Oriol Sansano Nadal

Nivell d'activitat física i comportament sedentari en gent gran: instruments de mesura i intervencions

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TESI DOCTORAL

Títol	Nivells d'activitat física i comportament sedentari en gent gran: instruments de mesura i intervencions
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Dirigida per	Dra. Carme Martín-Borràs Dra. Maria Giné-Garriga

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“*La ignorància afirma o nega rotundament,*

la ciència dubta.”

François-Marie Arouet (1694 – 1778)

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Resum

Versió en català

Títol: Nivells d'activitat física i comportament sedentari en gent gran: instruments de mesura i intervencions.

Resum: Els nivells d'activitat física (AF) i de comportament sedentari (CS) han esdevingut marcadors importants de la salut de les persones grans (≥65 anys). Tot i que ambdós comportaments estan molt relacionats entre ells, no s'associen de la mateixa manera amb l'estat de salut d'aquest col·lectiu. Aquest segment de població està augmentant molt ràpidament i és el menys físicament actiu i més sedentari. L'objectiu principal d'aquesta tesi doctoral és investigar la relació entre l'AF i el CS, així com també les intervencions per modificar ambdós comportaments, en l'estat de salut de les persones grans. Aquest objectiu s'ha dividit en tres estudis: (I) avaluar els efectes de les intervencions d'AF amb un seguiment mínim de sis mesos, i descriure les estratègies específiques implementades per millorar l'adherència a l'AF; (II) avaluar la validesa del *Sedentary Behaviour Questionnaire* (SBQ) per mesurar el CS de les persones grans mitjançant l'accelerometria com a criteri de validesa; (III) avaluar la relació entre l'AF i el CS auto-reportat i mesurat mitjançant accelerometria amb la qualitat de vida relacionada amb la salut (QVRS) de les persones grans. L'estudi I mostra que les intervencions basades en AF tenen un efecte significatiu sobre els nivells d'AF a l'acabar les intervencions respecte el grup control (GC) no actiu (diferència de mitjanes estandarditzada (DME)= 0.18); i passats sis mesos de seguiment (DME= 0.30). L'educació, la monitorització i la

planificació d'accions son les estratègies identificades més utilitzades. L'estudi II mostra un acord dèbil entre mesures (Correlació intraclasse (CIC)= 0.32) i una infravaloració de temps sedentari de 72.90 mins/dia de l'SBQ respecte l'accelerometria. L'estudi III mostra una relació estadísticament significativa però dèbil entre l'AF i el CS auto-reportada i mesurada mitjançant accelerometria amb la QVRS ($p \leq 0.05$), essent positiva amb l'AF i negativa amb el CS, especialment amb el *physical component score* (PCS) de l'SF-12. Respecte a l'estudi I, podem concloure que tot i mostrar uns resultats bastant heterogenis, les intervencions basades en AF tenen uns efectes estadísticament significatius sobre els nivells d'AF a l'acabar les intervencions amb una tendència a minvar a partir dels 12 mesos. Les estratègies més utilitzades han estat l'educació, l'auto-monitorització i la planificació d'accions, totes tres basades amb la Teoria Social Cognitiva (TSC). L'estudi II mostra que l'SBQ tendeix a infravalorar el temps en CS de la gent gran. Per tant, l'SBQ és una eina vàlida però poc fiable. Amb els resultats de l'estudi III, concloem que l'AF i el CS auto-reportat i avaluat mitjançant l'accelerometria s'associen significativament però dèbil amb la QVRS, diferenciant entre el PCS i el *mental component score* (MCS).

Paraules clau: activitat física; comportament sedentari; gent gran; instruments de mesura; intervencions.

Versión en castellano

Título: Niveles de actividad física y comportamiento sedentario en los adultos mayores: instrumentos de medida e intervenciones.

Resumen: Los niveles de actividad física (AF) y de comportamiento sedentario (CS) han pasado a considerarse marcadores importantes de la salud de las personas mayores (≥65 años). A pesar de que ambos comportamientos están muy relacionados entre sí, no se asocian del mismo modo con el estado de salud de la gente mayor. Este segmento de población está aumentando muy rápidamente y es el menos físicamente activo y más sedentario. El objetivo principal de esta tesis doctoral es investigar la relación entre la AF y del CS, así como también de las intervenciones para modificar ambos comportamientos, en la salud de las personas mayores. Este objetivo se ha dividido en tres estudios: (I) evaluar el efecto de las intervenciones de AF con un seguimiento mínimo de seis meses, y describir las estrategias específicas implementadas para mejorar la adherencia a la AF; (II) evaluar la validez del *Sedentary Behaviour Questionnaire* (SBQ) para medir el CS de las personas mayores mediante la acelerometría como criterio de validez; (III) evaluar la relación entre la AF y el CS auto-reportado y medido mediante acelerometría con la calidad de vida relacionada con la salud (CVRS) de las personas mayores. El estudio I muestra que las intervenciones basadas en AF tienen un efecto significativo sobre los niveles de AF al terminar las intervenciones respecto a los grupos control (GC) no activos (diferencia de medias estandarizada (DME)= 0.18); y a los 6 meses de seguimiento (DME= 0.30). La educación, la auto-monitorización y la planificación de acciones son las estrategias identificadas más utilizadas. El estudio II muestra un acuerdo débil entre medidas (Correlación intraclase (CIC)= 0.32) y una infravaloración del SBQ del tiempo sedentario de 72.90 mins/día respecto a la acelerometría. El estudio III muestra una relación estadísticamente significativa pero débil entre la AF y el CS auto-reportado y medido mediante acelerometría con la

CVRS ($p \leq 0.05$) siendo positiva con la AF y negativa con el CS, especialmente con el *physical component score* (PCS). Respecto al estudio I, podemos concluir que, a pesar de mostrar unos resultados bastante heterogéneos, las intervenciones basadas en AF tienen unos efectos estadísticamente significativos sobre los niveles de AF al terminar las intervenciones, con una tendencia a menguar a partir de los 12 meses. Las estrategias más utilizadas han sido la educación, la monitorización y la planificación de acciones, basadas con la Teoría Social Cognitiva (TSC). El estudio II muestra que el SBQ tiende a infravalorar el tiempo en CS de la gente mayor. Por lo tanto, el SBQ es un instrumento válido pero poco fiable. Con los resultados del estudio III, concluimos que la AF y el CS auto-reportado y medido mediante la acelerometría se asocian significativa pero débilmente con la CVRS, diferenciando entre el PCS y el *mental component score* (MCS).

Palabras clave: actividad física; comportamiento sedentario; adultos mayores; instrumentos de medida; intervenciones.

English version

Title: Physical activity levels and sedentary behaviour among older adults: measurement and interventions.

Summary: Physical activity (PA) levels and sedentary behaviour (SB) have become an important health marker for older adults (≥65 years old). Despite both behaviours are closely related, they are not equally associated with the older adults' health status. In the last decades, older adults have been the fastest growing segment population, and they are

the least active and most sedentary. The main aim of this doctoral thesis is to investigate the relation of PA and SB, as well as interventions to modify both behaviours, with older adults' health. The main aim has been targeted with three studies: (I) to evaluate the effect of PA interventions with a minimum six months follow-up, and to describe specific strategies implemented to improve adherence to PA; (II) to evaluate the validity of the *Sedentary Behaviour Questionnaire* (SBQ) to measure older adults' SB using accelerometry as a criterion validity; (III) to evaluate the relationship between PA and SB, self-reported and device-measured, with the health-related quality of life (HRQoL) among older adults. Study I shows that PA-based interventions have a significant effect on PA levels at the end of the interventions compared to non-active control groups (CG) (standardized mean difference (SMD)= 0.18); and at 6 months follow-up (SMD= 0.30). Education, self-monitoring and action planning are the most used identified strategies. Study II shows a weak agreement between measures (intraclass correlation coefficient (ICC)= 0.32) and an underestimation of the sedentary time with the SBQ of 72.90 mins/day against device-measured. Study III shows a statistically significant but weak relationship between PA and SB, self-reported and device-measured, with HRQoL ($p \leq 0.05$), being positive with PA and negative with SB, in particular with physical component score (PCS). Regarding study I, although showing quite heterogeneous results, PA-based interventions have statistically significant effects on PA levels at the end of the interventions, with a decline after 12 months. The most widely used strategies have been educations, self-monitoring and action planning, based on the Social Cognitive Theory (SCT). Study II shows that SBQ tends to underestimate SB time among older adults. Therefore, the SBQ is a valid but unreliable instrument. Based on the study III results, we conclude that PA and SB, self-reported and device-measured, are significant but weakly associated with HRQoL, with a variance between PCS and mental component score (MCS).

Key words: physical activity; sedentary behaviour, older adults; measurement; interventions.

Publicacions del compendi d'articles

- **Sansano-Nadal, O.**, Giné-Garriga, M., Brach, J., Wert, D., Jerez-Roig, J., Guerra-Balic, M., Oviedo, G., Fortuño, J., Gómara-Toldrà, N., Soto-Bagaria, L., Pérez, L., Inzitari, M., Solà, I., Martin-Borràs, C., & Roqué, M. (2019). Exercise-based interventions to enhance long-term sustainability of physical activity in older adults: A systematic review and meta-analysis of randomized clinical trials. International Journal of Environmental Research and Public Health, 16 (14). https://doi.org/10.3390/ijerph16142527

- **Sansano-Nadal, O.**, Wilson, J., Martín-Borràs, C., Brønd, J., Skjødt, M., Caserotti, P., Roqué I Figuls, M., Blackburn, N., Klenk, J., Rothenbacher, D., Guerra-Balic, M., Font-Farré, M., Denkinger, M., Coll-Planas, L., Deidda, M., McIntosh, E., Giné-Garriga, M., & Tully, M. (2021). Validity of the Sedentary Behavior Questionnaire in European Older Adults Using English, Spanish, German and Danish Versions. Measurement in Physical Education and Exercise Science, 1–14. https://doi.org/10.1080/1091367X.2021.1922910

- **Sansano-Nadal, O.**, Giné-Garriga, M., Rodríguez-Roca, B., Guerra-Balic, M., Ferri, K., Wilson, J., Caserotti, P., Olsen, P., Blackburn, N., Rothenbacher, D., Dallmeier, D., Roqué-Fíguls, M., Mcintosh, E., & Martín-Borràs, C. (2021). Association of Self-Reported and Device-Measured Sedentary Behaviour and Physical Activity with Health-Related Quality of Life among European Older Adults. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 13252, 18 (24), 13252. https://doi.org/10.3390/IJERPH182413252

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Resums a congressos

- **Sansano-Nadal O.**, Roqué M., Santiago M., Ferri K., Font-Farré M., Oviedo G., Caserotti P., Martín-Borràs C. Els reptes de la valoració objectiva del comportament sedentari, els nivells d'activitat física i la funció física de les persones participants del SITLESS a Barcelona. Comunicació oral. 24é Congrés de la Societat Catalana de Geriatria i Gerontologia. Barcelona, 2008.

- **Sansano-Nadal O.**.Objectively measured sedentary behaviour and physical activity levels in older adults from four European countries. Ponència al Simposi "Exercise Referral Schemes enhanced by self-management strategies to battle sedentary behaviour in older adults: the SITLESS project. VII Congreso Internacional de investigación en salud y envejecimiento & V Congreso internacional de investigación en salud. Madrid, 2020.

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Glossari d'abreviacions i acrònims

- FPCEE: Facultat de Psicologia,, Ciències de l'Educació i de l'Esport
- ACA: assaig clínic aleatoritzat
- AF: activitat física
- EACC: estratègies d'autogestió per al canvi de comportament
- CS: comportament sedentari
- QV: qualitat de vida
- CAP: centre d'atenció primària
- OMS: Organització Mundial de la Salut
- SBRN: *Sedentary Behaviour Research Network*
- MET: *metabolic equivalent of task*
- O^2: oxigen
- RS: revisió sistemàtica
- SBQ: S*edentary Behaviour Questionnaire*
- QVRS: qualitat de vida relacionada amb la salut
- KJ: kilojoules
- Kcal: kilocalories
- Km: kilòmetres
- EF: exercici físic
- AVD: activitats de la vida diària
- AFMV: activitat física moderada o vigorosa
- ISCA: *International Sport and Culture Association*
- CEBR: *Centre for Economics Business Research*
- IPAQ: *International Physical Activity Questionnaire*
- MLPAQ: *Minnesota Phyisical Activity Questionnaire*

- 7 day – PAR: *Seven-Day Physical Activity Recall*
- MOST: *Measuring Older Adults' Sedentary Time*
- AFM: activitat física moderada
- AFLL: activitat física lleu
- AFV: activitat física vigorosa
- TCC: tècniques de canvi de comportament
- TSC: teoria social cognitiva
- NU: Nacions Unides
- EQ-5D: Euro-QoL
- PCS: physical component score
- MCS: mental component score
- ODS: objectius de desenvolupament sostenible
- NHANES: *National Health and Nutrition Examination Survey*
- SPPB: *Short Physical Performance Battery*
- ERS: *Exercise Referral Schemes*
- CI: consentiment informat
- GC: grup control
- App: aplicació mòbil
- IDCC: intervencions digitals de canvi de comportament
- ASPCAT: Agència de Salut Pública de Catalunya
- PAFES: pla d'activitat física, esport i salut
- MTT: model transteòric
- CIC: correlació intraclasse

INTRODUCCIÓ

Introducció

En aquesta tesi es presenta el treball realitzat durant cinc anys vinculat al programa de doctorat en Ciències de l'Educació i de l'Esport de la Facultat de Psicologia, Ciències de l'Educació i de l'Esport (FPCEE) Blanquerna, Universitat Ramon Llull. El fil conductor d'aquest treball ha estat el projecte *SITLESS: Exercise Referral Schemes enhanced by Self-Management Strategies to battle sedentary behaviour*. Aquest estudi ha rebut finançament de la Unió Europea sota el marc del programa *Horizon* 2020 (H2020-Grant 634270).

El projecte SITLESS naix l'any 2015 amb l'objectiu de promoure un estil de vida actiu i saludable entre la població adulta major o gent gran resident a la comunitat de diferents països europeus. Es tracta d'un assaig clínic aleatoritzat (ACA) multicèntric de tres branques que té com objectiu poder determinar si una intervenció d'activitat física (AF), juntament amb estratègies d'autogestió per al canvi de comportament (EACC) per reduir el comportament sedentari (CS), incrementa els nivells d'AF i millora l'estat de salut, així com també la qualitat de vida (QV) i la funció física a llarg termini (22 mesos) (Giné-Garriga et al., 2017). Tant les intervencions proposades en cadascuna de les branques de l'estudi com les diferents avaluacions s'han dut a terme de manera multicèntrica majoritàriament als centres d'atenció primària (CAP) de les àrees urbanes de Barcelona (Catalunya), Odense (Dinamarca), Ulm (Alemanya) i Belfast (Regne Unit). Un total de 1360 persones grans van ser reclutades, avaluades i aleatoritzades en tres grups (Barcelona: n = 356; Odense: n = 338; Ulm: n = 345; i Belfast: n = 321).

La gent gran és el segment de població que està augmentant més ràpidament en les darreres dècades (World Health Organization & United States National Institute of Aging, 2011). Actualment, la població mundial de ≥60 anys és d'aproximadament 707 milions de persones (Gabinet d'Estudis Socials i Opinió Pública, 2020). (Gabinet d'Estudis Socials i Opinió Pública, 2020). Del 2025 al 2050 es preveu que aquest segment poblacional es duplicarà arribant als 2.100 milions aproximadament (World Health Organization, 2011).

L'Organització Mundial de la Salut (OMS) defineix l'AF com "qualsevol moviment corporal produït pel sistema múscul-esquelètic, fent que augmenti el consum energètic" (Bull et al., 2020; Caspersen et al., 1985). I, per tant, fa referència a qualsevol moviment, incloent tant el temps d'oci, el desplaçament o transport, com també el temps domèstic o de treball (Scarabottolo et al., 2019). Les recomanacions generals d'AF per a persones grans determinen que és necessària almenys la realització d'entre 150 a 300 minuts d'AF aeròbica d'intensitat moderada, d'entre 75 a 150 minuts d'AF aeròbica vigorosa o una combinació d'aquestes durant la setmana per millorar la salut (World Health Organization, 2010, 2018). A més, la mateixa OMS suggereix com a part d'aquesta AF setmanal per a persones grans incloure 3 o més dies el treball de l'equilibri i la força d'intensitat moderada o vigorosa per a millorar la seva capacitat funcional i prevenir les caigudes. Tot i aquestes recomanacions generals per a les persones grans, els darrers resultats de l'*Eurobarometer* mostren que els nivells d'AF de la població europea son insuficients en quasi bé tots els grups d'edat, essent menys actius a mesura que s'envelleix (European Commission, 2018).

La *Sedentary Behaviour Research Network* (SBRN) defineix el CS com "qualsevol comportament durant les hores del dia en el què la despesa energètica sigui ≤1.5 *metabolic equivalents* (METs) mentre s'estigui assegut, reclinat o estirat (Tremblay et al., 2017). Durant els últims anys, el CS ha estat reconegut com un problema de salut pública, i especialment en les persones grans (De Rezende et al., 2014; Wilson et al., 2019) ja que aquestes son el sector de la població que mostra els nivells de CS més elevats, passant de mitjana el 80% del temps desperts en CS (Giné-Garriga et al., 2020).

Tot i que l'AF i el CS estan molt relacionats entre ells, s'estudien de manera individual. Entre les seves diferències, sabem que no s'associen de la mateixa manera amb la funcionalitat ni amb l'estat de salut de la gent gran (Dogra et al., 2017; Dogra & Stathokostas, 2012). La literatura científica mostra que ser insuficientment actiu (van der Ploeg & Hillsdon, 2017) està altament associat amb un increment del risc de patir malalties no transmissibles i altres causes de mortalitat (Cunningham et al., 2020). Així mateix, estar llargs períodes de temps assegut també està associat negativament a l'estat de salut (Ku et al., 2018; Wilson et al., 2019). Per tant, la manca d'AF i els alts nivells de CS en aquest segment poblacional desencadenen en un paradigma en el què cal parar especial atenció degut a l'elevat risc per a la salut però també en les conseqüències sòcio-econòmiques a l'hora de combatre aquests problemes que se'n deriven. L'any 2012, el cost d'aquestes conseqüències sòcio-econòmiques va ascendir a 80.400 milions d'euros a nivell europeu (el 6.2% del cost total sanitari europeu). En aquest sentit, s'estima que reduir la inactivitat física en un 20% entre la població adulta suposaria un estalvi de 16.100 milions d'euros (ISCA-CEBR, 2015).

Endinsant-nos en aquest paradigma de l'AF i el CS en les persones grans, i també en l'impacte que se'n deriva sobre la salut d'aquesta població, descobrim l'objectiu principal d'aquesta tesi doctoral. Basant-nos en les mancances que trobem a la literatura científica en aquest camp, l'objectiu principal d'aquesta tesi és investigar l'impacte que poden tenir l'AF i el CS, així com també les intervencions per modificar ambdós comportaments, en l'estat de salut de les persones grans. Aquest objectiu principal, l'hem dividit en tres objectius específics dels quals se n'han redactat tres estudis publicats a revistes científiques.

L'objectiu del primer estudi ha estat avaluar l'efecte de les intervencions basades en AF en un seguiment mínim de sis mesos i descriure les estratègies específiques implementades durant la intervenció per millorar l'adherència a l'AF en persones grans de 65 anys o més que viuen a la comunitat. El disseny d'aquest estudi ha estat una revisió sistemàtica (RS) juntament amb un meta-anàlisi d'ACA. A la publicació d'aquest estudi, el doctorand ha contribuït amb el disseny de l'estudi, l'*screening* i l'elecció dels estudis inclosos en la RS i el meta-anàlisi, l'extracció de dades i també amb la revisió i l'aprovació de l'article.

L'objectiu del segon estudi ha estat avaluar al validesa del *Sedentary Behaviour Questionnaire* (SBQ) per mesurar el CS de les persones grans que viuen a la comunitat mitjançant l'accelerometria com a criteri de validesa. A la publicació d'aquest estudi, la contribució del doctorand ha estat en el disseny de l'estudi, l'anàlisi estadístic, la interpretació i redacció dels resultats, així com també en la redacció de la discussió i les conclusions. Finalment, també ha liderat la revisió per consemblants de la revista científica.

Per últim, l'objectiu del tercer estudi ha estat avaluar la relació entre l'AF i el CS auto-reportat i mesurat mitjançant accelerometria amb la QV relacionada amb la salut (QVRS) de les persones grans residents a la comunitat de quatre països europeus. La contribució del doctorand en aquest estudi ha estat en la conceptualització i metodologia, l'anàlisi estadístic, la redacció de l'article científic i també la revisió per consemblants de la revista científica.

Un cop contextualitzat el nostre camp d'investigació, i havent explicat l'objectiu principal així com també els específics dels 3 estudis, passarem a la presentació de l'estructura d'aquesta tesi.

Aquesta tesi ha estat presentada segons la normativa acadèmica del programa de doctorat en Ciències de l'Educació i de l'Esport de la FPCEE Blanquerna, Universitat Ramon Llull, adherint-nos al format per compendi d'articles. El document ha estat dividit en 6 parts: **introducció**, on s'ha presentat, contextualitzat i justificat l'estudi, així com també s'han introduït alguns conceptes; **marc teòric**, per entrar en detall amb les definicions d'aquells conceptes més rellevants de l'estudi com son l'AF i el CS, la gent gran, la QV i les intervencions d'AF i CS en aquesta població centrant-nos amb la intervenció SITLESS; **objectius i hipòtesi**, basats en la literatura científica; **material i mètodes**, presentats en format de 3 estudis que segueixen un fil conductor i es relacionen entre ells, i que s'han publicat en revistes científiques; **resultats i discussió general**, on es contrasten els resultats més rellevants obtinguts dels diferents estudis i les seves limitacions tenint en compte la literatura científica; i per últim les **conclusions**, amb els resultats més rellevants i les futures línies de recerca en aquest camp.

MARC TEÒRIC

Marc teòric

En aquest apartat detallarem aquells conceptes rellevants de l'estudi que considerem importants per poder seguir el fil conductor del treball. A continuació els definirem i exposarem l'evolució del seu estudi durant els darrers anys.

Activitat física i comportament sedentari

Definicions

El terme AF és defineix com qualsevol moviment corporal produït pel sistema múscul-esquelètic que comporti un augment del consum energètic (Caspersen et al., 1985) i que sigui superior al basal (Bouchard et al., 2007). Així doncs, entenem que l'AF fa referència a qualsevol moviment que es faci durant el dia, incloent el temps d'oci, el de desplaçament o transport, el temps dedicat a tasques domèstiques i també el temps dedicat a la feina o estudis (Scarabottolo et al., 2019).

Històricament, la unitat de mesura per calcular el consum energètic utilitzat per a realitzar una activitat havien estat els kilojoules (KJ)[1] o les kilocalories (Kcal)[2] per unitat de temps (minuts). Actualment, la unitat de mesura per a calcular el consum energètic o índex metabòlic

[1] El Joule és la unitat de mesura del sistema internacional per mesurar l'energia, el treball i el calor. Aquesta unitat de mesura deu el seu nom al físic anglès James Prescott Joule.

