ces 7 derniers jours** ? »]

___ ___ Heures par semaine [De 0 à 112]

___ ___ ___ ___ Minutes par semaine [De 0 à 6720, 9998, 9999]

9998. Ne sait pas/Pas sûr

9999. N'a pas répondu

5ème PARTIE : TEMPS PASSE ASSIS

LIRE : La dernière question porte sur le temps que vous avez passé *assis* ces 7 derniers jours. Incluez le temps passé au travail, à la maison, le temps passé à étudier ou en stage et le temps de loisirs. Cela peut comprendre le temps passé assis à votre bureau, assis lors d'une visite chez des amis, le temps passé à lire ou bien le temps passé assis ou allongé à regarder la télé. N'incluez pas le temps passé assis dans un véhicule motorisé que vous avez déjà mentionné.

26. En moyenne, ces 7 **derniers jours**, combien de temps avez-vous passé **assis pendant un jour de semaine** ?
___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas/Pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Incluez le temps passé allongé sans dormir en plus du temps passé assis.]

[**Précision pour l'enquêteur** : On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Au total, combien de temps avez-vous passé assis **mercredi dernier** ? »

___ ___ Heures le mercredi [De 0 à 16]

___ ___ ___ ___ Minutes le mercredi [De 0 à 960, 998, 999]

9998. Ne sait pas/Pas sûr

9999. N'a pas répondu

27. En moyenne, le week-end dernier, combien de temps avez-vous passé **assis au cours d'une journée** ?

___ ___ Heures par jour [De 0 à 16]

___ ___ ___ Minutes par jour [De 0 à 960, 998, 999]

998. Ne sait pas / pas sûr

999. N'a pas répondu

[**Clarification de l'enquêteur** : Incluez le temps passé allongé sans dormir en plus du temps passé assis.]

[**Précision pour l'enquêteur :** On recherche une durée moyenne par jour. Si la personne interrogée ne peut pas répondre parce que le temps consacré aux activités varie beaucoup d'un jour à l'autre, demandez : « Au total, combien de temps avez-vous passé assis **samedi dernier** ? »

___ ___ Heures le samedi [De 0 à 16]

___ ___ ___ ___ Minutes le samedi [De 0 à 960, 998, 999]

9998. Ne sait pas/Pas sûr

9999. N'a pas répondu

Résumé

Contexte : La surveillance de l'activité physique et des comportements sédentaires, et la question de leur mesure, sont primordiales dans un contexte où les sociétés modernes favorisent l'augmentation de l'incidence de nombreuses maladies associées à un mode de vie sédentaire. **Objectif** : L'objectif de cette thèse était d'approfondir les connaissances sur la surveillance et la mesure de l'activité physique et des comportements sédentaires. **Méthodes** : Quatre études ont été réalisées. Deux travaux s'attachaient à analyser et discuter le système français de surveillance de l'activité physique et des comportements sédentaires des adultes et des jeunes. Une étude a testé les propriétés psychométriques du questionnaire mondial sur la pratique d'activités physiques (GPAQ). Enfin, une revue de la littérature a été effectuée pour analyser le contenu des questionnaires disponibles pour mesurer les comportements sédentaires. **Résultats** : Les deux études portant sur la surveillance observent que les enquêtes mises en place utilisent des méthodologies différentes, en particulier concernant la mesure des activités physiques et sédentaires. Ce manque d'homogénéité et de constance dans le choix des outils de mesure limitent la comparaison des résultats entre les différentes enquêtes, et le suivi de l'évolution des pratiques. L'étude sur le GPAQ révèle des résultats, en termes de reproductibilité et de validité, similaires aux valeurs habituellement observées dans la littérature scientifique. Enfin, la revue de littérature a mis en évidence que les questionnaires mesurant les comportements sédentaires présentent des différences en termes de population cible (ex : adultes, enfants, personnes âgées), période de rappel (ex : hier, la semaine dernière, le mois dernier), nombre d'item (de 1 à plus de 100 items), et caractéristiques des comportements sédentaires mesurés (ex : temps assis devant la télévision vs temps assis au travail). **Conclusion** : Les travaux qui constituent cette thèse permettent d'émettre un certain nombre de recommandations afin d'améliorer la mesure et la surveillance de l'activité physique et des comportements sédentaires en France.
Mots clés : surveillance, questionnaire, activité physique, sédentarité, enquête

Summary

Background: Physical activity and sedentary behaviors are major health determinants and are being surveyed worldwide. **Objective**: The aim of this thesis was to contribute to the surveillance and measurement of physical activity and sedentary behaviors. **Method**: This thesis includes four studies. The first study analyzes and discusses the present situation of French national surveillance studies. The second study presents the results from the first French report card on physical activity for children and adolescents. The third study discusses the validity and reliability properties of the French version of the Global Physical Activity Questionnaire (GPAQ). The fourth study examines the content of questionnaires measuring sedentary behaviors. **Results**: Studies 1 and 2 reported measurement issues impairing the overall data quality, inter-study comparisons and survey of changes over time. In addition, there is a need to improve data collection for some indicators among youth and adults, including physical community and the built environment, and government strategies and investment. The study of GPAQ reported limited but acceptable reliability and validity for the measurement of physical activity and sedentary time in France. Finally, the systematic review on sedentary behaviors questionnaires reported large differences in the population targeted (ex: adults, youth, elderly), recall frame (ex: previous day, last 7 days, last month), the number of item (from 1 to more than 100), and the sedentary behaviors characteristics measured (from only sitting time to up to 27 sedentary behaviors). **Conclusion**: The work realized during this thesis allows the formulation of recommendations to improve the surveillance of physical activity and sedentary behaviors in France.
Key words: public health surveillance, questionnaire, physical activity, sedentary behaviors, survey