[2] 1 Kcal equival a 4184 KJ.

d'una persona son els *metabolic equivalent of task* (MET[3]). 1 MET equival a la quantitat O_2 consumit mentre s'està assegut en repòs i és igual a 3.5 ml d'O_2 x kg de pes corporal x minut (Ainsworth et al., 2011). Per tant, quantificar la despesa energètica que pot suposar la realització d'un tipus d'AF en concret, ens permet categoritzar aquesta AF en funció de la intensitat en què s'està duent a terme.

Els *metabolic equivalent of task* (MET) son la unitat de mesura de l'índex metabòlic d'una persona.

L'any 1993 es va publicar el primer *Compendium of Physical Activity: classification of energy costs of human physical activities* que classificava diferents tipus d'AF en funció de la seva intensitat (METs) (Ainsworth et al., 1993). Aquesta classificació es va actualitzar l'any 2000 (BE. Ainsworth et al., 2000), fent-ne una darrera actualització l'any 2011 (Ainsworth et al., 2011).

El *Compendium of Physical Activity* classifica diferents activitats segons la seva intensitat de la següent manera:

- CS: de 1.0 METs a 1.5 METs (exemples: estar assegut llegint o estirat mirant la televisió).
- Intensitat lleugera: de 1.6 METs a 2.9 METS (exemples: caminar a ritme lent o rentar els plats).
- Intensitat moderada: de 3.0 METs a 5.9 METs (exemples: caminar ràpid o fer treballs de jardineria)

[3] Els *metabolic equivalent of task* (MET) son la unitat de mesura de l'índex metabòlic d'una persona.

- Intensitat vigorosa: ≥6 METs (exemples: practicar esports de competició com el bàsquet i el tennis o córrer a ritme ràpid).

Segons aquesta classificació, el rang d'intensitat utilitzant els METs com unitat de mesura va des de 0.9 METs mentre dormim a 23.0 METs que equival a córrer a 22.5 kilòmetres (Km) per hora.

El terme exercici físic (EF), que molts cops erròniament s'utilitza com a sinònim d'AF, es considera una subcategoria de l'AF. Segons Caspersen i els seus col·laboradors (1985), la principal diferència entre ambdós conceptes és que l'EF es considera aquella AF planificada, estructurada, repetitiva i proposada amb un objectiu en concret, habitualment per a millorar i/o mantenir un o més components de la forma física (Caspersen et al., 1985).

El concepte CS es defineix com qualsevol comportament durant les hores del dia en el què la despesa energètica sigui ≤1.5 METs mentre s'estigui assegut, reclinat o estirat (Tremblay et al., 2017). Alguns exemples de conducta sedentària son estar estirat mirant la televisió, assegut llegint un llibre, fer la migdiada o viatjar assegut amb tren. El concepte sedentari/a no s'ha d'utilitzar com a sinònim d'insuficientment actiu/va. El concepte d'insuficientment actiu/va s'associa a aquelles persones que no compleixen la quantitat suficient d'AF recomanada per l'OMS d'entre 150 a 300 minuts d'AF aeròbica d'intensitat moderada, d'entre 75 a 150 minuts d'AF aeròbica vigorosa o una combinació d'aquestes durant la setmana (van der Ploeg & Hillsdon, 2017). Un exemple clar per poder diferenciar ambdós conceptes és el següent. Una persona pot estar moltes hores asseguda al dia ja que es desplaça amb transport públic de casa a la feina i viceversa, treballa asseguda a una oficina durant 7 hores i mira la televisió una estona, però va al gimnàs 1 hora tres cops per setmana. En aquest estil de vida, podem identificar la conducta sedentària durant la major part del dia. Tot i això, no podem considerar que aquesta persona sigui insuficientment activa ja que amb 180 minuts per setmana d'AF compleix les recomanacions generals d'AF segons l'OMS (World Health Organization, 2010, 2018). Cal dir que aquesta situació també és pot donar a la inversa. Una persona pot ser insuficientment activa però no tenir un estil de vida sedentari. Per tant entenem el CS i ser insuficientment actiu/va com dos conceptes diferents.

Efectes de l'activitat física i el comportament sedentari en la salut de les persones grans

Tal i com hem avançat a l'apartat d'introducció, tot i que l'AF i el CS estan molt relacionats entre ells, s'han d'estudiar de manera individual. Per aquest motiu, en aquest capítol diferenciarem els efectes d'ambdós comportaments sobre la salut de les persones grans. La gent gran ha demostrat ser la menys activa i la més sedentària; i per això és de rellevant importància poder mesurar els efectes d'aquest estil de vida sobre la salut.

Prèviament, creiem necessari definir el concepte de salut. L'any de creació de l'OMS (1946), la mateixa organització va definir la salut com "*l'estat de complet benestar físic, mental i social, i no només l'absència de malaltia*". El 1986 va clarificar que la salut havia d'esser *"un concepte positiu focalitzat amb els recursos socials i personals, així* *com també en les capacitats físiques"*. La definició d'aquest concepte ha anat evolucionant i adoptant diferents versions a conseqüència de l'avenç científic en totes les branques de la salut.

Pel que fa als nivells d'AF, cal dir que estan altament associats amb la salut de les persones grans (Taylor, 2014). La inactivitat és considera la quarta causa de mortalitat a nivell mundial (World Health Organization., 2010) i per això és considerada una pandèmia mundial accentuada sobretot en la gent gran (Kohl et al., 2012). Les recomanacions d'AF per a gent gran de l'OMS esdevenen un factor important relacionat amb la força, la flexibilitat i l'equilibri per a poder fer les activitats de la vida diària (AVD) a mesura que la població envelleix. Així mateix, la manca d'AF està associada a malalties no transmissibles com la hipertensió, malalties coronàries, l'infart de miocardi, la diabetis i els càncers de pit i colon (American College of Sports Medicine, 2018; American College of Sports Medicine et al., 2009; Garber et al., 2011; Hallal et al., 2012). També s'ha estudiat la relació entre l'increment dels nivells d'AF i les patologies del sistema múscul-esquelètic com l'artritis, osteoporosis o sarcopènia i s'associen significativament (Broskey et al., 2014). A més a més, amb uns elevats nivells d'AF hi ha una millor salut cognitiva i mental (Sparling et al., 2015). Cunningham i els seus col·laboradors (2020), en una RS recent han identificat que les persones grans (en aquest cas ≥60 anys) que son físicament actives tenen un risc menor de patir malalties cardiovasculars, càncer de pit i pròstata, fractures, problemes en les AVD, limitació funcional i risc de caigudes, així com també decadència cognitiva, demència, Alzheimer i depressió (Cunningham et al., 2020).

Per tant, la literatura científica ens mostra que tots els beneficis que aporta l'AF en la salut de les persones grans fa que disminueixin els índexs de mortalitat d'aquesta població. De fet, hi ha evidència científica que conclou que la realització d'una AF moderada o vigorosa (AFMV) de 75 minuts per setmana està associada a una reducció del 22% de totes les causes de mortalitat (Hupin et al., 2015). Aquest estudi és un exemple de la importància d'anar augmentant els nivells d'AF, encara que sigui en petites dosis per ajudar a les persones grans inactives o que presenten alguna malaltia crònica a anar incorporant l'AF en la seva rutina diària. En una altra RS recent, Geild i els seus col·laboradors (2020) conclouen que els nivells d'AF més alts estan associats amb un menor índex de mortalitat en adults amb diabetis tipus II, cardiopatia isquèmica i càncer de pit. També mostren que la corba dosi-resposta no mostra un clar efecte beneficiós de l'AF sobre la mortalitat, és a dir, que qualsevol tipus d'AF és millor que la manca d'aquesta (Geidl et al., 2020).

Com hem comentat anteriorment, l'AF i el CS no estan associats de la mateixa manera amb la funcionalitat ni amb l'estat de salut de la gent gran (Dogra et al., 2017; Dogra & Stathokostas, 2012). El CS, com a comportament independent de la inactivitat, s'associa a un major risc d'obesitat, al càncer de còlon o de pròstata, al síndrome metabòlic, a la diabetis tipus II i a la mortalitat per diverses causes (Gennuso et al., 2013). Estar estones llargues en CS durant el dia també redueix significativament l'estat de salut, inclús en persones grans considerades físicament actives (Gennuso et al., 2013). De fet, els efectes negatius per a la salut del temps en CS, o mirant la televisió[4], no es redueixen fent alts nivells d'AFMV entre les persones adultes (Matthews et al., 2012). Stamatakis i els seus col·laboradors (2019) en el seu darrer estudi de disseny longitudinal amb un seguiment a quasi bé 9 anys, discuteixen aquesta idea i conclouen que les dosis d'AFMV equivalents a complir les recomanacions actuals atenuen o eliminen eficaçment aquestes associacions del CS amb la mort per malalties cardiovasculars i/o altres causes (Stamatakis et al., 2019). Un altre estudi, també ens mostra que els elevats nivells de CS estan associats al nivell d'aïllament social de les persones grans (Tully et al., 2019).

Per tant, tenint en compte tots els efectes negatius que ens causen els alts nivells de CS de la població en general, i més accentuadament entre les persones grans, és important reduir les estones en CS. Estudis recents posen l'accent en reduir el temps en CS fent pauses o *breaks* per tal de millorar indicadors de salut com els nivells de glucèmia o l'adipositat (Chastin et al., 2015). En el cas de persones grans, amb nivells superiors al 80% del temps diari asseguts (Giné-Garriga et al., 2020), és important augmentar aquests *breaks* per tal de millorar la capacitat funcional i poder realitzar amb més facilitat les AVD així com també tenir una major independència (Liao et al., 2018; Sardinha et al., 2015; Walker et al., 2021). En aquest sentit, si l'augment dels *breaks* durant el temps en CS va acompanyat de l'augment dels nivells d'AF, aporta uns majors beneficis en la funcionalitat i pot evitar la fragilitat precoç de les persones grans (Mañas et al., 2021).

[4] El temps assegut, així com també el temps mirant la televisió, normalment s'associa amb el temps en CS i és un indicador de l'estat de salut (Owen et al., 2009).

Conclourem aquest apartat amb una referència al cost que suposa la manca d'AF i els elevats nivells de CS. Les conseqüències econòmiques d'aquests dos comportaments van comportar el 2015 a nivell europeu un total de 80.400 milions d'euros, és a dir, el 6.2% del cost total sanitari europeu. L'*International Sport and Culture Association* (ISCA) i el *Center for Economics Business Research* (CEBR) estimaren que reduir la inactivitat física en un 20% entre la població adulta suposaria un estalvi de 16.100 milions d'euros (ISCA-CEBR, 2015).

Instruments de mesura de l'activitat física i el comportament sedentari

Tenint en compte els efectes de l'AF i el CS en la salut de les persones grans, és important poder avaluar ambdós comportaments de la manera més exacta i precisa per tal d'entendre l'estil de vida de la gent gran i poder determinar quin tipus d'intervenció pot tenir un major impacte sobre seu dia a dia (Dogra et al., 2017).

Hi ha un ampli ventall d'instruments per avaluar l'AF i el CS però generalment els diferenciem entre aquells que son subjectius, és a dir, l'individu reporta la informació sobre la intensitat, la freqüència, el temps i el tipus d'activitat que ha fet; o bé els objectius, que inclouen tots aquells instruments que registren la intensitat, la freqüència i el temps a partir de l'acceleració o d'altres variables fisiològiques com la freqüència cardíaca (Hart et al., 2011).

Entre els instruments subjectius podem trobar els qüestionaris i diaris de registre. Ambdós instruments son habitualment auto reportats per l'individu estudiat i ens aporten informació tant quantitativa (intensitat, temps i freqüència) com també informació qualitativa (el context o el tipus d'activitat que han fet). Aquests instruments s'utilitzen habitualment en estudis amb molta mostra degut al seu baix cost econòmic i la poca dificultat a l'hora d'utilitzar i tractar les dades (Degroote et al., 2020). Dos aspectes que s'han de tenir en compte a l'hora d'utilitzar un instrument subjectiu o un altre son la seva fiabilitat i validesa (Lines et al., 2020). Tot i això, els instruments subjectius tenen una sèrie de limitacions com el biaix de les dades obtingudes i també la infravaloració (habitualment quan es reporta el CS) o sobrevaloració (quan es reporta l'AF) del temps en cada comportament (Aguilar-Farías et al., 2014). Un exemple de qüestionari validat que s'ha utilitzat al tercer estudi d'aquesta tesi doctoral per d'avaluar l'AF és l'*International Physical Activity Questionnaire* (IPAQ) (Craig et al., 2003). Altres exemples son el *Minnesota Leisure-Time Physical Activity Questionnaire* (MLPAQ) (Elosua et al., 1994) o el *7 day – PAR: Seven-Day Physical Activity Recall* (7day – PAR) (Zuazagoitia et al., 2014). Pel que fa a l'avaluació del CS també hi ha diversos qüestionaris validats, entre ells l'SBQ validat al segon estudi d'aquesta tesi doctoral (Sansano-Nadal et al., 2021). Altres exemples molt utilitzats en estudis epidemiològics son el *Measuring Older Aduts' Sedentary Time* (MOST) (Gardiner et al., 2011) o el *LASA Sedentary Behaviour Questionnaire* (Visser & Koster, 2013).

Quant als instruments objectius també disposem de diversos dispositius per a mesurar l'AF i el CS que tendeixen a ser més precisos i exactes a l'hora de mesurar ambdós comportaments (Matthews et al., 2012). Alguna de les limitacions que tenen és el seu elevat cost, que fa difícil utilitzar-los en estudis longitudinals amb una mostra molt gran. Altres limitacions son la manca d'informació respecte al context i el tipus d'activitat que s'està realitzant, així com també la dificultat d'assegurar el compliment dels participants en dur posat el dispositiu durant el temps que se'ls hi demana. També cal dir que aquests dispositius disposen de *software* particulars per al tractament de les dades per al qual és necessita un coneixement específic per a poder-los utilitzar (Wilson et al., 2020). Entre els instruments de mesura objectius per a l'AF i el CS diferenciem entre els podòmetres, acceleròmetres i inclinòmetres.

Els podòmetres s'han utilitzat durant molts anys per mesurar els nivells d'AF degut al seu baix cost respecte als acceleròmetres i inclinòmetres. Els podòmetres, habitualment col·locats al maluc, mesuren el número de passes a través d'un sensor mecànic que es basa amb la força generada durant la marxa (Ainsworth et al., 2015). Aquest sensor ha anat evolucionant al llarg dels anys i actualment utilitza un sistema microelectronicomecànic per mesurar el número de passes (Berlin et al., 2006). Una de les principals limitacions d'aquest instrument és la velocitat de la marxa. Per això, hi ha molts problemes a l'hora de comptabilitzar el número de passes si l'individu avaluat camina a ≤2.2 km/h i/o té dificultats en la marxa. Tot i aquestes limitacions, segons Crouter i els seus col·laboradors (2003) els podòmetres son els instruments més adequats per mesurar el número de passes (Crouter et al., 2003). No son gaire precisos per a mesurar la distància i encara menys les kcal. Tudor-Locke i els seus col·laboradors (2011) van classificar els nivells d'AF en funció del número de passes al dia. Un individu es considera molt poc actiu si fa entre 2.500 i 4.999 passes al dia; poc actiu entre 5.000 i 7.499 passes al dia; moderadament actiu entre 7.500 i 9.999 passes al dia; actiu entre 10.000 i 12.499 passes al dia; i molt actiu ≥12.500 passes al dia (Tudor-Locke et al., 2011). Els mateixos autors consideren que per raons saludables i tenir un estil de vida actiu s'haurien de fer 10.000 passes diàries, el que consideren AF moderada (AFM).

Els acceleròmetres es consideren instruments de mesura d'AF i CS que detallen molt acuradament i precisa l'estil de vida d'un individu (Karas et al., 2019). No existeix un dispositiu d'accelerometria *gold standard* per determinar exactament els nivells d'AF i CS (Dishman et al., 2012). Per tant, els mètodes i instruments per avaluar ambdós comportaments poden variar en funció del tipus d'estudi i anàlisi que s'està realitzant. Actualment, hi ha molts estudis que utilitzen l'accelerometria (per exemple l'ActiGraph o l'Axivity) per avaluar l'AF i el CS (Crowley et al., 2019; Giné-Garriga et al., 2020; Liao et al., 2018; Rowlands et al., 2018). Un dels acceleròmetres més utilitzats és l'ActiGraph (ActiGraph LLC, Pensacola, FL, USA) (Aguilar-Farías et al., 2014).

Aquest dispositiu, així com també la gran majoria, es pot posar al maluc o al canell. A partir de l'acceleració de l'individu i per tant del dispositiu, podem obtenir dades com els nivells d'AF lleu (AFLL), AFM, AF vigorosa (AFV), AFMV, CS, número de passes, entre moltes altres variables. Totes aquestes dades variaran en funció de la metodologia emprada utilitzant el *software ActiLife*. Migueles i els seus col·laboradors (2017), diferencien la metodologia de l'acceleròmetre

ActiGraph amb dos categories: (1) els protocols de recollida de dades, és a dir, les decisions que s'han de prendre prèviament com ara la col·locació dels dispositius a les persones analitzades o bé la freqüència de mostreig[5]; i (2) els criteris de processament de les dades, les decisions que es poden prendre a posteriori com ara els filtres, finestra de temps de mesura, definició de *non-wear time*[6], *cut-points* o punts de tall; i als algoritmes (Migueles et al., 2017). Un exemple de *cut-points* que hem utilitzat en els estudis amb dades d'aquest acceleròmetre han estat els que proposaren Troiano i els seus col·laboradors (Troiano et al., 2008). Les intensitats de l'activitat registrada es va calcular de la següent manera: el CS es considerava amb <100 *Counts Per Minute*[7] (CPM); l'AFLL entre 100 i 2019 CPM; i l'AFMV amb ≥2020 CPM. Segons estudis anteriors, per a què les dades es considerin vàlides, els individus han de dur el dispositiu durant 4 dies, entre els quals almenys 1 ha de ser cap de setmana (Ricardo et al., 2020).

Com hem avançat anteriorment, una de les limitacions d'aquests dispositius a l'hora d'avaluar l'AF i el CS és que s'ha de tenir un coneixement del *software* per poder tractar i analitzar les dades. Així mateix, una altra limitació a l'hora d'avaluar el CS és que l'ActiGraph no distingeix entre postures, és a dir, si l'individu està de peu o assegut/da i/o estirat/da doncs només disposa d'un acceleròmetre. I per últim, cal dir que aquests dispositius no es poden submergir a l'aigua. Per tant, perdem el registre d'activitats al medi aquàtic com la natació o

[5] La freqüència de mostreig en aquests dispositius pot variar d'entre 30 a 100 Hertz.

[6] Es refereix a la definició de l'estona que l'individu no duu el dispositiu posat.

[7] *Count Per Minute* és la unitat de mesura de l'activitat dels dispositius ActiGraph. Per obtenir aquesta mesura es té en compte el desplaçament, la velocitat i l'acceleració.

l'aiguagim. És per això, la importància d'utilitzar també els inclinòmetres.

Els inclinòmetres son els aparells que ens permeten detectar el canvi de postures de l'individu estudiat. L'aparell diferencia entre estar assegut o estirat, dempeus o bé en moviment. Actualment, els inclinòmetres més actuals també disposen d'acceleròmetre i per tant també poden detectar els nivells d'AF. Així com també, els acceleròmetres cada cop més s'estan utilitzant per registrar el CS (Júdice et al., 2019). Un dels inclinòmetres més utilitzats per estudiar el CS és l'ActivPAL (PAL technologies, Glasgow, Scotland), considerat un dispositiu vàlid i fiable per registrar aquest comportament (Bourke et al., 2019; Dowd et al., 2012). Algunes de les dades que podem obtenir d'aquest dispositiu son el número de passes, transicions entre assegut i estirat, dempeus i caminant, nivells d'AF, estimació del tipus d'AF (caminar, córrer o anar en bicicleta), estimació del consum energètic (METs) i Kcal. Habitualment, aquest dispositiu s'enganxa aproximadament coincidint amb la meitat de la cuixa, entre la cresta ilíaca anterior i la part superior de la ròtula, mitjançant un tipus de plàstic *film* transparent i impermeable (Sansano-Nadal et al., 2021). D'aquesta manera, a diferència de l'ActiGraph, el dispositiu no s'ha de treure i posar durant el dia i també enregistra les activitats al medi aquàtic.

Alguna de les limitacions d'aquest dispositiu, és que a l'igual que l'acceleròmetre ActiGraph, també disposa d'un *software* per poder tractar i analitzar les dades (PAL Software Suite version 8) i s'ha de tenir un coneixement previ a l'hora de programar, descarregar i analitzar les dades del dispositiu. Per altra banda, un estudi recent recomana precaució a l'hora de mesurar protocols d'AF relativament més intensa, avaluar la quantitat de transferències posturals o durant l'anàlisi del CS, ja que no es registren correctament alguns episodis sedentaris de curta durada i no es contemplen les transferències posturals (Bourke et al., 2019).

És important tenir en compte quins instruments de mesura hem d'utilitzar en funció del nostre objectiu d'estudi i quina ha de ser la metodologia que hem d'emprar. També s'ha de tenir en compte, que utilitzant instruments subjectius en persones grans, aquestes tendeixen a infravalorar els seus nivells en CS i a la vegada a sobrevalorar els nivells d'AF (Celis-Morales et al., 2012). Per tant, la relació d'ambdós comportaments amb els indicadors de salut es poden veure esbiaixats. És recomanable doncs, utilitzar simultàniament instruments de mesura d'AF i CS objectius, però també subjectius com els qüestionaris que ens permeten avaluar qualitativament els dominis específics del temps en ambdós comportaments (Sansano-Nadal et al., 2021).

Estratègies de canvi de comportament

Les intervencions per incrementar els nivells d'AF i reduir el CS mostren millores significatives en relació a la QVRS de la gent gran (Duda et al., 2014). Tot i això, estudis recents mostren que aquests beneficis difícilment es mantenen a llarg termini un cop s'acaba la intervenció (Gomes et al., 2017; Sansano-Nadal et al., 2019). En aquest sentit, hi ha directrius que recomanen l'ús de tècniques de canvi de comportament (TCC) per promoure l'augment dels nivells d'AF i reduir el CS (Martín-Borràs et al., 2018; Williams et al., 2007). Les TCC inclouen processos de canvi tant cognitiu com conductual, i s'associen a un augment dels efectes en les intervencions de canvi de comportament (Michie et al., 2009). Alguna de les teories més utilitzades per als canvis de comportament relacionats amb la salut son les teories psicològiques, com el model transteòric de Prochaska i Di Clemente (Prochaska & DiClemente, 1983) o la teoria social cognitiva (TSC) de Bandura (Bandura, 2001). Entre aquestes TCC, les EACC poden millorar amb èxit la pràctica d'AF en poblacions específiques, augmentant els nivells d'AF diària, millorant la QVRS i la salut mental i també produir una major confiança (Nour et al., 2006). Hi ha estudis recents, entre ells el projecte SITLESS (Giné-Garriga et al., 2017), dirigits a la reducció del CS en persones grans que han inclòs les EACC com la fixació d'objectius, seguiment i instruccions sobre com tenir un estil de vida actiu, l'autocontrol i la retroalimentació pel que fa al comportament (Baxter et al., 2016; Gardner et al., 2016; Matei et al., 2015). Alguns d'aquests estudis, mostren evidència de qualitat moderada on s'indica que les intervencions específiques tenen l'efecte suficient per reduir el CS en les persones grans (Baxter et al., 2016). A dia d'avui, manquen estudis que hagin avaluat els efectes d'una intervenció basada en AF i reforçada mitjançant EACC tant per augmentar els nivells d'AF com per reduir el CS en gent gran.

Gent gran

Envelliment poblacional, qualitat de vida i la seva relació amb l'activitat física i el comportament sedentari

Si bé és cert que les primeres quatre o cinc dècades de vida estan ben definides, el procés d'envelliment no té una definició ni temporalitat clara. Un dels principals motius és que l'envelliment es pot considerar de moltes maneres: segons els canvis socials, conductuals, fisiològics, morfològics, cel·lulars i moleculars (Balcombe & Sinclair, 2001).

Segons Balcombe i Sinclair (2001), l'envelliment es pot mesurar o categoritzar en funció de tres aspectes: l'edat cronològica, l'edat biològica i l'èxit de l'envelliment (Balcombe & Sinclair, 2001) (Taula 1).

Taula 1. Definició d'envelliment (adaptada de Balcombe i Sinclair, 2001).

Edat cronològica
Pas del temps des del naixement
És fàcil de mesurar
Augment de les taxes de mortalitat específiques per edats
Determinar la gent gran a partir de la jubilació

Edat biològica
Presència o absència de malaltia física, deteriorament funcional o cognitiu
Augment de la incidència de malalties cròniques a la vida tardana
Presència d'afeccions associades a l'edat
Millor marcador d'estat de salut que l'edat cronològica
Èxit de l'envelliment
Variabilitat en el procés d'envelliment
La vellesa ofereix l'oportunitat de canvis positius, novetats
Model mèdic ± compressió de morbiditat, absència de malaltia física i deteriorament funcional
Model social ± capacitat d'adaptació als canvis de la societat per mantenir el paper i l'estatus
Model psicològic ± manteniment de la competència mental i del benestar

Jayanthi i els seus col·laboradors (2010) expliquen la diferència entre senescència i envelliment. Son dos conceptes que estan molt relacionats i sovint s'utilitzen indistintament ja que ambdós es caracteritzen per canvis progressius en el teixit del cos, provocant una disminució de la funció i finalment provoquen la mort de l'organisme. El terme senescència es refereix a un procés post-maduratiu que provoca una disminució de l'homeòstasi i augmenta la vulnerabilitat de l'organisme fins arribar a la mort. En canvi, l'envelliment es refereix a qualsevol procés relacionat amb el temps i és un procés continu que comença des de la concepció i continua fins a la mort (Jayanthi et al., 2010).

L'OMS també defineix l'envelliment i ho fa a nivell biològic. El defineix com *"el resultat de l'impacte de l'acumulació d'una gran varietat de danys moleculars i cel·lulars al llarg del temps"*. Això, *"condueix a una disminució gradual de la capacitat física i mental, un risc creixent de malalties i, finalment, de mort"* (World Health Organization, 2011).

D'acord amb les definicions exposades anteriorment, i també amb les afirmacions de la majoria de gerontòlegs, queda clar que el procés d'envelliment humà és molt complex i individualitzat, i també que hi ha moltes variables implicades tant de l'àmbit biològic, psicològic com social (Dziechciaz & Filip, 2014).

Actualment, tant el número com la proporció de persones de 60 anys o més està augmentant (World Health Organization, 2011). Segons la mateixa organització, l'any 2030 una de cada sis persones al món tindrà 60 anys o més. Actualment, la població mundial de ≥60 anys és d'aproximadament 707 milions de persones (Gabinet d'Estudis Socials i Opinió Pública, 2020). L'OMS estima que l'any 2050 la població mundial de persones ≥60 anys es duplicarà, arribant a 2.100 milions de persones; i a més aquelles persones de 80 anys o més es triplicarà entre el 2020 i el 2050 arribant als 426 milions aproximadament (World Health Organization, 2011). Pel que fa a la classificació del moment en què un individu es considera una persona adulta difereix entre dos de les organitzacions amb més renom i influència a nivell mundial pel que fa a la salut. L'OMS considera un individu una persona gran a partir dels 65 anys, moment que habitualment coincideix amb la jubilació. En canvi, les Nacions Unides (NU) consideren les persones grans a partir de 60 anys. Aquesta variació de 5 anys l'entenem com la diferència entre l'envelliment o l'edat biològic/a i cronològic/a.

Havent comentat que l'envelliment son els canvis progressius en el teixit del cos provocant una disminució de la funció i que finalment comporta la mort de l'organisme, és obvi i inevitable que aquest procés, tant a nivell cronològic com biològic, no es pugui aturar. La diversitat que s'observa en el procés d'envelliment no és aleatòria. Hi ha aspectes no modificables com la família on vam nàixer, el sexe o l'ètnia que hi estan força implicades. En canvi, n'hi ha d'altres com els entorns físics i socials de les persones i l'impacte que aquests generen sobre les oportunitats i comportaments de salut, entre ells els estils de vida, que son modificables (Dahlgren & Whitehead, 2021).

Com a conseqüència del procés d'envelliment i per tant del deteriorament de tots els teixits de l'organisme, més enllà dels canvis antropomètrics, els sistemes com el cardiovascular, el respiratori i el múscul-esquelètic es veuen greument afectats. Amb el deteriorament d'aquests sistemes augmenta la fatigabilitat així com també la fragilitat de les persones grans, condicionant que augmenti el CS i es redueixin els nivells d'AF d'aquesta població. Fried i els seus col·laboradors (2001) defineixen la fragilitat com un síndrome biològic resultat de la disminució generalitzada de diversos sistemes fisiològics i causant vulnerabilitat a resultats adversos. Els mateixos autors distingeixen el concepte de fragilitat de la discapacitat i inclouen entre els marcadors de fragilitat les disminucions associades a l'edat de la massa corporal magra, la força, la resistència, l'equilibri, el rendiment per caminar, i els nivells baixos d'AF (Fried et al., 2001). És així com aquest canvi en l'estil de vida degut al deteriorament de l'organisme desencadena en una major dependència i condiciona, per tant, una càrrega per a la societat. En el moment que es comencen a apreciar aquests canvis en l'organisme degut a l'envelliment, la QV d'aquestes persones també es veu afectada.

És cert que hi ha molts paràmetres que es poden quantificar objectivament per valorar l'estat de salut de les persones com per exemple l'absència o no de malaltia. En canvi, la QV engloba diverses dimensions les quals s´han de valorar subjectivament pel propi individu. De fet, l'OMS defineix la QV com *"les percepcions dels individus sobre la seva posició a la vida en el context cultural i els sistemes de valors en què viuen, en relació amb els seus objectius, expectatives, estàndards i preocupacions"* (World Health Organization, 1998). Tot i el punt de dificultat que hi ha per valorar la QV, en les darreres dècades ha estat un indicador molt utilitzat per quantificar l'estat de salut de les persones (De Rezende et al., 2014; Wardoku et al., 2019).

Un altre concepte el qual és necessari definir, és la QVRS. A la literatura científica es poden identificar diverses definicions d'aquest concepte (Karimi & Brazier, 2016). Nosaltres ens quedem amb la definició de Hays i Reeve (2010), doncs creiem que és la que millor encaixa amb el concepte de salut holística actual. Defineixen la QVRS com *"el funcionament d'una persona en la seva vida i el seu benestar percebut en els dominis físics, mentals i socials de la salut"* (Hays & Reeve, 2010).

Havent explicat els canvis en l'organisme degut al procés d'envelliment, diversos estudis conclouen que aquest està altament associat amb la percepció de la QVRS de les persones grans (Choi et al., 2017; Machón et al., 2017). Manchón i els seus col·laboradors (2017) estudien la relació de marcadors de l'estat de salut associats al procés d'envelliment, com les malalties cròniques i l'augment de la medicació ($p < 0.0001$), la depressió ($p < 0.0001$) i el deteriorament sensorial ($p = 0.001$), i conclouen que aquestes persones majors de 65 anys tenien una pitjor percepció de la seva QVRS respecte a aquells que no estaven diagnosticats d'aquests marcadors de salut. Altres marcadors de l'estat de salut com la pràctica d'AF, la qualitat del son i l'alimentació també s'associaven positivament ($p \leq 0.005$) amb una millor percepció de la QVRS (Machón et al., 2017). A més a més, variables de la dimensió social com la participació a activitats lúdiques, per exemple tallers d'estimulació cognitiva ($p \leq 0.05$) o activitats en grup ($p \leq 0.05$), també s'associaven positivament amb una millor QVRS (Machón et al., 2017). Per tant, a mesura que envellim i van apareixent tots aquests canvis en l'organisme, la percepció de la QVRS empitjora, però hi ha aspectes modificables, entre ells la realització d'AF, que poden contribuir a millorar-la.

A l'hora d'avaluar la QVRS, els instruments utilitzats son els qüestionaris degut al caràcter subjectiu d'aquesta variable. Quan utilitzem aquests instruments és important ser conscients de les seves limitacions, així com també tenir en compte la seva validació i fiabilitat. Dos dels qüestionaris més utilitzats i validats per avaluar la QVRS a nivell genèric[8] son l'Euro-QoL (EQ-5D) (Herdman et al., 2001) i l'SF-36 (Vilagut et al., 2005) amb la versió reduïda SF-12 (Ware et al., 1996).

Seguidament detallarem les dimensions de l'SF-36 així com també de l'SF-12, doncs aquest segon ha estat l'instrument utilitzat per avaluar la QVRS en el tercer estudi d'aquesta tesi doctoral. El qüestionari SF-36 consta de 36 preguntes que avaluen 8 dimensions: funció física, rol físic, dolor corporal, salut general, vitalitat, funció social, rol emocional, i salut mental. Aquestes dimensions representen els conceptes de salut utilitzats amb més freqüència en els principals qüestionaris de salut, així com també els aspectes més relacionats amb les malalties i els tractaments (Vilagut et al., 2005). D'aquest qüestionari se'n deriva la seva versió reduïda, l'SF-12. Aquest qüestionari consta de 12 ítems i també s'avaluen 8 dimensions: funció física, limitacions de rol degudes a problemes de salut, dolor corporal, salut general, vitalitat, funció social, salut mental, i limitacions de rol degut a problemes emocionals. Amb la puntuació d'aquestes 8 dimensions se'n poden extreure dos components: l'estat de la salut física i també de la salut mental. Aquests dos components (*physical component score* (PCS) i *mental components score* (MCS)) son en els que ens hem centrat al tercer estudi d'aquesta tesi doctoral.

Per a mantenir un bon estat de salut durant el procés d'envelliment és important mantenir un estil de vida actiu o tenir un envelliment saludable. Com ja hem comentat anteriorment, el procés

[8] Hi ha qüestionaris per avaluar la QVRS de la població general de caràcter genèric; i també n'hi ha d'altres específics per avaluar la QVRS en població específica i/o variables específiques (per exemple: el dolor o la funció sexual).

d'envelliment no el podem aturar i per tant ens hem de centrar en aquells aspectes i/o comportaments que poden modificar-lo o influenciar-hi. L'envelliment saludable o actiu és el procés d'optimitzar les oportunitats per a la salut, la participació i la seguretat amb l'objectiu per millorar la QV de les persones a mesura que envelleixen (World Health Organization, 2002). És per això que el nivell d'AF i CS juguen un paper determinant en l'envelliment actiu o també amb el que en la literatura científica es coneix com a envelliment amb èxit (*successful ageing*). Alguns estudis recents, entre ells una RS amb meta-anàlisi (Yi-Hsuan et al., 2020), conclouen que el nivell d'AF de la gent gran que viu a la comunitat pot ser essencial per mantenir un envelliment amb èxit i per tant una bona QVRS (Choi et al., 2017). En una altra RS amb meta-anàlisi recent, els autors expliquen que la relació de la inactivitat física s'associa negativament amb la QVRS en persones grans (Cunningham et al., 2020). Amb aquests exemples pel que fa a la importància de l'AF, entenem la importància d'assolir les recomanacions actuals d'AF per tenir una millor QVRS a mesura que envellim. Pel que fa al CS, Kim i Lee (2019) mostren l'associació entre els nivells més elevats de CS amb una pitjor QVRS i viceversa. Aquelles persones grans que passen menys temps al dia en CS reportaven una millor QVRS (Kim & Lee, 2019). A més, en aquest mateix estudi comparaven entre persones grans de 65 a 74 anys i aquelles persones de 75 anys o més. Van concloure que a major edat cronològica, pitjor QVRS (Kim & Lee, 2019).

L'augment de l'esperança de vida és pot considerar un èxit per a la societat però al mateix temps també és un repte. Els professionals de la salut pública i també la societat en general, han d'abordar aquestes evidències en els canvis de l'estat de salut de les persones grans tenint en compte les polítiques i les oportunitats per garantir que aquesta població pugui tenir un envelliment saludable i, per tant, un bon estat de salut.

En aquest sentit, l'Assemblea General de les NU va declarar el període d'anys entre 2021-2030 com *la Dècada de l'Envelliment Saludable*, liderada per l'OMS i donant suport a l'Agenda 2030 de les NU sobre desenvolupament sostenible i els objectius de desenvolupament sostenible (ODS). *La Dècada de l'Envelliment Saludable* és una col·laboració mundial entre diversos governs, societat civil, agències internacionals, professionals, acadèmics i altres organitzacions i entitats per treballar conjuntament en una mateixa direcció amb l'objectiu d'afavorir vides més llargues i saludables.

L'activitat física i el comportament sedentari en la gent gran

En els capítols anteriors hem explicat detalladament com es defineixen els conceptes d'AF i CS, així com també els efectes d'ambdós comportaments sobre la salut i la QVRS de la gent gran, i la seva relació amb l'envelliment de la població. A continuació, ens centrarem tant amb els nivells d'AF com els de CS de la gent gran. Tal i com hem avançat, degut al procés d'envelliment, aquest segment poblacional és el que menys AF duu a terme i també el que més temps passa en CS (European Commission, 2018).

En les últimes dècades i donada la rellevància d'aquests comportaments com a indicadors de l'estat de salut de la població, hi ha molts estudis que els avaluen. A continuació detallarem els nivells que s'han publicat en la literatura científica recent amb aquesta població.

Els nivells d'AF avaluats mitjançant l'accelerometria son les dades més precises que podem trobar en la literatura. Berkemeyer i els seus col·laboradors (2016) van estudiar els nivells d'AF de la gent gran del Regne Unit i Estats Units a partir de la mostra utilitzada als estudis EPIC-Norfolck (Atienza et al., 2011) i *National Health and Nutrition Examination Survey* (NHANES) (Hayat et al., 2014), respectivament. Pel que fa a la població britànica (n = 4052; edat mitjana = 69.0 anys) van mostrar que només un 4.1% de la població complia amb les recomanacions d'AF de 30 minuts al dia d'AFMV segons l'OMS utilitzant ≥2020 CPM com a *cut-point*. En canvi, reduint aquest *cut-point* a >809 CPM, el que ja consideraríem AFLL, el percentatge de persones grans que complien amb les recomanacions de l'OMS era del 18.7% (Berkemeyer et al., 2016). Quant a la població americana (n = 3549; <40 anys), utilitzant els mateixos *cut-point* (≥2020 CPM i >809 CPM) només un 2.5% i un 9.5%, respectivament, complien amb els 30 minuts al dia d'AFMV (Berkemeyer et al., 2016). En aquests estudis la mostra es considerava població general però els nivells d'AF es reduïen significativament quan les persones grans tenien algun tipus de limitació física. Pahor i els seus col·laboradors (2014) estudiaren una mostra de 1635 subjectes d'entre 70 i 89 anys amb alguna d'aquestes limitacions (puntuació ≤9 a l'*Short Physical Performance Battery* (SPPB) i capaços de caminar 400 metres) i van mostrar uns nivells d'AFM de 28.3 minuts al dia (*cut-point* de 760 CPM) (Pahor et al., 2014). Un altre estudi que utilitzà l'ActivPAL3 (inclinòmetre i acceleròmetre) per avaluar 656 subjectes (≥66 anys) va concloure que hi havia diferències en els nivells d'AFLL entre homes i dones. Els investigadors van afegir també que els nivells d'AFMV es reduïen a mesura que la població era més gran així com també en aquelles persones obeses o amb limitacions físiques i/o funcionals (Dohrn et al., 2020). Les dades d'aquest estudi objectiven que la gran majoria dels participants ≥80 anys no compleixen les recomanacions d'AF. Centrant-nos amb les dades de 1360 subjectes (≥65 anys) del projecte SITLESS, aquests mostraren una mitjana de 2.6% de les hores que estaven desperts fent AFMV (Giné-Garriga et al., 2020). Aquest percentatge equival a uns 17.3 minuts al dia tenint en compte que la mitjana d'hores al dia que van portar el dispositiu ActiGraph va ser de 14.4. Per tant, com hem observat a la majoria d'estudis que avaluen els nivells d'AF de la gent gran, generalment aquesta població no compleix amb les recomanacions d'AF segons l'OMS.

Pel que fa al CS, Harvey i els seus col·laboradors (2015) reportaven en una RS on es van incloure 22 estudis amb una mostra total de 349.689 persones grans (≥60 anys), que aquests individus estaven una mitjana de 9.4 hores al dia en CS avaluat mitjançant accelerometria (Harvey et al., 2015). És a dir, entre un 65% i 80% de les hores del dia que estaven desperts les passaven asseguts o estirats. Pel que fa a les mesures auto-reportades o subjectives de la mateixa població, la mitjana d'hores al dia en CS era bastant inferior (5.3 hores al dia). En un altre estudi recent on es va avaluar el temps en CS de 439 subjectes (mitjana d'edat de 71.6 anys) mitjançant l'acceleròmetre ActiGraph, els subjectes passaven una mitjana de 10 hores al dia en CS (Vanderlinden et al., 2020). En dades de l'estudi SITLESS, Giné-Garriga i els seus col·laboradors (2020) publicaren els nivells de CS de les 1360 persones grans avaluades mitjançant accelerometria i mostraren uns nivells del 78.8% de les hores del dia que estaven desperts en CS (Giné-Garriga et al., 2020). Aquest percentatge equivaldria a unes 11 hores al dia aproximadament. Per últim, en el segon estudi d'aquesta tesi s'utilitzà una submostra de l'estudi SITLESS de 801 participants per avaluar el CS mitjançant l'ActivPAL i l'Axivity (Sansano-Nadal et al., 2021). La mitjana de temps en CS d'aquesta submostra amb aquests dos dispositius va ser de 9.1 hores al dia.

En aquest capítol referent als nivells d'AF i CS de la gent gran, podem entendre millor la necessitat d'avaluar i intentar modificar aquests comportaments en la gent gran doncs els nivells son alarmants, tant pel que fa a la manca d'AF com als excessos en CS, i també de rellevant importància per a combatre les conseqüències sòcio-econòmiques que se'n deriven a nivell de salut en la societat actual, i de manera específica en la QV d'aquesta població.

Intervencions d'activitat física i comportament sedentari en la gent gran

D'ençà a finals del segle XX, el disseny d'intervencions per augmentar el nivell d'AF i reduir el CS de la gent gran ha esdevingut un dels objectius principals tant per als professionals de salut, educadors físics com també polítics degut a què els beneficis que aporten a la societat, prèviament explicats, estan més que justificats. Els *exercise referral schemes (ERS)* o sistemes de derivació de pacients son un dels mecanismes més utilitzats en la promoció de l'AF des dels serveis de salut (habitualment els CAPs) cap a serveis de la comunitat (centres esportius, casals de gent gran, centres de dia, centres ocupacionals) (Martín-Borràs et al., 2018). Aquesta derivació pel que fa a la promoció de l'AF, habitualment es fa des dels professionals de la salut (metges/ses de família, infermers/es, fisioterapeutes, etc.) cap a un centre esportiu o directament cap als professionals de l'AF per prescriure i dur a terme un programa d'AF estructurat (Shore et al., 2019). En aquest capítol, explicarem algunes de les intervencions per a la gent gran que s'han dut a terme recentment a la comunitat, detallant la intervenció del projecte SITLESS.

La intervenció del projecte SITLESS i altres intervencions

El projecte SITLESS, com ja hem comentat en els capítols anteriors, és el fil conductor d'aquesta tesi doctoral. L'objectiu d'aquest projecte és promoure un estil de vida actiu entre la gent gran de diferents països europeus (Giné-Garriga et al., 2017). El disseny d'aquest estudi ha estat un ACA multicèntric amb una fase experimental de tres branques. En aquest estudi hi han participat un total de 1360 persones grans que van ser reclutades majoritàriament a través dels CAPs a les ciutats de Barcelona (Catalunya) (n = 356), Odense (Dinamarca) (n = 338), Ulm (Alemany) (n = 345) i Belfast (Regne Unit) (n = 321).

Els criteris d'inclusió dels participants van ser: (1) tenir ≥65 anys; (2) viure a la comunitat; (3) ser capaç de caminar sense l'ajuda d'un instrument o d'una altra persona durant almenys 2 minuts; (4) no tenir limitacions físiques (puntuació ≥4 avaluades amb l'SPPB); (5) ser insuficientment actiu/va responent a la pregunta "Practiques AF regularment durant almenys 30 minuts, 5 o més dies a la setmana?"; i/o (6) reportar passar estones llargues en CS responent a la pregunta "La majoria de dies, creus que passes assegut/da massa estona (≥6-8 hores al dia)?" (exemples: mirant la televisió, treballant a l'ordinador o realitzant altres hobbies assegut/da). Els participants van ser exclosos si: (1) tenien demència moderada o severa (≥3 errors avaluada amb el *six-item screener* per identificar deteriorament cognitiu); (2) prescripció de medicació que pogués interferir en el disseny de l'estudi; (3) condicions mèdiques inestables (per exemple augment de la tensió arterial per ús de medicació, tenir una hipertensió descontrolada, o alguna malaltia o simptomatologia cardiovascular amb contraindicacions per a la pràctica d'AF); (4) no poder assistir a un 75% de les sessions durant la intervenció; i/o (5) haver participat en algun programa d'AF a través de sistemes de derivació de pacients o *ERS* en els darrers sis mesos.

Tots els participants inclosos a l'estudi, havent signat el consentiment informat (CI) prèviament, doncs la participació era voluntària, van ser avaluats i aleatoritzats en una de les tres branques experimentals.

Aquest tipus d'intervenció és considerada una intervenció complexa ja que hi intervenen diversos components que interactuen durant les dues fases experimentals i de control. També hi ha altres característiques rellevants com el nombre de components requerits per als participants, el nombre de grups a nivell organitzatiu, el nombre de variables i resultats, i també, el grau de flexibilitat permesa en la intervenció (Craig et al., 2008).

D'aquestes tres branques, començarem explicant el grup control (GC), doncs és la fase més senzilla. Havent aleatoritzat tots els participants, aquells que formaven part del GC (n = 458), van tenir dues reunions als seus CAPs de referència amb l'instructor d'AF (graduat en CAFE i/o fisioterapeuta) (Figura 1). Els temes tractats eren els estils de vida saludables, les recomanacions per a la pràctica d'AF segons l'OMS, així com també se'ls va donar un informe dels resultats de les avaluacions basals. Aquestes trobades es van dur a terme a la setmana 5 i a la 11 des de l'inici de la intervenció en aquell centre. Un cop els altres dos grups experimentals van acabar la intervenció, els subjectes del GC van ser citats de nou per dur a terme les avaluacions de seguiment.

La intervenció d'AF la van dur a terme 447 participants i va tenir una durada de 16 setmanes amb dos sessions setmanals d'entre 45 i 60 minuts cada sessió (Figura 1). A més a més, se li demanava al participant afegir una tercera sessió individual de treball aeròbic com caminar 30 minuts. En funció del lloc d'intervenció, les sessions es duien a terme a l'interior (als CAPs, centres municipals, gimnasos, casals de gent gran) o també a l'exterior (habitualment als parcs o jardins propers als centres d'intervenció). Els components bàsics de les sessions eren el treball aeròbic, el treball de força i resistència, així com també el d'equilibri amb exercicis funcionals i de flexibilitat a partir d'estiraments i control de la respiració. Quant a l'estructura de les sessions, es començava amb 5-10 minuts d'escalfament basat amb la interacció social i mobilitat articular; seguida de 35 minuts com a part principal de la sessió on cada dia es treballava un o més dels components comentats anteriorment de manera adaptada a la condició física i el nivell funcional de cada participant; i finalment, la tornada a la calma amb uns 5-10 minuts d'estiraments i exercicis de respiració. La progressió d'aquestes 32 sessions es basava amb la durada (temps) i la intensitat (utilitzant l'escala de Borg[9]) així com també el volum (sèries i repeticions de cada exercici). El material emprat en aquestes sessions podia variar en funció de la disponibilitat de cada centre d'intervenció. Als centres d'intervenció de Barcelona la majoria de les intervencions es van fer a l'aire lliure, s'utilitzaren els banquets i les escales dels parcs, material reciclat com ampolles d'aigua o sacs de sorra o arròs, i també disposaren de gomes elàstiques. Altres centres disposaven de material de gimnàs com peses, cicloergòmetres i plataformes inestables. En tot cas, tot i la variabilitat del tipus d'exercicis i els materials utilitzats, en totes les seus d'intervenció l'objectiu principal era l'adaptació del treball a les característiques dels participants, així com també buscar exercicis el més funcionals possible.

Quant a la intervenció d'AF juntament amb EACC, la van dur a terme 455 participants. La intervenció d'AF va ser exactament la mateixa que va realitzar l'altre grup experimental (32 sessions d'AF). El procés del disseny de la intervenció d'EACC per reduir el CS va ser complex. Es va iniciar amb una RS per identificar les TCC més utilitzades en aquest tipus d'intervencions, particularment les que es basaven amb la TSC (Bandura, 2001). Havent escollit i dissenyat un primer esborrany de la intervenció d'EACC per reduir el CS, es van dur a terme diversos focus grup amb gent gran de les diferents seus d'intervenció per obtenir un *feedback* de la població a la qual aniria dirigida la intervenció. Per

[9] L'Escala de Borg es basa amb la percepció de l'esforç i ens permet identificar la intensitat de l'esforç en funció de la sensació d'exigència o dificultat que percebem. La primera versió d'aquest instrument anava del 0 (sensació de repòs total) al 20 (sensació d'esforç màxim). Aquesta escala va ser simplificada del 0 al 10 mantenint els mateixos nivells d'esforç percebut (Borg, 1970).

últim, la intervenció es va testar a cadascun dels quatre països amb una submostra per valorar la seva viabilitat abans de dur a terme la intervenció final. Es va dissenyar el material necessari per a dur-la a terme i també es va formar als instructors que se n'havien d'encarregar.

Les sessions i seguiment d'aquesta intervenció es van realitzar de manera presencial i també mitjançant trucades telefòniques individuals, l'estructura de les quals es basava amb les TCC (Michie et al., 2013) (Figura 1). La intervenció d'EACC constava d'11 sessions dividides en tres etapes: (1) etapa de familiarització; (2) etapa d'aproximació i manteniment; i (3) etapa d'adherència. La primera sessió (etapa de familiarització) es realitzava de manera individual just abans de començar les sessions d'AF grupals; a mesura que anava avançant la intervenció hi havia 6 sessions grupals als centres d'intervenció (etapa d'aproximació i manteniment); i finalment hi havia 4 trucades telefòniques (etapa d'adherència) per oferir suport addicional al participant i saber com s'estaven duent a terme les EACC.

A la sessió individual o entrevista (etapa de familiarització) d'una durada de 50 a 60 minuts, els objectius principals eren presentar la intervenció d'EACC i el material que s'utilitzaria així com també iniciar una relació entre participant i instructor. Al participant se li entregava un full informatiu amb detalls sobre el CS i també algunes estratègies per ser menys sedentari i més actiu (Consells SITLESS[10]). També se li entregava un podòmetre Yamax DigiWalker SW-200 per portar durant

[10] Els consells *SITLESS* eren consells per ajudar als participants a reduir el seu CS en diferents situacions com el temps davant les pantalles, activitats domèstiques, etc. (veure l'annex 1; pàgina 281)

tota la intervenció amb les instruccions corresponents juntament amb un diari d'activitat per controlar i anotar el número de passes diàries i/o temps d'AF setmanal i poder anar modificant l'objectiu de passos diaris o setmanals. Finalment, el participant, assessorat per l'instructor, establia uns objectius funcionals a llarg termini per aconseguir en els mesos posteriors a la finalització de la intervenció.

A partir de la setmana 3, es van dur a terme les 6 sessions grupals (etapa d'aproximació i manteniment) d'una durada de 45 a 60 minuts. Exactament, aquestes sessions es van realitzar la setmana 3, 4, 5, 7, 9 i 11 de la intervenció (Figura 1). Els objectius principals d'aquestes sessions eren compartir el recompte de passes dels participants de la setmana anterior i també modificar o mantenir els consells SITLESS acordats a les sessions anteriors. L'instructor animava al participant a augmentar gradualment el número de passes diàries a mesura que anava avançant la intervenció així com també anar afegint més consells SITLESS per reduir el CS. A més a més, a cada sessió s'abordava un tema específic més enllà dels objectius de passes i consells SITLESS, com la identificació de barreres i facilitadors sobre AF i CS al barri i en el context dels seus domicilis. En aquestes sessions s'utilitzava la tècnica de resolució de problemes a partir de la discussió entre tots els membres del grup. La intervenció d'EACC tenia l'objectiu de millorar i augmentar la motivació entre els participants a partir del suport social per reduir el CS i augmentar el nivell d'AF.

		AF	EACC	GC
Mes 1	**Setmana 1**		Entrevista individual	
	Setmana 2	2 Sessions grupals d'AF		
	Setmana 3	2 Sessions grupals d'AF	1a sessió grupal	
	Setmana 4	2 Sessions grupals d'AF	2a sessió grupal	
Mes 2	**Setmana 5**	2 Sessions grupals d'AF	3a sessió grupal	Sessió grupal
	Setmana 6	2 Sessions grupals d'AF		
	Setmana 7	2 Sessions grupals d'AF	4a sessió grupal	
	Setmana 8	2 Sessions grupals d'AF		
Mes 3	**Setmana 9**	2 Sessions grupals d'AF	5a sessió grupal	
	Setmana 10	2 Sessions grupals d'AF		
	Setmana 11	2 Sessions grupals d'AF	6a sessió grupal	Sessió grupal
	Setmana 12	2 Sessions grupals d'AF		
Mes 4	**Setmana 13**	2 Sessions grupals d'AF		
	Setmana 14	2 Sessions grupals d'AF		
	Setmana 15	2 Sessions grupals d'AF	1a trucada telefònica	
	Setmana 16	2 Sessions grupals d'AF		
Mes 5	**Setmana 17**	2 Sessions grupals d'AF		
		[.....]		
	Setmana 20		2a trucada telefònica	
Mes 7	**Setmana 25**		3a trucada telefònica	
Mes 8	**Setmana 30**		4a trucada telefònica	

Figura 1. Esquema de la intervenció SITLESS.

Com hem comentat anteriorment, a dia d'avui també s'han realitzat moltes altres intervencions d'AF i CS per millorar la QVRS així com també altres components relacionats directament amb alguna malaltia associada a l'envelliment.

Una RS d'intervencions d'AF per persones grans amb sarcopènia (Vlietstra et al., 2018) ens mostra diversos exemples on les intervencions dels estudis inclosos tenien una durada d'entre 3 i 6 mesos (2-3 sessions per setmana; i aproximadament 45 minuts per sessió). Majoritàriament, les sessions es realitzaven de manera grupal realitzant un treball específic de força, resistència i equilibri, i en algun estudi també utilitzaven plataformes vibratòries. En algun estudi inclòs a la RS, les sessions es realitzaven individualment a casa dels participants. Un altre exemple de RS sobre intervencions d'AF és amb persones grans fràgils (Zhang et al., 2020). En aquest cas, els estudis inclosos tenien una durada d'entre 8 i 48 setmanes (3-5 sessions per setmana; i 45-60 minuts per sessió). Pel que fa al tipus de sessions, les que es realitzaven de manera grupal es duien a terme a centres esportius o espais adaptats per a la pràctica d'AF, i les que es realitzaven de manera individual es duien a terme a casa dels participants. El tipus d'AF també es basava amb el treball de força, resistència i equilibri. Relacionat amb la fragilitat, també hi ha intervencions d'AF basades en el treball d'equilibri per a la prevenció de caigudes amb una estructura molt similar als estudis inclosos en les RS comentades anteriorment (Thomas et al., 2019).

Aquestes intervencions incloses a les RS detallades anteriorment, tenien un objectiu concret en relació a la millora dels paràmetres de fragilitat, la prevenció de caigudes o la sarcopènia. Tot i això, també hi ha intervencions on l'objectiu principal és augmentar els nivells d'AF de la gent gran. Liu i els seus col·laboradors (2020), en una RS analitzaren l'efectivitat de les intervencions basades amb un monitor d'activitat (podòmetre o polsera d'activitat) per a millorar el nivell d'AF en persones grans amb nivells elevats de CS (Liu et al., 2020). En aquesta RS també estudiaren quines eren les TCC més utilitzades. En relació al monitor d'activitat aquestes TCC eren (1) establir objectius (de comportament i de resultat); (2) *feedback* del comportament i dels resultats; i (3) autocontrol; mentre que les més utilitzades en relació a l'instructor de la intervenció eren (4) utilitzar recursos realistes; (5) revisar el comportament i els objectius establerts; i (6) donar *feedback* al participant sobre el comportament i els resultats obtinguts a través del monitor d'activitat (Liu et al., 2020).

Tenint en compte l'avenç tecnològic a l'era actual, algunes intervencions per augmentar el nivell d'AF i reduir el CS utilitzen aplicacions mòbils (app) com a monitor d'activitat doncs la majoria de *smartphones* disposen d'un acceleròmetre. Yerrakalva i els seus col·laboradors (2019) publicaren una RS amb meta-anàlisi on s'estudiaren els efectes d'intervencions basades amb una app de salut per augmentar el nivell d'AF, reduir el CS i millorar la condició física de les persones grans (Yerrakalva et al., 2019). Tots els estudis inclosos en aquesta RS (6 ACA) avaluaven l'AF i el CS de manera objectiva mitjançant accelerometria o podòmetres. La durada de les intervencions variava entre 2 i 6 mesos. Els resultats principals, tenint en compte l'anàlisi quantitatiu a partir del meta-anàlisi (5 ACA), mostren que la utilització d'una app en intervencions de ≤3 mesos està associat a la reducció del CS, incrementa el número de passes (506 passes/dia) i també millora diferents components de la condició física (per exemple la capacitat aeròbica i la força) de les persones grans. Pel que fa a les intervencions de ≥6 mesos mostren un increment de 753 passes al dia. Quant a l'anàlisi qualitatiu tenint en compte el tipus de TCC que s'utilitzen i la freqüència d'utilització d'aquestes tècniques van ser l'establiment d'objectius (100%), l'autocontrol (80%), instruccions sobre estratègies per augmentar l'AF i reduir el CS (80%), recompensa social (80%), suport social (60%) i identificació de riscos (60%) (Yerrakalva et al., 2019).

Pel que fa a la promoció d'AF específicament, en una RS amb meta-anàlisi recent on s'inclogueren només estudis sobre intervencions per a la promoció d'AF identificaren un impacte significatiu en el nivell d'AF de la gent gran que viu a la comunitat (Grande et al., 2020). Entre el tipus d'intervencions incloses al meta-anàlisi hi havia sessions tant individuals com grupals, exercicis generals i terapèutics, programes educacionals, consells i *coaching* per part del professional d'AF, tècniques cognitives comportamentals, i *feedback* a partir de dispositius objectius de mesura d'AF (Grande et al., 2020).

L'any 2007 l'Agència de Salut Pública de Catalunya (ASPCAT) va iniciar el Pla d'Activitat Física, Esport i Salut (PAFES). Aquest projecte interdisciplinari, on hi havia involucrat el Departament de Salut i també la Secretaria General de l'Esport, tenia l'objectiu de promoure un estil de vida saludable, basat amb la pràctica d'AF, entre la població adulta a través dels CAPs. En aquesta línia, l'augment del nivell d'AF de la població adulta insuficientment activa i també sedentària a partir d'intervencions comunitàries era prioritari. Per facilitar informació d'hàbits saludables relacionats amb l'AF, es va formar els professionals sanitaris dels CAPs per poder aconsellar i prescriure AF a la població, per a fomentar alhora, la utilització d'equipaments esportius municipals i posar a les persones grans en mans dels professionals de l'AF (Gonzalez-Viana et al., 2018).

Centrant-nos únicament amb la reducció del CS, detallarem les conclusions d'una RS en què s'avalua quantitativament l'efecte (a partir d'un meta-anàlisi) de les intervencions per reduir el CS però també qualitativament per identificar les TCC més utilitzades. Un exemple n'és l'estudi de Chase i els seus col·laboradors (2020) on quasi bé totes les intervencions incloses es basaven amb la TSC (Chase et al., 2020). El tipus d'intervencions variaven quant al lloc i/o el contingut. La majoria es duien a terme en espais de la comunitat, centres clínics o de recerca, però en alguns estudis les intervencions s'havien dut a terme en el context dels seus domicilis. En aquestes intervencions es duia a terme una entrevista individual, seguida de sessions grupals d'AF o grups de discussió per aprendre diferents TCC. En tots els casos però, s'utilitzaven TCC com l'establiment d'objectius, programes d'AF individualitzats o registre del nivell d'AF a partir de podòmetres. Les recomanacions d'AF així com també altres consells d'estils de vida saludables es donaven als participants amb llibrets. Pel que fa a la durada, variava entre 8 i 12 setmanes. Amb el meta-anàlisi, els autors conclogueren que l'efecte d'aquestes intervencions per reduir el CS era moderat i que s'haurien d'utilitzar diverses TCC per encoratjar les persones grans a reduir el CS a partir de l'educació sobre el canvi de comportament, l'establiment d'objectius o la monitorització d'activitat i CS (Chase et al., 2020).

De la mateixa manera que la promoció d'AF es pot fer a través d'una app, hi ha intervencions recents en què s'utilitza el suport digital per reduir el CS. Les Intervencions Digitals de Canvi de Comportament (IDCC) poden ser a través d'una app o també des d'una plataforma digital i s'han utilitzat anteriorment en persones grans per programes de rehabilitació, adherència a la medicació, deixar de fumar, etc. i han tingut una gran acceptació per part d'aquesta població (Stockwell et al., 2019). Els mateixos autors lideraren una RS amb meta-anàlisi per avaluar l'eficàcia de les IDCC per a reduir el CS i mostraren una reducció de 58 minuts al dia de mitjana en el temps en CS. La duració d'aquestes intervencions era d'entre 6 i 52 setmanes (mitjana de 12 setmanes) i les 5 TCC més utilitzades en els estudis inclosos a la RS eren: (1) suport social; (2) afegir recursos a l'entorn; (3) instruccions sobre com gestionar-se el temps en CS; (4) registrar el temps en CS; i (5) *feedback* sobre el CS (Stockwell et al., 2019).

Com hem vist en aquest darrer exemple, el suport social és la TCC més utilitzada entre els 22 articles inclosos a l'estudi. Cal recordar que els elevats nivell de CS de les persones grans està associat al nivell d'aïllament social (Tully et al., 2019). Les persones grans amb un millor nivell de suport social tendeixen a realitzar més AF en el temps de lleure i habitualment va relacionat amb menys estona en CS, especialment si el suport social és a nivell familiar (Smith et al., 2017). Tenint en compte aquesta associació, és recomanable que les sessions d'intervencions amb l'objectiu de reduir el CS i augmentar el nivell d'AF es puguin realitzar de manera grupal doncs poden tenir un efecte més significatiu i també més adherència per part dels participants a l'exercici.

L'adherència a les intervencions d'activitat física i comportament sedentari

Una altra part important a l'hora d'avaluar els efectes de les intervencions per augmentar el nivell d'AF i reduir el CS és l'adherència de la gent gran a aquest tipus d'intervencions. L'adherència es defineix com "*fins a quin punt el comportament d'una persona, prendre medicaments, seguir una dieta i/o executar canvis d'estils de vida, correspon a les recomanacions acordades d'un proveïdor d'atenció mèdica en funció de la finalització, assistència, durada i intensitat mentre es sotmet a una determinada intervenció*" (World Health Organization, 2003). Tot i que es reconeix que l'adherència és polifacètica, quan es vol dissenyar una intervenció d'aquest tipus, és important incorporar les opinions de les persones grans sobre les necessitats i percepcions que els preocupen per millorar la sostenibilitat de la intervenció i l'adherència a llarg termini, millorar el suport social i la participació en el programa (Martín-Borràs et al., 2018).

Un concepte que s'utilitza per a mesurar l'adherència a una intervenció, ja sigui d'AF i CS o d'un altre tipus com pot ser l'adherència a un medicament o una dieta, és el compliment de les condicions establertes un cop accedeixes a participar en una intervenció. En la RS de Room i els seus col·laboradors (2017) s'identifiquen les variables més utilitzades per a mesurar l'adherència o compliment d'una intervenció així com també el manteniment d'aquesta adherència a llarg termini (Room et al., 2017). Aquestes variables son: (1) el percentatge de sessions que s'ha assistit o s'han realitzat (notes de l'instructor, si la intervenció és presencial; o diaris, si la intervenció no és supervisada); (2) auto-reportar el nivell d'AF (més o menys de 3 cops per setmana d'AFLL); (3) diaris d'AF auto-reportats; i (4) feedback d'un podòmetre per mesurar el nivell d'AF (Room et al., 2017).

Per mesurar l'adherència també s'utilitzen les etapes de canvi basades amb el model transteòric (MTT) de Prochaska i DiClemente

(Prochaska & DiClemente, 1983; Prochaska & Velicer, 1997). Aquest model és considerat un dels millors models que entén i prediu els canvis de conducta en l'adherència a l'AF. Es va començar a utilitzar en estudis per deixar de fumar (Prochaska & DiClemente, 1983), però actualment s'utilitza també en estudis per a la promoció d'estils de vida saludables (Jiménez-Zazo et al., 2020). El MTT es considera un model que explica el canvi de comportament com un procés dinàmic, d'una dimensió temporal, descrivint les etapes i processos com una seqüència mitjançant la qual l'individu progressa per adaptar-se a un comportament regular (Prochaska et al., 2015). En aquest model s'inclouen 5 dimensions o etapes: (1) precontemplació, (2) contemplació, (3) preparació per a l'acció, (4) acció, i (5) manteniment. Habitualment, també se n'inclou una sisena, (6) la recaiguda.

Taula 2. Descripció de cada dimensió o etapa del MTT segons la seva aplicabilitat a l'adherència a l'AF (adaptada de Jiménez-Zazo et al. 2020)

Etapes	**Descripció**
Precontemplació	Insuficientment actiu. No hi ha intenció de dur a terme AF regularment durant els propers 6 mesos.
Contemplació	Insuficientment actiu però té la intenció de dur a terme AF regularment en els propers 6 mesos.
Preparació per a l'acció	Es comença a comprometre's en dur a terme AF regularment.
Acció	S'ha establert un compromís per dur a terme AF regularment, però ho ha complit durant menys de 6 mesos.
Manteniment	S'ha mantingut el compromís de dur a terme AF regularment durant més de 6 mesos.

L'avaluació de l'adherència en aquest tipus d'intervencions ha estat estudiat en els últims anys (Morelhao et al., 2017; Zubala et al., 2017). Tot i això, manquen estudis de l'adherència d'intervencions d'AF a llarg termini, considerant llarg termini com a mínim 12 mesos havent finalitzat la intervenció. Per això, en el primer estudi d'aquesta tesi doctoral s'analitza l'adherència i el seu manteniment a llarg termini així com també quines son les TCC més utilitzades per aconseguir aquesta adherència (Sansano-Nadal et al., 2019). En aquesta RS, els resultats mostren com les intervencions d'AF incloses al meta-anàlisi comparades amb un GC no actiu, tenen un efecte poc rellevant en la millora del nivell d'AF. Aquest efecte augmenta lleugerament als 6 mesos però a partir d'aquest punt, s'intueix una tendència a la baixa amb el pas del temps. Tot i això, no hi ha resultats concloents als 12 mesos un cop finalitzades les intervencions (Martín-Borràs et al., 2018; Sansano-Nadal et al., 2019).

OBJECTIUS I HIPÒTESIS

Objectius

Havent revisat la literatura científica on s'ha estudiat l'AF i el CS en les persones grans, així com també el seu impacte sobre la salut d'aquesta població, i basant-nos amb les mancances que hi hem identificat, plantegem l'objectiu principal d'aquest treball.

L'objectiu principal d'aquesta tesi doctoral és investigar l'impacte que poden tenir l'AF i el CS, així com també les intervencions per modificar ambdós comportaments, en l'estat de salut de les persones grans.

Aquest objectiu principal l'hem dividit en tres objectius específics dels quals se n'han redactat tres estudis publicats a revistes científiques:

Estudi I

- Avaluar l'efecte de les intervencions basades en AF en l'augment dels nivells d'AF de les persones grans amb un període de seguiment mínim de sis mesos.

- Descriure les estratègies específiques implementades durant la intervenció per millorar l'adherència a l'AF de les persones grans de 65 anys o més que viuen a la comunitat.

Estudi II

- Avaluar la validesa del *Sedentary Behaviour Questionnaire* (SBQ) per mesurar el CS de les persones grans que viuen a la comunitat mitjançant l'accelerometria com a *gold standard* (prova de referència).

Estudi III

- Avaluar la relació entre l'AF i el CS auto-reportat i mesurat mitjançant accelerometria amb la QVRS de les persones grans residents a la comunitat de quatre països europeus.

Hipòtesis

Centrant-nos amb l'objectiu principal, la nostra hipòtesi de partida és que tant l'AF com el CS, així com també les intervencions per modificar aquests comportaments, tenen un impacte significatiu i rellevant en l'estat de salut de les persones grans que viuen a la comunitat.

Les hipòtesis específiques treballades a partir dels tres estudis científics son les següents:

Estudi I

- Les intervencions basades en AF tenen un efecte significatiu sobre la millora dels nivells d'AF de les persones grans, fins i tot 6 mesos o més després de la finalització de la intervenció.

- Les estratègies específiques més utilitzades per a millorar l'adherència a l'AF de les persones grans majors de 65 anys son aquelles que es basen amb la TSC de Bandura o el MTT de Prochaska i DiClemente.

Estudi II

- El *Sedentary Behaviour Questionnaire* (SBQ) és un instrument vàlid per a mesurar el CS de les persones grans que viuen a la comunitat.

Estudi III

- Hi ha una relació significativa entre l'AF i el CS auto-reportat i mesurat mitjançant l'accelerometria amb la QVRS de les persones grans residents a la comunitat dels quatre països europeus estudiats.

MATERIAL I MÈTODES

Estudi I

Sansano-Nadal, O., Giné-Garriga, M., Brach, J., Wert, D., Jerez-Roig, J., Guerra-Balic, M., Oviedo, G., Fortuño, J., Gómara-Toldrà, N., Soto-Bagaria, L., Pérez, L., Inzitari, M., Solà, I., Martin-Borràs, C., & Roqué, M. (2019). Exercise-based interventions to enhance long-term sustainability of physical activity in older adults: A systematic review and meta-analysis of randomized clinical trials. International Journal of Environmental Research and Public Health, 16 (14). https://doi.org/10.3390/ijerph16142527

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Exercise-Based Interventions to Enhance Long-Term Sustainability of Physical Activity in Older Adults: A Systematic Review and Meta-Analysis of Randomized Clinical Trials

Oriol Sansano-Nadal [1], Maria Giné-Garriga [1,2,3] *, Jennifer S. Brach [4], David M. Wert [4], Javier Jerez-Roig [1,2,5], Myriam Guerra-Balic [1], Guillermo Oviedo [1], Jesús Fortuño [1], Natàlia Gómara-Toldrà [3], Luis Soto-Bagaria [6,7], Laura Mónica Pérez [6,7], Marco Inzitari [6,7,8], Ivan Solà [9,10], Carme Martin-Borràs [1,3] and Marta Roqué [9,10,11]

1. Department of Physical Activity and Sport Sciences. Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Císter 34, 08022 Barcelona, Spain
2. School of Health and Life Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, UK
3. Department of Physical Therapy. Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Padilla 326-332, 08025 Barcelona, Spain
4. Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Forbes Tower, 3600 Atwood St, Pittsburgh, PA 15260, USA
5. Research group on Methodology, Methods, Models and Outcome of Health and Social Sciences (M_3O), Faculty of Health Science and Welfare, University of Vic-Central University of Catalonia (UVIC-UCC), Sagrada Família 7, 08500 Vic, Spain
6. Intermediate Care Hospital, Parc Sanitari Pere Virgili, Avinguda de Vallcarca 169-205, 08023 Barcelona, Spain

7. RE-FiT Barcelona Research Group, Vall d'Hebrón Institute of Research (VHIR), Passeig de la Vall d'Hebron 119-129, 08035 Barcelona, Spain
8. Department of Medicine, Universitat Autònoma de Barcelona, Plaça Cívica, 08193 Bellaterra, Barcelona, Spain
9. Iberoamerican Cochrane Centre. Institute of Biomedical Research Sant Pau (IIB-Sant Pau), Sant Antoni Marià Claret 167, pavilion 18, 08025 Barcelona, Spain
10. CIBER Epidemiology and Public Health, CIBERESP, 28029 Madrid, Spain
11. Institute on Health and Aging, Universitat Autònoma de Barcelona (UAB), Sant Antoni Marià Claret 171 (Casa Convalecencia), 08041 Barcelona, Spain

*Correspondence: mariagg@blanquerna.url.edu; Tel.: +34932533000

Abstract

Exercise is a form of physical activity (PA). PA is an important marker of health and quality of life in older adults. The purpose of this study was to conduct a systematic review of the literature to assess the effect of exercise-based interventions on an at least six-month follow up PA measure, and to describe the specific strategies implemented during the intervention to strengthen the sustainability of PA in community-dwelling 65+ year-old adults. We registered and conducted a systematic review and meta-analysis (PROSPERO: CRD42017070892) of randomized clinical trials (RCT). We searched three electronic databases during January 2018 to identify RCT assessing any type of exercise-based intervention. Studies had to report a pre-, post-, and at least 6-month post-intervention follow-up. To be included, at least one PA outcome had to be assessed. The effect of exercise-based interventions was assessed compared to active (e.g., a low-intensity type of exercise, such as stretching or toning activities) and non-active (e.g., usual care) control interventions at several time points. Secondary analyses were conducted, restricted to studies that reported specific strategies to enhance the sustainability of PA. The intervention effect was measured on self-reported and objective measures of time spent in PA, by means of standardized mean differences. Standardized mean differences of PA level were pooled. Pooled estimates of effect were computed with the DerSimonian–Laird method, applying a random effects model. The risk of bias was also assessed. We included 12 studies, comparing 18 exercise intervention groups to four active and nine non-active control groups. Nine studies reported specific strategies to enhance the long-term sustainability of PA. The strategies were mostly related to the self-efficacy, self-control, and behavior capability principles based on the social cognitive theory. Exercise interventions compared to active control showed inconclusive and heterogeneous results. When compared to non-active control, exercise interventions improved PA time at the six-months follow up (standardized mean difference 0.30; 95%CI 0.15 to 0.44; four studies; 724 participants; I^2 0%), but not at the one- or two-years follow-ups. No data were available on the mid- and long-term effect of adding strategies to enhance the sustainability of PA. Exercise interventions have small clinical benefits on PA levels in community-dwelling older adults, with a decline in the observed improvement after six months of the intervention cessation.

Keywords: Older adults; physical activity; sustainability; adherence; meta-analysis; systematic review

Introduction

Many health-oriented systems and organizations are faced with the challenge of implementing new health-related practices, and while many of these programs demonstrate initial success, they fail to become a habit or routine for the participants. Policy makers and other stakeholders are increasingly concerned with the long-term impact of their investment. Greenhalgh et al. (Greenhalgh et al., 2004) pointed out there was a near absence of studies focusing primarily on how to sustain health promotion interventions in the long term.

While intervention sustainability is defined as the continued use of intervention components and activities for the continued achievement of desirable health outcomes within the population of interest (Scheirer & Dearing, 2011), determining how to foster the maintenance of health-related benefits acquired by the intervention's recipients once it ends is another great challenge (Weber et al., 2018). Adherence, similarly, is defined as the extent to which a person's behavior (e.g., lifestyle changes) corresponds with agreed recommendations from a health care provider (World Health Organization, 2003), based on completion (e.g., retention), attendance, duration, and intensity while undergoing a certain intervention.

The incidence rate of many chronic diseases increases with age (Matthews et al., 2013; Prince et al., 2015). Physical activity (PA) is a major aspect of chronic disease self-management (Baumann et al., 2018; Motl & McAuley, 2010; Reiner et al., 2013; Santanasto et al., 2017; Schuch et al., 2016; Stubbs et al., 2015; Tada, 2018), and higher levels of PA are associated with healthy ageing (Daskalopoulou et al., 2017). In particular, for older adults, balance and resistance training programs are an effective way to maintain mobility and independence (Stubbs et al., 2015). People who undertake regular PA tend to experience better health and live longer (Bembom et al., 2009; Ekelund et al., 2015), even with small increases each day (Ekelund et al., 2015). However, insufficient amounts of PA remain one of the major behavioral burdens worldwide (Das & Horton, 2012; Hallal et al., 2012; Institute for Health Metrics and Evaluation, 2016). Older adults are the less active group, with only about 11% meeting the current PA recommendations (Gomes et al., 2017; Federal Interagency Forum on Aging-Related Statistics, 2016), creating a ripe environment for PA intervention research. The road towards sustainable maintenance to PA might be the cornerstone of health promotion.

Interventions to promote maintenance of PA once the intervention ends in older adults have achieved limited success, particularly over the long term (Chase, 2015; Daskalopoulou et al., 2017; Morelhao et al., 2017; Richards et al., 2013; Sørensen et al., 2006; Williams et al., 2007; Zubala et al., 2017). A clear definition of long-term sustainability is still lacking, so we will consider long-term as a person maintaining a recommended behavior over a 12-month period (World Health Organization, 2003). Most current studies thus far have focused on identifying the factors that are critical to the success of initial implementation efforts. The development of alternative approaches based on end-users' preferences, and which implement behavioral change concepts, have been repeatedly requested (Chao et al., 2000). Some of the most used theories in health behavior change include psychological theories, such as the transtheoretical model (Prochaska & Velicer, 1997) and the social cognitive theory (SCT) (Bandura, 2001). Behavioral change techniques (BCTs) include cognitive and behavioral processes of change, and had been associated with an increase in the effects of behavior change interventions (Michie et al., 2009). There is a need for designing effective and sustainable interventions to promote PA in the long term in older adults (Weber et al., 2018).

The purpose of this study was to conduct a systematic review of the literature to assess the effect of exercise-based interventions, implemented in community-dwelling older adults (65+ years of age), on an at least six-month follow up of PA—and subsequently describe the specific strategies implemented to strengthen the long-term sustainability of PA. We hypothesized that interventions that described specific strategies to enhance the sustainability of PA practice would be more effective in PA maintenance, at least after the six-month post-intervention cessation. Our paper aimed to inform an agenda for research, funding, and policies on PA promotion in older adults.

Material and methods

Study selection

We conducted a systematic review of the literature to assess the effect of exercise-based interventions, implemented in community-dwelling older adults, at least six-months post-intervention, on the sustainability of PA (PROSPERO: CRD42017070892). The guidelines for conduct and a report of systematic reviews in the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 (Higgins & Green, 2011) and PRISMA statement (Moher et al., 2009) were followed. We searched MEDLINE, EMBASE, and CENTRAL up to January 2018 without language or date restrictions. We designed a search strategy adapted to the requirements of each database, combining their controlled vocabularies and text terms. We used, among others, keywords like older, elderly, ageing, aging, sustainable, sustainability, maintenance, adherence, long-term effects, and physical activity, exercise, rehabilitation (see Supplementary Table S1; page 313). We approached other sources (references from relevant systematic reviews and meta-analyses, or personal communication with experts) to identify additional studies. Title words had to include 'exercise' or 'physical activity' or 'exercise referral schemes' and 'older adults'. Results from the search procedures were imported into Mendeley bibliographic software and duplicates were removed. Study titles and abstracts of identified studies were screened by pairs of authors independently (M.G.-G., N.G.-T., M.G.-B., L.S.-B., J.J.-R, O.S.-N., G.O., J.F., J.S.B., D.M.W.) to exclude studies that clearly did not meet the inclusion criteria. Full text versions of potentially eligible studies were retrieved and assessed independently by pairs of authors (M.G.-G., N.G.-T., J.S.B., D.M.W., L.S.-B., L.M.P., M.I., M.G.-B., J.J.-R., O.S.-N. G.O., J.F.) against the inclusion criteria, and agreements were reached by consensus. Articles were excluded at all stages of the review and the reasons for exclusion were recorded (see Figure 1: study flow chart).

Studies were included if they were randomized clinical trials (RCT) involving any type of exercise program (e.g., exercise referral scheme, aerobic and/or strength exercise programs, tai-chi) in community-dwelling older adults aged 65 years or older of both genders. Studies had to report at least pre-, post-, and at least six-month post-intervention follow-up exercise intervention measurements. Furthermore, at least one valid PA outcome had to be assessed (e.g., self-report, activity monitor) as a primary or secondary outcome measure. Studies were included if the exercise-based intervention was compared to either a non-active control, such as usual care, or an active control, if participants performed a low intensity type of exercise such as stretching or toning activities, or physiotherapy. We included studies aimed at assessing the sustainability of PA and studies that assessed PA as a health-related outcome measure.

Studies with participants younger than 65 years old were only included in the review if the mean age was over 65, and the study either mostly included participants over 65, or presented results specifically for the subgroup of 65+ participants.

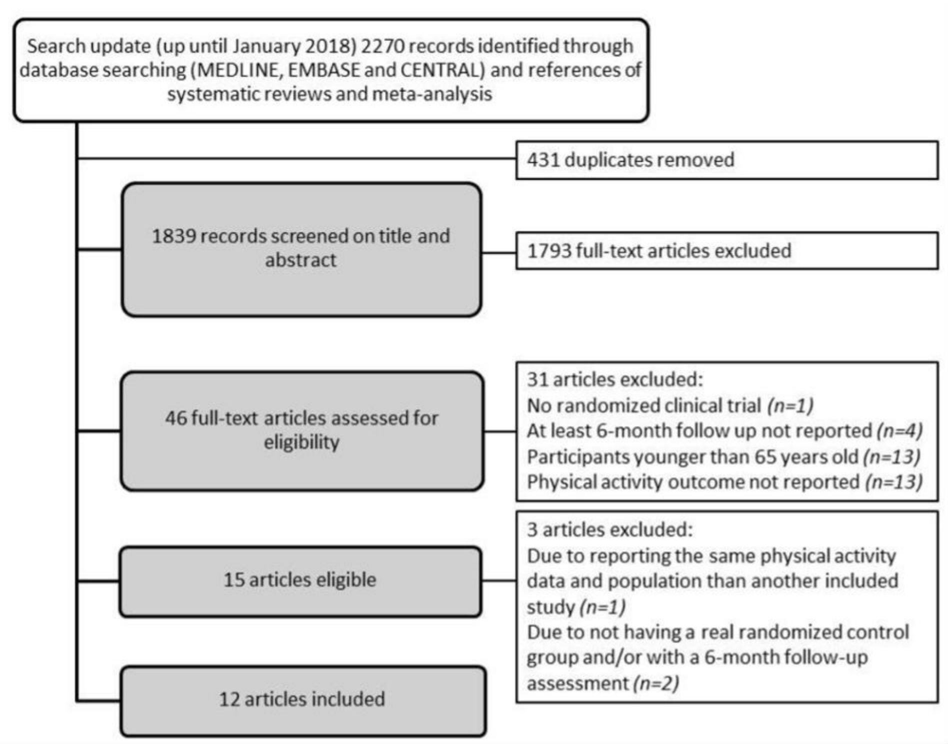

Figure 1. Flow chart of study inclusion.

Quality assessment

The validity of the results provided by the studies was assessed using the Cochrane Collaboration's risk of bias tool (Higgins & Green, 2011) by two independent reviewers, with two added questions. The domains of selection bias, performance bias, outcome assessment bias, attrition bias, and selective reporting bias were assessed through the following measures: (1) random sequence generation; (2) allocation concealment; (3) adherence to intervention; (4) contamination; (5) objective PA assessment; (6) incomplete outcome data; and (7) incomplete or selective reporting, based on published papers and documentation in trial registries. The risk of bias for each item could be rated as 'high' (+), 'low' (−), or 'unclear' (?).

Performance bias items related to the blinding of participants and personnel were not included, as this is typically not feasible for exercise interventions. The assessments of both reviewers were compared, and disagreements were resolved by discussion (see Supplementary Table S2; page 318).

Data extraction

Pairs of independent reviewers (M.G.-G and N.G.-T., J.S.B. and D.M.W., L.S.-B. and L.M.P., M.I. and M.G.-B., J.J.-R. and O.S.-N., G.O. and J.F.) extracted information about the mean age, inclusion and exclusion criteria, setting, PA and physical function outcomes, instruments, and time point measured (Supplementary Table S3; page 319). The extraction of specific details on intervention components included dose (frequency, intensity, time, and type), profile of the professional delivering it, control intervention description, compliance, and the specific strategies targeted to increase the sustainability of PA practices and its relevant theory background (Supplementary Table S4; page 319).

Data regarding study characteristics was extracted into an electronic database. Three independent reviewers checked the accuracy of this procedure (M.G.-G., M.R., C.M.-B.) and if any discrepancy arose, consensus through discussion was sought.

Outcomes

The primary outcome of the review was time spent in PA, either assessed with valid objective measures with any kind of activity monitor (e.g., accelerometer or pedometer) or self-reported instruments. Information on the instruments used in each study (e.g., validation and recall periods of the self-reported measures) can be found in Supplementary Table S3 (page 319).

Statistical Analysis

We assessed the effect of exercise-based interventions on PA levels at several time-points (immediately after intervention, at mid-term (between 6 and 11 months after), and long-term (12 or more months after)). Data at three-months follow-up from a study (Hauer et al., 2003) have been included in the mid-term category for comprehensiveness purposes.

The effect of exercise-based interventions was organized in two comparisons, defined by the type of control: exercise-based interventions compared to active control interventions (e.g., a low-intensity type of exercise, such as stretching or toning activities, or physiotherapy); and compared to a non-active control (e.g., usual care). We conducted secondary analyses restricted to those studies that reported specific strategies to enhance the sustainability of PA.

The effect of intervention on objective and self-reported time spent in PA was assessed with standardized mean differences, due to the variability of PA measures applied across trials. Pooled estimates of effect were computed with the DerSimonian–Laird method, applying a random effects model. Heterogeneity was assessed by means of the I^2 statistic, considering values over 50% to indicate serious inconsistency (Higgins & Green, 2011). When high statistical or clinical heterogeneity was found, the pooled estimates of effect were unreliable.

Three studies comparing either two or three active interventions to one control arm (Dohrn et al., 2017; Karinkanta et al., 2009; McMahon et al., 2017) were included in the meta-analysis by merging their intervention arms into a single arm, to avoid double counting of data. Data from a four-arm study (Uusi-Rasi et al., 2017) was presented as two comparisons.

Results

Description of Study Inclusion (Figure 1)

The search update identified 2270 records, of which 46 were eligible after title and abstract screening. After the full-text assessment, 15 studies (Beyer et al., 2007; De Vries et al., 2016; Dohrn et al., 2017; Hage et al., 2003; Hars et al., 2014; Hauer et al., 2003; Karinkanta et al., 2009; Martín-Borràs et al., 2018; McAuley et al., 2007; McMahon et al., 2017; Patel et al., 2013; Rejeski et al., 2009; Ståhle et al., 1999; Uusi-Rasi et al., 2017; Witham et al., 2007) remained eligible for inclusion, but three studies were later excluded (De Vries et al., 2016; Hage et al., 2003; Hars et al., 2014), one for reporting the same PA measures and population as another included study (Hage et al., 2003), and two for not having a real randomized control group and/or not having a six-month follow up assessment (De Vries et al., 2016; Hars et al., 2014). The 12 studies that were included in the final analyses investigated a total of 18 exercise-based arms (Beyer et al., 2007; Dohrn et al., 2017; Hauer et al., 2003; Karinkanta et al., 2009; Martín-Borràs et al., 2018; McAuley et al., 2007; McMahon et al., 2017; Patel et al., 2013; Rejeski et al., 2009; Ståhle et al., 1999; Uusi-Rasi et al., 2017; Witham et al., 2007), compared to four active control groups (Hauer et al., 2003; McAuley et al., 2007; McMahon et al., 2017; Rejeski et al., 2009) and nine non-active control groups (usual care) (Beyer et al., 2007; Dohrn et al., 2017; Karinkanta et al., 2009; Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999; Uusi-Rasi et al., 2017; Witham et al., 2007). It is worth noting that the targeted older adults were heterogeneous in terms of comorbidities and functional status.

The principal investigators of four studies were contacted because of incomplete reporting of PA data (Beyer et al., 2007; Karinkanta et al., 2009; McAuley et al., 2007; Uusi-Rasi et al., 2017). Baseline data of one included study (Uusi-Rasi et al., 2017) were retrieved in a previous article (Patil et al., 2016). After personal communication, we obtained additional information for two studies (Karinkanta et al., 2009; Uusi-Rasi et al., 2017).

Characteristics of Exercise Arms Included in the Meta-Analysis

We described the exercise arms assessed in the included trials in Supplementary Table S3 (page 319), and the description of the interventions and strategies applied to enhance long-term sustainability of PA levels is presented in Supplementary Table S4 (page 319). Trials included a range of 52 to 422 participants, that were, on average, 75.8 years old and 73.7% were female. Only three trials reported specific information regarding the race/ethnicity of the participants, with between the 80% and 95% of the sample being Caucasian (McAuley et al., 2007; McMahon et al., 2017; Rejeski et al., 2009).

Intervention duration varied across the 12 studies, ranging from 8 weeks to 24 months. All interventions were supervised, the frequency of supervised exercise sessions was mainly two or three times a week, and session duration ranged from 30 to 90 minutes. Prescribed exercise intensity was not described in most of the included studies (Beyer et al., 2007; Dohrn et al., 2017; McAuley et al., 2007; McMahon et al., 2017; Patel et al., 2013; Ståhle et al., 1999; Witham et al., 2007) (Supplementary Table S4; page 319).

Comparison 1: Exercise-Based Intervention Versus Active Control

Three studies with 265 participants compared active interventions against active controls. Two of the studies assessed intervention effect on self-reported measures of PA (McMahon et al., 2017; Rejeski et al., 2009), while the third study applied both self-reported and objective measures of PA (Hauer et al., 2003). Two of the studies implemented strategies to enhance sustainability (McMahon et al., 2017; Rejeski et al., 2009) and one study (Hauer et al., 2003) did not. The main analyses showed heterogeneity in self-reported estimates of PA, at all-time points. One of the studies showed a consistent effect of the intervention immediately and at the six-month and two-year follow ups (Rejeski et al., 2009), while the other two showed either no effect (McMahon et al., 2017), or an initial immediate effect that disappeared during follow ups (Hauer et al., 2003) (Figure 2). The secondary analyses restricted to the two trials with sustainability-enhancing strategies reached similar results and heterogeneity levels as the main analyses (Supplementary Figure S1; page 320). The only study measuring PA objectively (McMahon et al., 2017) showed no differences between intervention and active control, neither immediately post-intervention (SMD 0.16; 95%CI −0.30 to 0.62; 100 participants) nor at the six-month follow up (SMD 0.15; 95%CI −0.31 to 0.61).

Eight studies with 1676 participants compared exercise-based interventions against non-active controls (Beyer et al., 2007; Dohrn et al., 2017; Karinkanta et al., 2009; Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999; Uusi-Rasi et al., 2017; Witham et al., 2007). All but two studies implemented sustainability-enhancing strategies (Dohrn et al., 2017; Karinkanta et al., 2009). Five studies provided only on self-reported PA data (Beyer et al., 2007; Karinkanta et al., 2009; Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999), one study provided only objective PA data (Witham et al., 2007), and one study provided both types of data (Uusi-Rasi et al., 2017). One additional study could not be included in the analysis for not presenting results data for the intervention and control groups separately (McAuley et al., 2007).

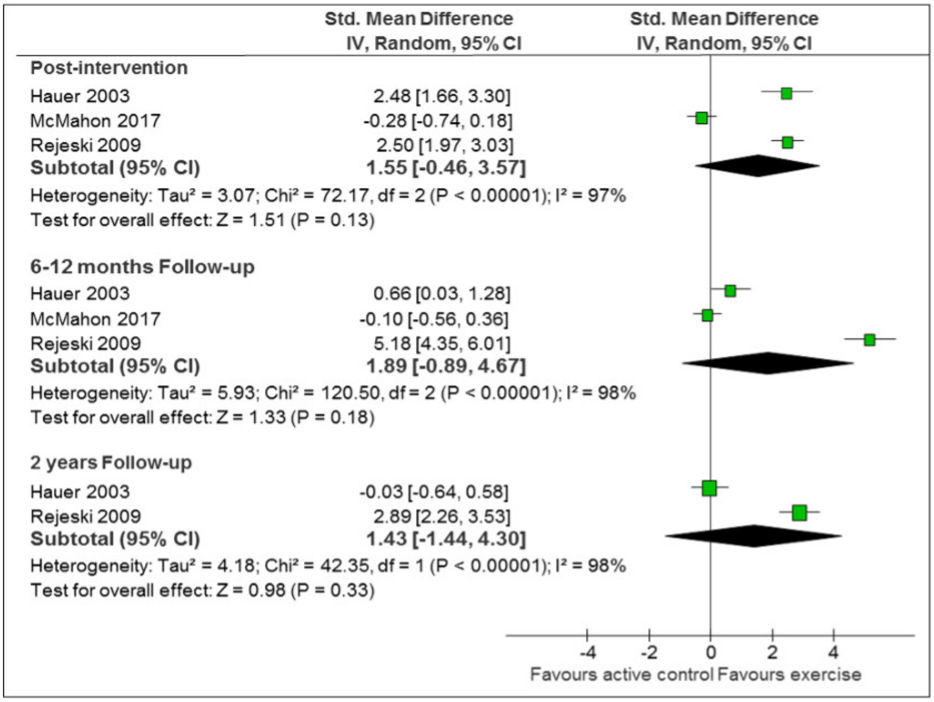

Figure 2. Exercise-based intervention versus active control (self-reported PA: physical activity). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: *p* value.

Comparison 2: Exercise-Based Intervention versus Non-Active Control

Active interventions had a small effect on self-reported PA time compared to non-active control, both immediately post intervention (SMD 0.18; 95%CI −0.01 to 0.37; five studies (Karinkanta et al., 2009; Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999; Uusi-Rasi et al., 2017); 1257 participants; I^2 63%), and at the six-month follow up (SMD 0.30; 95%CI 0.15 to 0.44; four studies (Beyer et al., 2007; Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999); 724 participants; I^2 0%). The effect was gradually lost over time, with irrelevant long term results at the one-year follow up (SMD 0.27; 95%CI 0.05 to 0.48; one study (Martín-Borràs et al., 2018); 239 participants) and the two-year follow up (SMD 0.03; 95%CI −0.18 to 0.24; one study (Uusi-Rasi et al., 2017); 350 participants) (Figure 3). When restricting the analyses to the four studies who applied some kind of strategy to enhance sustainability, the immediate post-intervention effect became significant and less heterogeneous (SMD 0.25; 95%CI 10.0 to 40.0; four studies (Martín-Borràs et al., 2018; Patel et al., 2013; Ståhle et al., 1999; Uusi-Rasi et al., 2017); 1108 participants; I^2 31%) (Supplementary Figure S2; page 321).

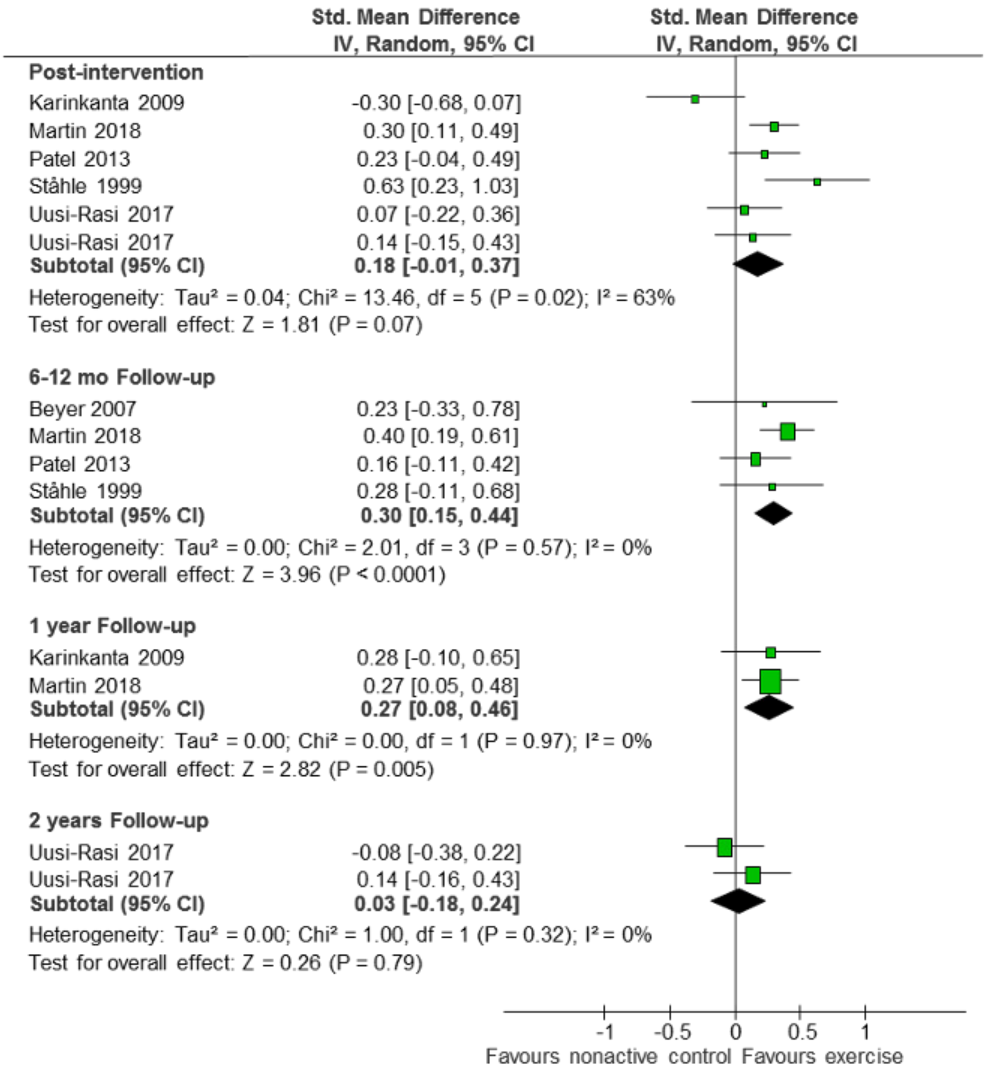

Figure 3. Exercise-based intervention versus non-active control (self-reported PA). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: *p* value.

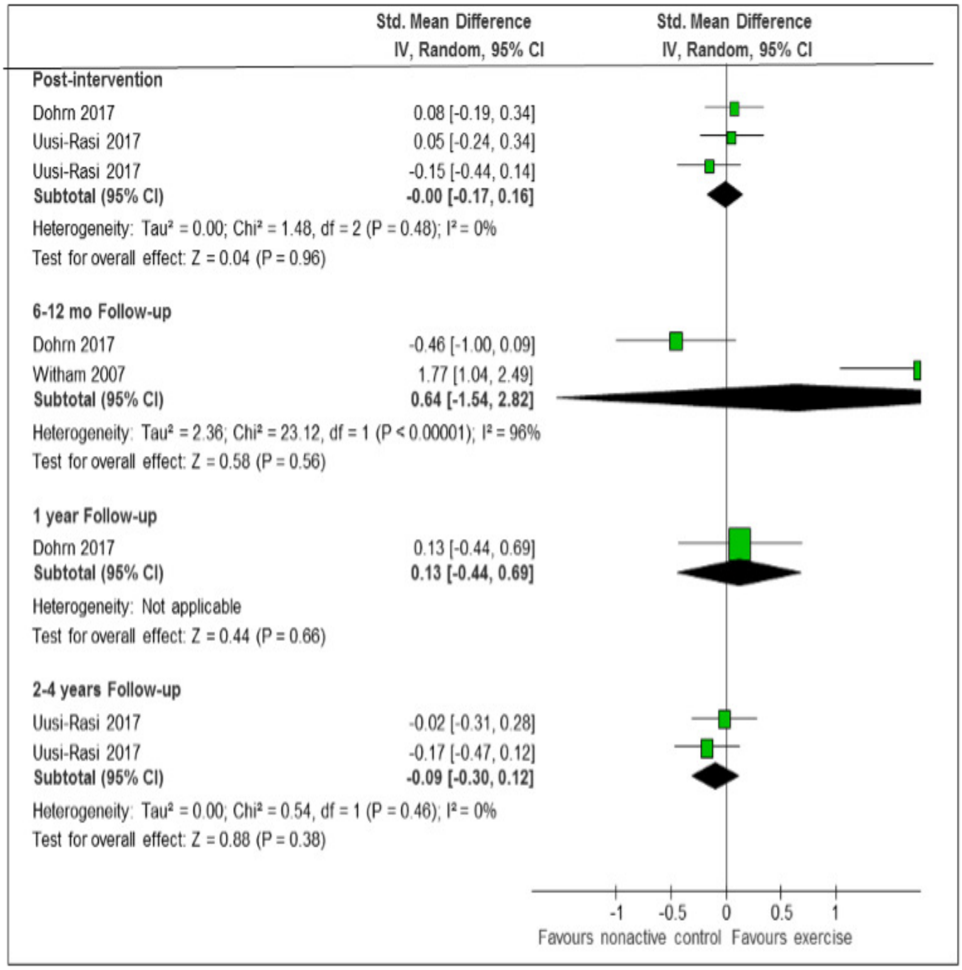

Figure 4. Exercise-based intervention versus non-active control (objective measures of PA). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: *p* value.

The three studies which provided data with objective measures of PA were extremely heterogeneous, with two of them showing no differences between intervention and non-active control, either immediately or at any time point (Dohrn et al., 2017; McMahon et al., 2017), and the third study showing significant differences in the changes between the baseline and the nine-month follow up (Witham et al., 2007) (Figure 4). The secondary analysis restricted to two studies which applied sustainability-enhancing strategies was still quite heterogeneous (Supplementary Figure 3; page 322).

Reported Strategies to Enhance Long-Term Sustainable Maintenance of PA

In the present review, we classified the strategies according to the SCT (e.g., self-efficacy, behavioral capability, reinforcements, observational learning, expectations, expectancies, and self-control) (Bandura, 2001). Nine studies reported specific strategies to enhance the long-term sustainability of PA once the intervention had ended (Beyer et al., 2007; Martín-Borràs et al., 2018; McAuley et al., 2007; McMahon et al., 2017; Patel et al., 2013; Rejeski et al., 2009; Ståhle et al., 1999; Uusi-Rasi et al., 2017; Witham et al., 2007). In one study, the authors offered for the intervention group to continue the PA sessions once a week, and informed the control group about a training program available in the community (Ståhle et al., 1999). Similarly, in one study, researchers invited the participants to keep their PA monitors after the study, to favor sustaining the PA practice (McMahon et al., 2017). In another study, the person delivering the intervention applied the principles of self-efficacy, regular performance feedback, and positive reinforcement to enhance the motivation for exercise progression and maintenance (Beyer et al., 2007). McAuley et al. used self-efficacy as the guiding theoretical construct, and participants were sent feedback on their measures by mail as a reinforcement strategy, so that they could see their improvements in health outcomes (McAuley et al., 2007). In two studies, patients kept an activity diary and agreed to establish weekly goals for increased activity with the training provider (Patel et al., 2013; Witham et al., 2007). In another study, each participant engaged in weekly group-mediated behavioral counselling sessions that focused on self-regulatory skills central to promoting PA, for the first 10 weeks (Rejeski et al., 2009). In the study that assessed outcomes two years post-intervention, participants were encouraged to keep their pedometers and were invited to continue with the exercise training, or encouraged to participate in any other preferred PA (Uusi-Rasi et al., 2017). In the most recent study, the exercise specialist identified a leader in each exercise group to organize a third session each week on their own, to enhance the autonomy of the participants and the sustainable maintenance of PA practice (Martín-Borràs et al., 2018). All participants were offered a personalized exercise program and visits with all participants were made to the nearest community resources (e.g., sport facilities) (Martín-Borràs et al., 2018). This latest intervention included mechanisms to enhance social support during the cool-down phase of each session, such as social influence/social comparison, social control, self-esteem, sense of control and belonging, and companionship (Martín-Borràs et al., 2018).

The sustainability-enhancing strategies most associated with success were two behavioral strategies: self-control and behavioral capability. Self-control strategies used by participants to maintain self-motivation and achieve personal goals were the use of tracking monitors, daily step diaries, and individualized step-based goals. Behavioral capability strategies included individualized counselling on the role of PA in disability prevention, designed to promote PA, and visits to community resources (e.g., sport facilities) where the regular PA practice could be continued.

Discussion

The current systematic review synthesized the data from 12 RCTs, including 18 exercise-based arms, compared to four active control and nine non-active control groups that evaluated the effects of exercise-based interventions implemented in older adults to sustain the maintenance of PA increases for the mid- and long-term, and to describe the strategies used in the interventions to enhance the sustainability of PA in this population.

Results of the effect of exercise interventions on the sustainability of PA were heterogeneous in the present study. The results of a recent meta-analysis also revealed a high heterogeneity associated with the pooled treatment, with a significant small effect favoring exercise interventions over control (Chase, 2015; Morelhao et al., 2017). As the authors included non-randomized trials, it is possible that the effect reported was overestimated (Chase, 2015; Morelhao et al., 2017). Supervised exercise interventions with specific strategies to enhance sustainability had statistically significant beneficial effects on PA levels at the end of intervention compared to non-active controls or active controls. However, at 12 months post-intervention cessation, benefits subsided. Unclear effects on maintenance beyond 12 months were noted in other reviews of PA promotion, due to a lack of high-quality longitudinal studies, heterogeneity of interventions, and a high chance of bias (Zubala et al., 2017).

Researchers tended to describe some strategies to enhance PA sustainability in the intervention, although most researchers failed to design the intervention bearing sustainability in mind (Weber et al., 2018). Approximately 80 theories related to behavior change had been identified in the literature, and one of the most used is the SCT (Davis et al., 2015). The specific strategies described to enhance sustainability in the included studies might not be applicable to all populations, or might not be explicitly based on theory. Choosing a relevant theory can be a challenging task for intervention designers, especially given the large number of theories.

Mechanisms that Underpin our Main Finding

Insufficient PA is a modifiable lifestyle factor that leads to an increasing pressure to deal with additional health care costs associated with an ageing population and chronic disease burden (Hallal et al., 2012). A recent systematic review suggested that participants who engaged in PA had their odds of living a healthy life in older age increased compared to participants that were physically less active (Daskalopoulou et al., 2017). The present systematic review does not show a successful picture of exercise-based interventions to increase PA levels in older adults in the long-term, as only one intervention that added specific strategies to sustain PA maintenance showed better effects in the long-term (Witham et al., 2007). Public health interventions targeting insufficient PA levels are usually developed without the involvement of end-users, which seems to be the case for all the studies included in the present review. One promising way to develop effective PA-based interventions (e.g., exercise-based) is to combine theory-based with solution-based approaches, characterized by considering individuals' interests, forming cooperative teams of stakeholders, and distributing actions and decisions (Finegood et al., 2011). Patient and public involvement (PPI) has developed into an integral part of research practice over the last 25 years. It is thought that involving end-users in the development of solution-based interventions using key elements derived from participatory methodologies such as PPI may increase the likelihood of producing sustainable change (Green et al., 1996). However, none of the studies included in our review reported any approach of PPI in the design of the exercise-based intervention.

Behavioral-type components, such as self-monitoring, goal setting, and prompting, engage participants in actively changing physical behaviors (Samdal et al., 2017). Cognitive-type components, such as education, problem solving, or counselling, promote change in cognitive processes, attitudes, or beliefs (Conn et al., 2003). Some of the most cited strategies used in the included studies were education (Nutbeam, 2000), self-monitoring (Cohen et al., 2013), and action planning (Pearson, 2012). These have all been acknowledged in the literature as important theoretical constructs for successful behavior change, however, in the included studies they might not have been sufficiently addressed in the intervention design and across the intervention period (Davis et al., 2015). A recent narrative systematic review supports combination strategies as more successful in changing PA behavior (Chase, 2015) than interventions that target a standalone behavioral strategy. However, none of the strategies described in the present review suggested the inclusion of the end-user themselves, which may be one of the most vital components for finding the right motivating factors to improve long-term exercise/PA participation among older adults. The behavioral capability strategies reported in some of the included studies aimed at engaging participants in existing community resources. Community-based resources to facilitate health behavior change may include a wide range of available opportunities, such as city-based exercise programs (Glasgow et al., 2004), referral to fitness professionals, or fitness centers (Ackermann et al., 2005). Referrals to specific community programs, such as exercise for adults, have shown a positive effect on patient behavior (Ackermann et al., 2005; Green et al., 2002). Self-control strategies are aimed at providing regular performance feedback to enhance the motivation for activity maintenance (e.g., pedometer, daily steps diary). Several studies have shown the positive effects of activity trackers for enhancing PA levels. However, while some short-term studies support success, more recent data question the longer-term effects on PA change (Jakicic et al., 2016; Piwek et al., 2016).

It is important to note that this area of PA research is characterized by a dearth of knowledge of the effects of exercise interventions on long-term sustainability, particularly among older adults (Brawley et al., 2003). Brawley et al. highlighted the need for longitudinal research investigating not only the factors associated with activity maintenance after the program ends, but also the psychological strategies that were most effective for attenuating the rate of declining activity levels beyond program completion (Brawley et al., 2003). A whole system-oriented approach is required that is tailored to meet the needs of older adults and aligns with social, individual, and environmental factors (Michie et al., 2009). A patient-centered approach supporting clinical reasoning to detect needs, limitations, and strengths in both the participant and the physical and social environment and choosing evidence-based interventions to enhance behavior change was described in one study, which had to be excluded from the present review for not reporting a six-month follow-up (De Vries et al., 2016). Mechanisms to enhance social support and participation might be effective for battling social isolation and enhancing adherence (Martín-Borràs et al., 2018).

PA is continuously ubiquitous throughout the day (Sartini et al., 2015), so understanding usual PA patterns might help turn daily routines into opportunities for exercising rather than performing specific exercise programs (Clemson et al., 2012). Interventions should be developed in coherence with their daily routine, tailored to an individual's context and circumstances to improve adherence (Martin et al., 2005).

Strengths and limitations

To our knowledge, this is the first systematic review focusing on the sustainability of exercise-based interventions to maintain increases in PA levels in older adults, in the mid- and long-term. The strengths of the current meta-analysis are the extensive search strategy, the inclusion of RCTs, and the number of exercise arms, as well as the description of specific strategies to enhance sustainability of PA practice. However, the present systematic review is restricted to three databases. In addition, two studies could not be included due to not being able to contact the main author. The meta-analyses were performed on few studies, which caused estimates to be more imprecise. This imprecision, added to the observed heterogeneity, limits our confidence in the results. On the other hand, even though we aimed at describing the long-term effects of current interventions on enhancing PA sustainability, very few studies reported this, so the analysis had to focus on the six-month follow up period.

Besides this, most of the studies included in the review assessed PA with a self-report instrument, increasing the impact of recall bias (Cumming & Klineberg, 1994). There was also lack of consistency regarding the way frequency, intensity, and duration of PA were reported. Similar problems are also mentioned in other systematic reviews of PA (Chao et al., 2000; Chase, 2015; Daskalopoulou et al., 2017; Richards et al., 2013).

Conclusions

Exercise interventions are statistically significant but translate to a small clinical benefit on PA levels in community-dwelling older adults. Among those studies that reported longer-term follow up (six months after the intervention cessation) improvements have been shown to decline. Only one intervention that added specific strategies to enhance sustainability demonstrated maintenance of PA practice in the long term. Further research is needed to conclude the most effective strategies to enhance the sustainability of PA for older adults.

This review could be of interest to clinical or institutional leaders and administrators, as well as to health professionals and researchers in order to inform clinical decisions and policies.

Data Statement

The data will be made available to interested researchers. Please contact the corresponding author.

Abbreviations

PA physical activity; RCT randomized clinical trials; SCT social cognitive theory; BCTs behavioral change techniques.

Supplementary materials

The following are available online at www.mdpi.com/xxx/s1 and also in the annexes of this document. Supplementary S1. Search Strategy, Supplementary S2. Risk of bias, Supplementary S3. Description of included studies, Supplementary S4. Description of the interventions and strategies to enhance long-term adherence of PA levels, Supplementary Figure 1. Exercise-based intervention vs active control (self-reported PA) restricted to studies with adherence-enhancing strategies. Supplementary Figure 2. Exercise-based intervention vs non-active control (self-reported PA) restricted to studies implementing adherence-enhancing strategies. Supplementary figure 3. Exercise-based intervention vs non-active control (objective measures of PA) restricted to studies implementing adherence-enhancing strategies.

Author Contributions

M.G.-G., J.S.B., M.I., M.R. and O.S.-N. contributed to the concept and design of the study. I.S. conducted the literature search. M.G.-G., N.G.-T., M.G.-B., L.S.B., J.J.-R., O.S.-N, G.O., J.F., J.S.B., D.M.W. conducted the title and abstract screening for eligibility. M.G.-G., N.G.-T., J.S.B., D.M.W., L.S.B., L.M.P., M.I., M.G.-B., J.J.R., O.S.-N., C.M.B., G.O., J.F., C.M.-B. gathered and conducted the full text data extraction. M.R. performed the data analysis. All authors have revised the manuscript and approved the final version.

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Conflicts of interests

The authors declare no conflict of interest.

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Estudi II

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Validity of the Sedentary Behaviour Questionnaire in European Older Adults using English, Spanish, German and Danish versions

Oriol Sansano-Nadal[1]; Jason J. Wilson[2,3]; Carme Martín-Borràs[1,4]; Jan Christian Brønd[5]; Mathias Skjødt[5]; Paolo Caserotti[5]; Marta Roqué i Figuls[6]; Nicole E. Blackburn7; Jochen Klenk[8]; Dietrich Rothenbacher[8]; Myriam Guerra-Balic[1]; Manel Font-Farré[1]; Michael Denkinger[8]; Laura Coll-Planas[6]; Manuela Deidda[9]; Emma McIntosh[9]; Maria Giné-Garriga[1,4]*; Mark A. Tully[2]*

1. Department of Physical Activity and Sport Sciences, Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Barcelona, Spain
2. Institute of Mental Health Sciences, School of Health Sciences, Ulster University, Newtownabbey, UK
3. School of Sport, Ulster Univeristy, Newtownabbey, UK
4. Department of Physical Therapy, Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Barcelona, Spain
5. Department of Sports Science and Clinical Biomechanics, Center for Active and Healthy Ageing (CAHA), Syddansk Universitet, Odense, Denmark
6. Fundació Salut i Envelliment (Foundation on Health and Ageing)-UAB, Universitat Autònoma de Barcelona, Barcelona, Spain
7. Institute of Nursing and Health Research, School of Health Sciences, Ulster University, Newtownabbey, UK
8. Institute of Epidemiology and Medical Biometry, Ulm University, Ulm, Germany

9. Health Economics and Health Technology Assessment (HEHTA), Institute of Health and Wellbeing (IHW), University of Glasgow, Glasgow, United Kingdom.

*Dr. Maria Giné-Garriga and Dr. Mark A. Tully should be considered joint senior author.

Corresponding Author

Oriol Sansano-Nadal; Facultat de Psicologia, Ciències de l'Educació i de l'Esport Blanquerna (Universitat Ramon Llull), C/ Císter 34, 08022 Barcelona, Spain; +34 932533000 (5332); oriolsn@blanquerna.url.edu.

Abstract

The main aim of this study was to assess the criterion validity of the Sedentary Behaviour Questionnaire (SBQ) to measure SB in community-dwelling older adults using thigh-measured accelerometry as the criterion method. 801 participants (75.6 ± 6.1 years old, 57.6% females) provided valid thigh-based accelerometer data (ActivPAL/Axivity) and completed the SBQ. Criterion validity was assessed using Spearman's Rho coefficients. Bland-Altman plots, including 95% limits of agreement and Intraclass Correlation Coefficient (ICC) were used to assess the agreement between self-report and device-measured daily SB time. Strength of the association was examined using multiple linear regression. There was a weak correlation (Rho= 0.25, p< 0.001) between self-reported and device-based SB measures. The SBQ under-estimated daily SB time compared to accelerometry. Our results highlighted an overall weak-to-moderate correlation between measures, with significant differences between each country's version. Researchers should be cautious when using the SBQ to provide an estimation of SB time in older adults.

Key words: Sedentary behaviour; ActivPAL; Axivity; Older adults

Introduction

Reducing sedentary behaviour, defined as any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting, reclining or lying posture (Tremblay et al., 2017), has been recognised as an important public health target in older adults (De Rezende et al., 2014; Sparling et al., 2015). Older adult populations exhibit the highest levels of sedentary behaviour, spending up to 80% of their waking hours sitting (Giné-Garriga et al., 2020; Harvey et al., 2015; Wullems et al., 2016). Researchers have demonstrated that sitting or lying for prolonged periods of time is negatively associated with health status (Ku et al., 2018; Wilson et al., 2019). Pavey and colleagues highlighted that older women who sat 8 to 11 hours/day and those who sat ≥11 hours/day had 1.45 and 1.65 times higher risk of all-cause mortality respectively, compared to older women who sat less than 4 hours per day (Pavey et al., 2015). High levels of sedentary behaviour have also been associated with increased levels of social isolation in older adults (Tully et al., 2019). Though the cost of sedentary behaviour to the UK national health service has been estimated as £0.8 billion in the 2016-2017 financial year (Heron et al., 2019), the actual burden is likely to be higher, considering the broader societal costs associated with sedentary behaviour. The negative health consequences of high levels of sedentary behaviour appear to hold true even for those who meet the physical activity recommendations of the World Health Organization (WHO), of at least 150 minutes per week of moderate-intensity physical activity, but higher levels of physical activity may ameliorate this effect (Ekelund et al., 2016; Gennuso et al., 2013;

Katzmarzyk et al., 2009; Patel et al., 2010; van der Ploeg et al., 2012; van Uffelen et al., 2010).

Accurate measurement of sedentary behaviour is important in order to facilitate rigorous scientific evaluations of interventions designed to reduce sedentary behaviour. Device-based (e.g. hip-worn ActiGraph accelerometer; wrist-worn Axivity accelerometer; and thigh-worn ActivPAL accelerometer) and self-reported measures (e.g. Sedentary Behaviour Questionnaire (SBQ); Measuring Older Adults Sitting Time (MOST); International Physical Activity Questionnaire (IPAQ); LASA Sedentary Behaviour Questionnaire) are available. Self-report questionnaires have been predominantly used in large scale studies due to low administration cost and due to providing more information about the context of behaviour (e.g. watching television, reading, playing computer/video games, driving/riding in a car). Nevertheless, some limitations such as recall bias and the underestimation of sedentary time are likely with self-reported measures (Aguilar-Farías et al., 2014). The SBQ is a self-report instrument developed to evaluate the amount of time doing nine context-specific behaviours on weekdays and weekend days. The English-language version has been validated in overweight adults (Rosenberg et al., 2010); an adapted Spanish-language version was validated in patients with fibromyalgia (Munguía-Izquierdo et al., 2013); and a Turkish-language version in an adult population (Bakar et al., 2018). A recent study compared the Slovenian version of the SBQ (weekdays) against the ActivPAL3 micro also in an adult population (Kastelic & Šarabon, 2019). However, there are currently no studies that have validated the use of the SBQ in older adults. There has also been a lack of validation studies of self-reported sedentary behaviour measures in languages other than in English in older adults.

Authors of a recent study have shown minor differences assessing different physical behaviours, as well as both sitting and lying, between three different accelerometers placed at the thigh (ActiGraph GT3X, ActivPAL micro and the Axivity AX3). Researchers suggested that raw data should be processed and analysed in an identical manner (Crowley et al., 2019). However, some limitations for using accelerometers include their high cost and the added complexity when using them in large cohort studies, including participant's responsibility to wear the device for at least seven days to provide representative data as shown in previous studies (Hart et al., 2011). Older adults have reported additional challenges such as mild skin irritation with continuous wear (van der Berg et al., 2016), forgetting to replace the belt in the morning after removing it for sleeping and finding the device uncomfortable (Schrack et al., 2014). Thus, assessing the validity of self-report questionnaires such as the SBQ is especially relevant in the older adult population.

Therefore, the main aim of this study was to assess the criterion validity of the SBQ to measure sedentary behaviour in community-dwelling older adults using thigh and hip accelerometry. Our secondary aim was to validate the English, Spanish, German and Danish versions of the SBQ in the same population.

Material and methods

Study design & participants

This validation study used a cross-sectional design using baseline data collected from the SITLESS study. Briefly, the SITLESS study was a multi-center pragmatic three-armed randomized controlled trial which aimed to determine whether exercise referral schemes could be enhanced by self-management strategies to reduce sedentary behaviour, increase physical activity levels and improve health in the long-term in community-dwelling European older adults (≥65 years old). Full details of the study were described elsewhere (Giné-Garriga et al., 2017). All participants gave their informed consent prior to participation. From the overall SITLESS participants (N= 1360), a subsample of 801 participants (mean age 75.6 ± standard deviation 6.1 years old and 57.6% females) who answered all items in the SBQ and provided valid thigh-based accelerometry data in the baseline assessment were included in this validation study.

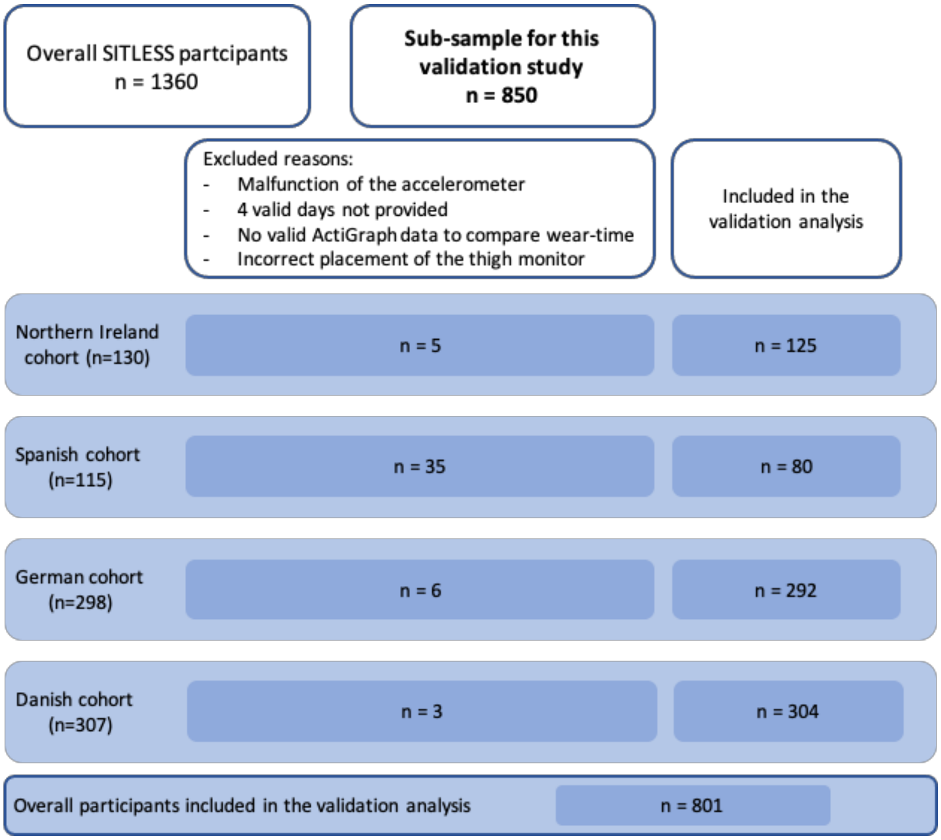

Figure 1. Sample flowchart

Measurement & procedure

Sedentary Behaviour Questionnaire (SBQ)

The SBQ version used was previously validated against self-reported measures by Rosenberg and colleagues (2010) in overweight male adults. Data showed an acceptable intraclass correlation coefficient (ICC) for all items and the total scale (range= 0.51-0.93), and significant relationships between SBQ items and the International Physical Activity Questionnaire (IPAQ) sitting time and body mass index (BMI) (Rosenberg et al., 2010). The SBQ assessed the amount of time spent doing nine context-specific behaviours during weekdays and weekend days, with the question 'on a typical weekday or weekend day, how much time do you spend (from when you wake up until you go to bed) doing the following?': watching television; playing computer/video games; sitting while listening to music; sitting and talking on the phone; doing paperwork or office work; sitting and reading a book or magazine; playing a musical instrument; doing arts and crafts; and sitting and driving/riding in a car or train. The possible responses options were: none, 15 minutes or less, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, or 6 hours or more. To obtain daily time sitting or lying, weekday hours were multiplied by five and weekend hours were multiplied by two; summed hours per week were divided by seven and finally multiplied by 60 to give minutes in sedentary behaviour per day.

Translation process

The translation and adaptation from English language to Spanish, German and Danish was completed following the recommendations of Hambleton et al. (Hambleton, 2005). The direct and inverse translation method in each language was completed by two independent bilingual translators to identify any discrepancies between the meaning of the translation and the original questionnaire. After a final consensus, researchers and translators generated the final versions of the questionnaires in Spanish, German and Danish.

Accelerometry

Participants were asked to wear an accelerometer on their dominant thigh continuously (24 hours/day) for seven consecutive days after completion of the SBQ. Two types of thigh accelerometers were used according to their availability at each site. The cohorts from Spain and Germany (n= 372) wore the ActivPAL3c (PAL technologies, Glasgow, Scotland) and the cohort from Northern Ireland and Denmark (n= 429) wore the Axivity AX3 (AXIVITY Ltd., Newcastle, UK). The ActivPAL (weighing 9g and measuring 25x45x5mm) was initialized using ActivPAL Professional Software (version 7.2.38.2) with a sampling frequency of 20Hz and a g range of ±2g and the Axivity (weighing 11g and measuring 23x32,5x7,6mm) was initialized using Open Movement OmGui Software (version 1.0.0.43) with a sampling frequency of 50Hz and a g range of ±8g. The ActivPAL and Axivity accelerometers were positioned on the dominant thigh midway between the anterior superior iliac spine and the patellar tendon and attached using a waterproof transparent film (hypoallergenic Tegaderm foam adhesive dressing, 3M, USA). For the purposes of determining accelerometer wear time for this specific study, participants were also asked to simultaneously wear the ActiGraph wGT3X-BT + (ActiGraph LLC, Pensacola, FL, USA) alongside the thigh accelerometer. The ActiGraph device was placed on the dominant hip using an elastic belt, just above the iliac crest, during waking hours only (removed during night-time sleep and water-based activities) for seven consecutive days. The ActiGraph wGT3X-BT (weighing 19g and measuring 46x33x15mm) was initialised using the ActiLife (version 6.13.4) software with a sampling frequency of 30Hz and a g range of ±6g (Robusto & Trost, 2012).

Data from both thigh-based accelerometers were pooled together and harmonized. Sedentary behaviour time (i.e. combined sitting/lying time) for the Axivity AX3 data was classified using the method described by Skotte and colleagues (Skotte et al., 2014). This method uses threshold values of standard deviation of acceleration, angle and also inclination to determine different types of activities, including sedentary behaviour (Skotte et al., 2014). This method has demonstrated an excellent sensitivity and specificity (93 to 100%) in semi-standardized and free-living settings (Crowley et al., 2019). Sedentary behaviour time from the ActivPAL was classified by the ActivPAL Professional Software (version 7.2.38.2) algorithm because the ActivPAL3 uses a lower sampling frequency compared to the Axivity (i.e. 20 vs 50Hz). The ActivPAL3 also covers a more limited g range (±2g) compared to the Axivity (±8g). The assessment of daily sedentary behaviour time from each thigh-worn accelerometer was restricted to wear time extracted from the .agd files generated by the hip-worn ActiGraph. Wear time information in the .agd files was identified using the Choi 2011 wear time algorithm using the ActiLife software (Giné-Garriga et al., 2020). With a small number of participants, it was observed that while the ActiGraph had been worn, the thigh-based accelerometer had not been worn in conjunction or suffered from a malfunction. In order to exclude these days from the analysis, the output derived from the harmonization process were subsequently manually cleaned by two authors (JJW and MS). The cleaning process ensured only valid days were included (at least four valid days (including one weekend day) and ≥600 minutes/day wear time) as suggested in previous studies (Migueles et al., 2017). Daily sedentary time, normalized at a daily level, was then calculated from the thigh-based monitors once the cleaning process had been completed.

Additional data

Additional data were included to describe the sample including age (years), sex (male and female), country (Northern Ireland, Spain, Germany and Denmark), BMI (kg/m2; using the Tanita BC 420 bioelectrical impedance scales and a Seca 213 portable stadiometer) to categorize weight status (normal and underweight: <25kg/m2; overweight: 25-29.9kg/m2; obese: >30kg/m2), Short Physical Performance Battery (SPPB) score to determine low or high physical function (<10 SPPB score or >10 SPPB score, respectively) (Guralnik et al., 1994) and the Trail Making Test (TMT) (Soukup et al., 1998) time to determine cognitive (TMT A; intact <78 seconds; deficient >78 seconds) / executive (TMT B; intact <180 seconds; mildly reduced >181 seconds) function used in several studies (Bowie & Harvey, 2006; Roy & Molnar, 2013), as well as with an older adult population (Cangoz et al., 2009).

Statistical analysis

The chosen analytical approach has been guided by recommendations for validating self-reported behaviour (Welk et al., 2019). Before conducting analyses, all variables were examined for normality using Shapiro-Wilk Test or Kolmogorov-Smirnov Test.

Paired samples t-tests were used to assess the differences in the mean values for daily sitting time between self-reported and device-measured daily sedentary behaviour time. Correlations were interpreted as follows: coefficient value between ± 0.50 and ± 1: strong positive/negative linear relationship or correlation; between ± 0.30 and ± 0.49: moderate positive/negative linear relationship or correlation; below ± 0.29: weak positive/negative linear relationship or correlation (Rumsey, 2005). Criterion validity was assessed using nonparametric Spearman's Rho coefficients.

To assess the agreement between daily sedentary behaviour time measured by the SBQ compared to the accelerometer estimated sedentary time, Bland-Altman plots (including the 95% limits of agreement) and Intraclass Correlation Coefficients (ICC) were utilised. The mean difference ± 1.96 x the standard deviation of the mean difference was added to the plot to derive the limits of agreement. These limits defined the interval in which differences between methods could be expected for 95% of future measurements in comparable people (Bland & Altman, 2007). Differences of the two measures were checked to be normally distributed (Giavarina, 2015). Accelerometer estimated sedentary time was used as the criterion measure; a mean difference close to y= 0 was a good indicator of agreement, as was a confidence interval encompassing y= 0, thus indicating higher levels of agreement with the daily sitting time from the SBQ. We considered wide limits of agreement having a mean difference of more than 240 minute/day of sedentary time according to two previous research studies (Aguilar-Farías et al., 2014; Gilbert et al., 2016).

The strength of the association between daily sedentary time measured by the SBQ compared to the accelerometer estimated sedentary time was examined using multiple linear regression with age, gender, country of origin, BMI, SPPB score and TMT times for cognitive and executive functioning as adjustment covariates in the same model.

Additional sub-group analyses were conducted to explore possible differences in the validity of SBQ in different languages (English versus Spanish versus German versus Danish); sex (males versus females); age groups (young-old: 65 to 74 years versus middle-old: 75 to 84 versus oldest-old: >85 years); weight status (normal and underweight versus overweight versus obese); physical functioning (low function versus high function); executive and cognitive functioning (intact executive/cognitive function versus reduced executive/cognitive function).

All statistical analyses were performed using IBM SPSS Statistics 26 (SPSS, Inc, an IBM Company, Chicago, IL, USA) and the significance level was set at $p < 0.05$.

Results

Out of 850 participants from the SITLESS study who were asked to wear a thigh accelerometer for seven consecutive days, 801 participants (57.6% female and 75.6 ± 6.1 years old) provided valid data for the SBQ and the thigh-based accelerometers. N= 49 participants were excluded as their data did not meet the pre-specified wear time criteria or there were technical problems with data processing.

Demographic characteristics are presented overall and by country in Table 1. Approximately 75% of the overall sample size was overweight or obese. The German cohort had the highest percentage of participants with low physical function (male: 71.5% and female: 77.8%) compared to the other three countries (Table 1). Executive and cognitive functions were similar across German, Danish and Northern Irish participants, but Spanish participants had lower executive and cognitive function (21.6% and 50.7%, respectively) (Table 1).

Table 1 Descriptive characteristics of the sample by gender and country.

	All participants			N. Ireland		Spain		Germany		Denmark	
	N (%)	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
N	801	340	461	65	60	16	64	130	162	129	175
Gender (%)	801 (100)	42.4	57.6	52	48	20	80	44.5	55.5	42.4	57.6
Mean age (years ± SD)	75.6 ± 6.1	75.8 ± 6.2	75.4 ± 6.1	71.8 ± 5.3	72.9 ± 5.7	78.7 ± 4.4	77.1 ± 6.4	74.9 ± 6.4	74.6 ± 6.0	78.5 ± 5.2	76.3 ± 5.8
Age (years) (%)											
65 to 74	427 (53.3)	178 (52.4)	249 (54.0)	83.1	71.7	18.8	42.2	59.2	56.2	34.1	50.3
75 to 84	307 (38.3)	133 (39.1)	174 (37.7)	13.8	25.0	81.3	43.8	30.8	37.0	55.0	40.6
≥ 85	67 (8.4)	29 (8.5)	38 (8.2)	3.1	3.3	-	14.1	10.0	6.8	10.9	9.1
Mean BMI (kg/m² ± SD)	28.5 ± 5.3	28.7 ± 4.1	28.5 ± 6.0	29.2 ± 4.6	28.6 ± 5.4	28.4 ± 4.0	29.6 ± 4.9	29.4 ± 4.4	29.3 ± 6.4	27.6 ± 3.5	27.2 ± 6.0
BMI (%)											
Normal and underweight (<25)	200 (25.0)	58 (17.1)	142 (30.8)	20.0	28.3	18.8	18.8	10.8	25.3	21.9	41.1
Overweight (25 to 29.9)	325 (40.6)	174 (51.3)	151 (32.8)	41.5	30.0	50.0	32.8	52.3	38.3	55.5	28.6
Obese (>30)	275 (34.4)	107 (31.6)	168 (36.4)	38.5	41.7	31.3	48.4	36.9	36.4	27.7	30.3
SPPB (%)											
Low function (<10 SPPB Score)	515 (64.3)	201 (59.1)	314 (68.1)	24.6	43.3	43.8	73.4	71.5	77.8	65.9	65.7
High function (>10 SPPB Score)	286 (35.7)	139 (40.9)	147 (31.9)	75.4	56.7	56.3	26.6	28.5	22.2	34.1	34.3
TMT (%)											
Executive function											
Mildly reduced	190 (24.2)	75 (22.6)	115 (25.3)	1.5	8.3	27.3	55.2	25.4	31.7	30.2	15.4
Intact	596 (75.8)	257 (77.4)	339 (74.7)	98.5	91.7	72.7	44.8	74.6	68.3	69.8	84.6
Cognitive function											
Deficient	84 (10.7)	32 (9.7)	52 (11.4)	1.5	-	9.1	32.2	12.3	16.1	11.2	4.0
Intact	702 (89.3)	299 (90.3)	403 (88.6)	98.5	100.0	90.9	67.8	87.7	83.9	88.8	96.9
Average Daily Wear Time (mins ± SD)	865.0 ± 68.0	863.1 ± 69.6	866.4 ± 66.9	861.8 ± 57.7	862.6 ± 61.7	860.0 ± 74.1	845.0 ± 71.6	857.7 ± 76.1	866.6 ± 66.6	896.4 ± 68.1	875.4 ± 65.7

SD = standard deviation; BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test

The criterion validity of the self-report daily minutes spent in sedentary behaviour assessed with the SBQ against accelerometer estimated sedentary behaviour is shown in Table 2. There was a weak correlation (Rho= 0.25, $p < 0.001$) between self-reported and device-based measures. Overall, participants reported an average of 472.9 ± 168.5 mins/day of sedentary behaviour with the SBQ. Accelerometers measured an average of 545.9 ± 112.9 mins/day from 865.0 ± 68.0 mins/day of wear time during waking hours. The difference between self-reported and accelerometers was 72.90 mins/day (95%CI -85.45, -60.32; $p < 0.001$) with the SBQ underestimating sedentary behaviour time compared to the accelerometer estimated sedentary behaviour.

Bland-Altman plots were used to graphically compare the differences between device-based and self-reported measurements (Figure 2). Overall, participants reported lower daily sitting time using the SBQ with a mean difference of -73.4 mins/day and a wide range of limits of agreement (LoA) (upper LoA= 278.8 mins/day, lower LoA= -425.6 mins/day) compared to the same outcome assessed with the device-based instruments. Divided by country, Northern Irish, German and Danish participants under-reported their time spent in sedentary behaviour with a mean difference of -60.7, -62.7 and -108.0 mins/day, respectively (range of upper LoA= 273.4 mins/day, lower LoA= -434.1 mins/day) (Figure 3). Spanish participants self-reported daily sitting time using the SBQ with a mean difference of 10.75 mins/day although with a wide range of LoA (upper LoA= 508.1 mins/day, lower LoA= -486.6 mins/day) compared to the device-based measured values (Figure 3). Participants with higher levels of accelerometer measured sedentary behaviour tended to overreport their sedentary time in the SBQ; while participants with lower levels of sedentary behaviour tended to underreport their sedentary time. This feature can be seen in Figure 3, markedly for Danish and Northern Irish participants. Overall, ICC data showed a weak agreement between both measures (ICC= 0.32, 95%CI 0.19, 0.43). Weak agreement between measures were also found across each language version (Table 2).

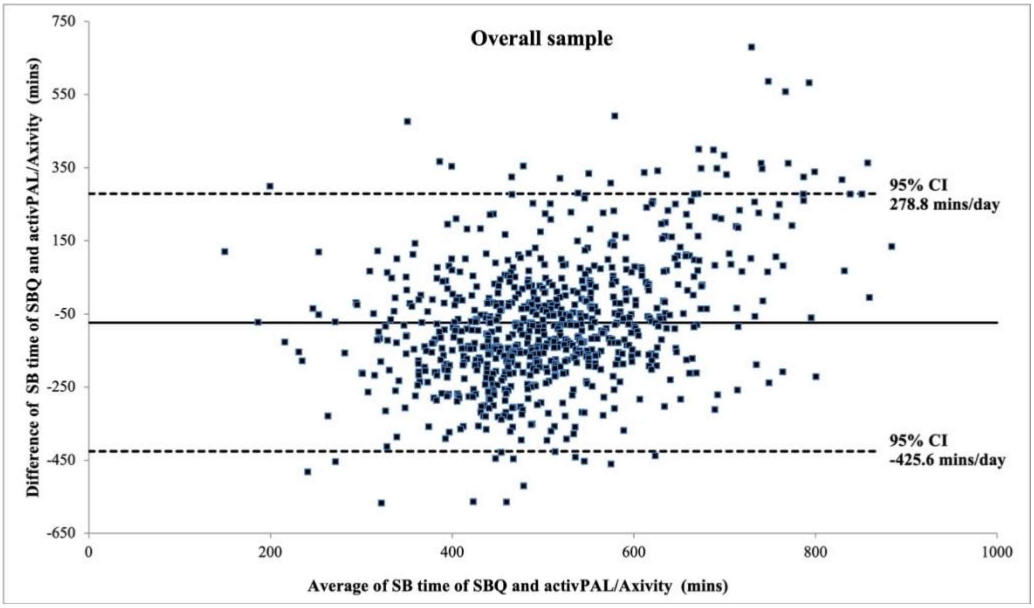

Figure 2. Overall Bland-Altman Plot. Solid line shows the mean different between the two measures; dash lines represent the 95%CI.

Table 2. Daily average minutes spent in sedentary behaviour overall and by country from the SBQ and ActivPAL/Axivity [mean ± standard deviation]; 95%CI; Intraclass Correlation Coefficient (Confidence intervals 95%); Rho Spearman's correlation; and *p* value.

	SBQ	**ActivPAL/Axivity**	**95% CI**	**ICC (95% CI)**	**Rho**	***p* value**
N. Ireland (n=125)	486.6 ± 173.3	547.3 ± 87.9	-91.02, -30.41	0.34 (0.08, 0.53)	0.28**	0.001
Spain (n=80)	472.1 ± 236.0	461.3 ± 121.3	-49.75, 71.26	0.15 (-0.36, 0.48)	0.06	0.613
Germany (n=292)	463.8 ± 149.1	526.5 ± 121.6	-82.20, -43.22	0.36 (0.18, 0.50)	0.23**	<0.001
Denmark (n=304)	476.2 ± 165.6	583.0 ± 95.7	-125.48, -88.12	0.32 (0.06, 0.50)	0.30**	<0.001
Total (n=801)	472.9 ± 168.5	545.9 ± 112.9	-85.48, -60.32	0.32 (0.19, 0.43)	0.25**	<0.001

Note. SBQ = Sedentary Behaviour Questionnaire; ICC = Intraclass Correlation Coefficient; ** $p \leq 0.001$

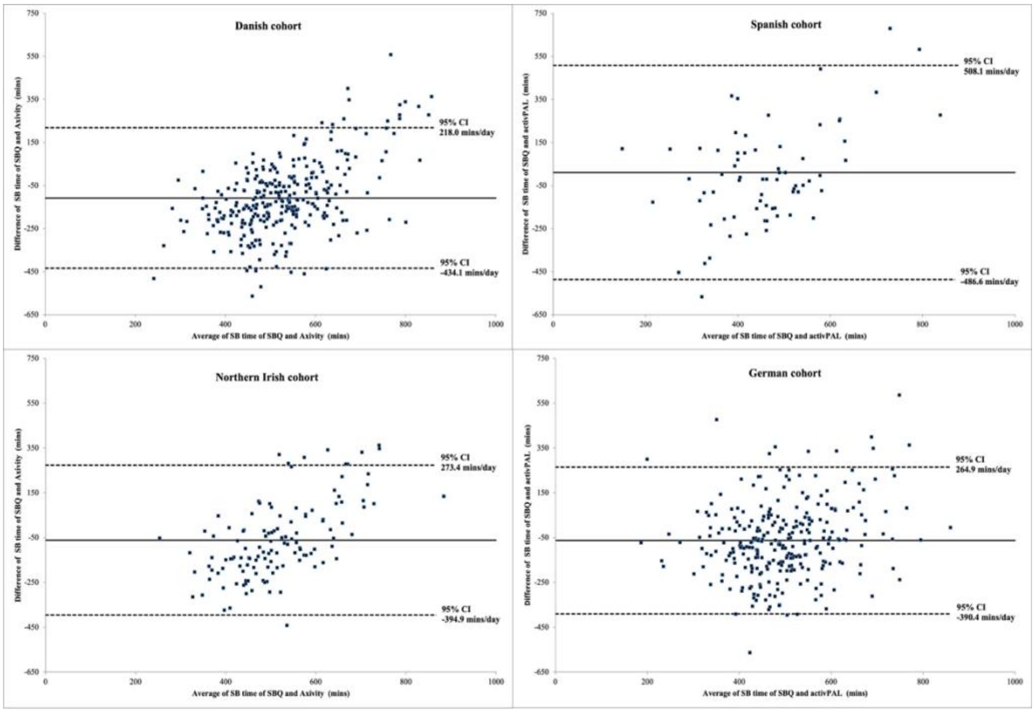

Figure 3. Bland-Altman Plot Panel by country. Solid line shows the mean different between the two measures; dash lines represent the 95%CI.

Table 3 shows the multiple linear regression model with daily sedentary behaviour time measured with the SBQ and covariates (country, age, gender, BMI, physical function and executive and cognitive functions) that predicted the response variable: accelerometer-measured daily sedentary time. The full model predicted 19% of the total variance. The effect modification was significant in all explanatory variables except for age and cognitive function (TMT A) ($p < 0.05$). After adjusting the model separately for each country, the model for the Danish cohort ($R^2 = 0.23$, $p < 0.001$), followed by those for German and Northern Irish participants ($R^2 = 0.16$, $p < 0.001$; $R^2 = 0.16$, $p = 0.003$, respectively) were able to explain the accelerometer-measured daily sedentary time better than the model for the Spanish cohort (R^2= 0.10, p= 0.567).

Criterion validity of each version of the SBQ with the matching language was analysed separately (Table 2). Data from the Danish version showed a moderate correlation (Rho= 0.30, $p \leq 0.001$) and data from the English, German and Spanish versions showed weak correlations (Rho= 0.28, $p < 0.001$; Rho= 0.23, $p < 0.001$ and Rho= 0.06, p= 0.613, respectively).

Correlations between SBQ and the accelerometer estimated sedentary time measures across countries and sub-groups are presented separately. In the Northern Irish cohort (see Supplementary Material 1; page 338), higher significant associations were found in the female subgroup (Rho= 0.35, p= 0.006) and the obese participants (Rho= 0.30, p= 0.032). Spanish participants (see Supplementary Material 2; page 339) showed no significant associations divided by subgroups. However, males and participants with intact executive function showed slightly higher associations than the other subgroups (Rho= 0.39, p= 0.076; Rho= 0.30, p= 0.223, respectively). Although associations were weak in the German version, moderate associations were found in different subgroups (see Supplementary Material 3; page 340). Those groups that showed slightly higher significant associations were participants with normal and underweight (Rho= 0.45, $p < 0.001$) and high physical function (Rho= 0.45, $p < 0.001$). The association was weak-to-moderate and almost equivalent in each Danish subgroup (see Supplementary Material 4; page 341) but showed slightly higher significant association in female (Rho= 0.39, $p < 0.001$) and the low function participants subgroup (Rho= 0.34, $p < 0.001$).

Table 3. Multiple linear regression model for daily sedentary time measured with accelerometry adjusted by average minutes spent in sedentary behaviour measured with SBQ, centre of study, age, gender, BMI, physical function and executive and cognitive functioning in the same model.

	Overall			N. Ireland			Spain			Germany			Denmark		
	R^2	**St. Beta**	***p* value**	**R^2**	**St. Beta**	***p* value**	**R^2**	**St. Beta**	***p* value**	**R^2**	**St. Beta**	***p* value**	**R^2**	**St. Beta**	***p* value**
Model	0.19	-	<0.001	0.16	-	0.003	0.10	-	0.567	0.16	-	<0.001	0.23	-	<0.001
Average minutes spent in sedentary time (SBQ)		0.217	<0.001		0.255	0.005		0.066	0.649		0.259	<0.001		0.246	<0.001
Center of study		-0.222	<0.001		-	-		-	-		-	-		-	-
Age		0.005	0.904		-0.021	0.839		0.092	0.528		-0.004	0.947		0.049	0.385
Gender		-0.280	<0.001		-0.202	0.026		-0.152	0.307		-0.311	<0.001		-0.211	<0.001
BMI		0.076	0.031		0.129	0.179		-0.050	0.728		0.032	0.577		0.217	<0.001
Physical function (SPPB Score)		-0.107	0.006		-0.180	0.095		0.047	0.782		0.014	0.827		-0.129	0.032
Executive functioning (TMT B)		-0.147	0.001		-0.026	0.830		-0.297	0.077		-0.054	0.486		-0.098	0.126
Cognitive functioning (TMT A)		0.050	0.260		-0.001	0.994		0.231	0.172		0.034	0.656		0.142	0.023

Dependent variable: Daily sedentary time measured with accelerometry

R^2 = R Squared; St = Standardized coefficient; SBQ = Sedentary Behaviour Questionnaire; BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test.

Discussion

This is the first study to assess the validity of the SBQ in four different languages (English, Spanish, German and Danish) in an older adult population. Our results showed an overall weak positive correlation between the self-reported measures and the accelerometer estimated sedentary time. However, whenever each version of the SBQ with the matching language was analysed separately, data of the Danish version showed a moderate correlation while the English, German and Spanish versions showed weak correlations. When overall absolute agreement was assessed, daily minutes in sedentary behaviour of the SBQ with the equivalent variable derived from the accelerometer data, suggested a weak agreement between measures.

Similar to other studies, our findings showed an underestimation of 72.90 mins/day between self-reported and accelerometer measures. Kastelic and Sarabon (2019) compared the Slovenian version of the SBQ (weekdays) against the ActivPAL in an adult population and showed an underestimation of the SBQ with a mean difference between measures of -181 mins/day (Kastelic & Šarabon, 2019). The Bouchard Activity Record, which is a self-report instrument used to assess all levels of the physical activity spectrum from lying and sitting to vigorous-intensity activity, detected significantly less time in sedentary behaviour (487.0 ± 194.3 mins/day) than the ActivPAL (518.5 ± 147.8 mins/day) (Hart et al., 2011). Another questionnaire specific to older adults (e.g. the MOST questionnaire), also underestimated daily sedentary behaviour time by 3.6 hours compared to accelerometer-based measures (Gardiner et al., 2011). Self-reported measures appear to have poor accuracy and generally provide an underestimation of the time spent in sedentary behaviour, especially in older adults (Celis-Morales et al., 2012). According to Harvey et al. (2013), 58.9% of the participants (n= 372,550 older adults from seven countries) included in a meta-prevalence analysis of sitting time reported sitting >4 hours per day, 26.6% reported >6 hours per day and just 5% reported over 10h per day; whereas 67% of these participants were sedentary for more than 8.5 hours per day using objective measures (Harvey et al., 2013).

The Bland-Altman plot of overall absolute agreement of daily minutes in sedentary behaviour of the different SBQ versions with the equivalent variable derived from the accelerometers data showed a mean difference of -73.45 minutes, and the limits of agreement were (-425 mins to 278 mins), suggesting an overall weak agreement (ICC= 0.32, 95%CI 0.19, 0.43). Our study showed slightly higher agreement between measures compared to another study that found a ICC= 0.014 (95%CI -0.21, 0.26) (Kastelic & Šarabon, 2019).

In comparison with other studies, our data displayed slightly higher correlation coefficients than shown in previous SBQ validation-based studies (Bakar et al., 2018; Kastelic & Šarabon, 2019; Munguía-Izquierdo et al., 2013; Rosenberg et al., 2010). Bakar et al. (2018) used the self-reported IPAQ as a validity criterion (Craig et al., 2003) showing a weak correlation (Rho between -0.026 to 0.144 on weekdays and -0.083 to 0.175 on weekends). However, it is important to consider that using another subjective measure as a criterion measure was not ideal. The Slovenian version of the SBQ (weekdays) showed a weak correlation (Rho= 0.01) compared to the ActivPAL among adult population (Kastelic & Šarabon, 2019). Similarly, the Spanish version of the SBQ validated among fibromyalgia patients (Munguía-Izquierdo et al., 2013) showed a weak correlation (Rho= 0.06) compared with the SenseWear Pro3 Armband monitor. Rosenberg and colleagues (2010) showed no correlation for males but a higher association for females (Rho= 0.26) compared to the ActiGraph accelerometer measure. Similarly, Nelson and colleagues (2019) compared the IPAQ sedentary time question against the ActiGraph device in undergraduate students and also showed a weak correlation (Rho= 0.26) (Nelson et al., 2019). However, these validation studies have used hip-worn accelerometers that are poor at distinguishing between postures. Our study used well-accepted thigh-based accelerometry to measure postural changes which could potentially explain the differences when compared to the other validation studies.

Underestimation of sedentary behaviour in older adults could be explained due to a lack of awareness of the many occasions which require time spent sitting down. Memory capacity may also be reduced in some older adults, making it difficult to accurately provide relevant answers for self-reported instruments. A 10-item questionnaire developed for older adults (e.g. LASA Sedentary Behaviour Questionnaire), correlated moderately (Rho= 0.35, $p < 0.001$) with total objective sedentary time (Visser & Koster, 2013). Activities such as napping, hobbies or talking with friends were included in this questionnaire and could explain some of the difference with our results since the SBQ does not include such activities. Time spent in activities such as afternoon napping or chatting after eating could potentially explain the weak association found in the Spanish cohort. Despite some studies highlighting poor associations between questionnaire and accelerometry-measured sedentary behaviour, others have shown more moderate correlations. Aguilar-Farías et al. (2014) showed a weak-to-moderate correlation (Rho= 0.28 to 0.33) against the ActivPAL accelerometer worn by older adults using one single question on weekdays and weekend days: "How many hours each day do you typically spend sitting down while doing things like visiting friends, driving, etc.?" (Aguilar-Farías et al., 2014).

In the present study, some differences between versions were apparent. For our analysis, the English, German and Danish versions (Rho= 0.28, 0.25 and 0.30, respectively) showed higher correlations between self-reported and device-based measures than the Spanish version (Rho= 0.06). Differences between versions could potentially be explained due to the small Spanish sample size included in the analysis compared to the other countries. In the current study, higher associations in females in the Danish, English and German versions (Rho= 0.39, 0.35, 0.27, respectively) were found compared to males except in the Spanish version (Rho< 0.01). Likewise, in Rosenberg and colleague's study, these findings suggest that females report their sedentary behaviours with greater accuracy (Rosenberg et al., 2010).

To accurately self-report sedentary behaviour, cognitive function, concentration and memory should be intact (Rikli, 2000). Munguía-Izquierdo and colleagues (2013) used the Spanish version of the Mini-Mental State Examination (Blesa et al., 2001) to screen cognitive function and excluded those participants with moderate-to-severe cognitive decline. In the current study, the TMT (Soukup et al.,

1998) was used to assess cognitive functions. The low association found between measures in participants with deficient cognitive function could be explained due to the small percentage of participants in this group (10.7% overall). However, our findings suggest that self-reported sedentary behaviour may not be suitable for individuals classified in the 'cognitively deficient' group on the TMT.

Assessing sedentary behaviour in older adult populations may be challenging (Wullems et al., 2016). It is important to accurately measure sedentary behaviour to determine its association with health status, to planning effective interventions, and to informing public health policy makers. Capturing its two primary components (posture and energy expenditure) can be challenging. Moreover, there are many factors that can bias the assessment such as an inappropriate criterion measure (e.g. motion sensors instead of direct observation), mode of administration (e.g. interview or self-report), the recall period, and the population being assessed (e.g. children, adults or older adults) (Kang & Rowe, 2015). Sedentary behaviour is not commonly structured and purposive like physical activity; and it tends to be scattered throughout the day. This may negatively impact participants' ability to recall accurately the amount of time spent in sedentary behaviours (Healy et al., 2011). It may also be challenging for researchers and health professionals to design robust strategies to reduce sedentary behaviour based on total daily sedentary time (e.g. basic summary measures obtained with objective and self-report instruments). Because the SBQ describes time in sedentary behaviour in several context-specific behaviours throughout an entire week (i.e. also including weekend days alongside weekdays), individualized and targeted interventions can more effectively target time spent in these sedentary activities. It is also worth noting that accelerometry assesses both sitting and lying behaviours whereas the SBQ asks specifically for sitting time spent in 4/9 context-specific activities, three of which could be completed lying down and would not be captured with this questionnaire (sitting while listening to music; sitting and talking on the phone; sitting and reading a book or magazine; sitting and driving/riding in a car or train). This would be counted as a limitation of the questionnaire.

Furthermore, the weak correlation could also be explained due to the limited sedentary behaviour domains that the SBQ includes, which may not completely align with some daily common activities that older adults tend to do in these countries. Outdoor activities such as playing board games in leisure centres, sitting in a park or in a bar with friends and having long meals in restaurants, should be considered in country-specific SBQ versions due to different environmental conditions (e.g. weather) and cultures.

This is the first study that has attempted to validate the SBQ in older adults. Our results provide initial evidence of the English, Spanish, German and Danish SBQ versions showing a weak relationship against the thigh-based accelerometry measures, a well-accepted criterion standard used to assess sedentary behaviour across many studies. However, given the overall weak correlation, further research is needed to include other sedentary behaviour-related daily activities older adults may spend time in to get more accurate estimates of total daily sedentary time. Napping (in some cultural-specific domains), eating breakfast, lunch and dinner could be one of the reasons for under-reporting. Also, the SBQ includes some questions that may not be suitable for most older adults, such as playing computer or video games.

The findings of this study suggest that the SBQ may not provide a robust estimation of daily sedentary time in older adults in population-based studies. It is important to consider that older adult populations have generally tended to underestimate their levels of daily sedentary time (Celis-Morales et al., 2012; Gardiner et al., 2011). The under-reporting of sedentary behaviour also suggests that epidemiological studies assessing the relationship between self-reported sedentary time and health outcomes may underestimate the true relationship. Therefore, it is recommended that researchers and clinicians should try to concurrently utilise device-based measures to provide a more accurate estimation of sedentary behaviour as well as questionnaires to evaluate specific domains of sedentary time in this population.

Strengths and limitations

The large sample size from four different European countries and the use of thigh-based accelerometry as a criterion measure should be considered strengths of this study. However, when criterion validity was assessed separately by country, the small sample size of the Spanish cohort compared to the other countries should be considered as a limitation that could be biasing the study results. Additionally, several subgroups, such as participants over 85 years old or participants with deficient cognitive function at the TMT, were low percentage in some cohorts. Associations between self-reported and objective measures in those groups should be considered an exploratory analysis due to small sample sizes. Another limitation was that accelerometers account for both sitting and lying behaviours whereas the SBQ specifically assesses sitting time in 4/9 context-specific behaviours, which could partially explain the weak correlation between both tools. Finally, being unable to use the same algorithm to classify sedentary behaviour time for both the Axivity and ActivPAL3 was not ideal.

Conflict of interest and Source of Funding

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Estudi III

Sansano-Nadal, O., Giné-Garriga, M., Rodríguez-Roca, B., Guerra-Balic, M., Ferri, K., Wilson, J., Caserotti, P., Olsen, P., Blackburn, N., Rothenbacher, D., Dallmeier, D., Roqué-Fíguls, M., Mcintosh, E., & Martín-Borràs, C. (2021). Association of Self-Reported and Device-Measured Sedentary Behaviour and Physical Activity with Health-Related Quality of Life among European Older Adults. International Journal of Environmental Research and Public Health 2021, Vol. 18, Page 13252, 18 (24), 13252. https://doi.org/10.3390/IJERPH182413252

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Association of self-reported and device-measured sedentary behaviour and physical activity with health-related quality of life among European older adults.

Oriol Sansano-Nadal[1]*; Maria Giné-Garriga[1,2]; Beatriz Rodríguez-Roca[3]; Myriam Guerra-Balic[1]; Kelly Ferri[1]; Jason J. Wilson[4,5]; Paolo Caserotti[6]; Pia Øllgaard Olsen[6]; Nicole E. Blackburn[7]; Dietrich Rothenbacher[8]; Dhayana Dallmeier[9,10]; Marta Roqué-Fíguls[11]; Emma McIntosh[12]; Carme Martín-Borràs[1,2]

1. Department of Physical Activity and Sport Sciences, Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Císter 34, 08022 Barcelona, Spain.
2. Department of Physical Therapy, Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Padilla 326-332, 08025 Barcelona, Spain.
3. Department of Physiatry and Nursing, Faculty of Health Sciences. University of Zaragoza, Domingo Miral, 50009, Zaragoza, Spain.
4. Sport and Exercise Sciences Research Institute, School of Sport, Ulster University, Newtownabbey, BT37 0QB, UK.
5. Institute of Mental Health Sciences, School of Health Sciences, Ulster University, Newtownabbey, BT37 0QB, UK.
6. Center for Active and Healthy Ageing (CA-HA), Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark.
7. Institute of Nursing and Health Research, School of Health Sciences, Ulster University, Newtownabbey, BT37 0QB, UK.

8. Institute of Epidemiology and Medical Biometry, Ulm University, Helmholtztr 22, 89081 Ulm, Germany.
9. Research Unit on Aging, Agaplesion Bethesda Clinic, Zollernring 26, 89073 Ulm, Germany.
10. Department of Epidemiology, Boston University School of Public Health, 715 Albany Street Boston, MA 02118 USA.
11. Fundació Salut i Envelliment (Foundation on Health and Ageing)-UAB, Universitat Autònoma de Barcelona, Sant Antoni Maria Claret 171, 08041 Barcelona, Spain.
12. Health Economics and Health Technology Assessment (HEHTA), Institute of Health and Wellbeing (IHW), University of Glasgow, Glasgow, G12 8QQ, UK.

*Correspondence: oriolsn@blanquerna.url.edu; 34 93253300

Abstract

Human movement behaviours such as physical activity (PA) and sedentary behaviour (SB) during waking time have a significant impact on health-related quality of life (HRQoL) in older adults. This study aimed to analyse the association between self-reported and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries. A subsample of 1193 participants from the SITLESS trial (61% women and 75.1 ± 6.2 years old) were included in the analysis. The association between self-reported and objective measures of SB and PA, and HRQoL were quantified using Spearman's Rho coefficients. The strength of the associations between self-reported and device-measured PA and SB with self-rated HRQoL (mental composite score – MCS and physical composite score – PCS) were assessed through multivariate multiple regression analysis. Self-reported and device-measured PA and SB levels showed significant but poor associations with PCS ($p < 0.05$). The association with MCS was only significant but poor with self-reported light PA (LPA) and moderate-to-vigorous PA (MVPA). In conclusion, the findings of this study suggest that both self-reported and device-measured PA of all intensities were positively and significantly associated, while SB was negatively and significantly associated with the PCS of the SF-12.

Keywords: Sedentary behaviour; Physical activity; Accelerometer; Health-related Quality of life; Older adults.

Introduction

Human movement behaviours such as physical activity (PA) and sedentary behaviour (SB), have a significant impact for health and quality of life (QoL) in older adults (Gennuso et al., 2013; López-Torres et al., 2019). Health-related quality of life (HRQoL) in the older adult population is gaining researchers' and policy makers' attention since life expectancy worldwide, especially in European countries, is increasing. In 2015, the older adult population (≥65 years old) was 17.4% worldwide (He et al., 2016); this percentage is expected to increase, reaching 33% by 2060 (Federal Office of Statistics, 2015).

Low levels of SB, defined as any waking behaviour with an energy expenditure ≤1.5 Metabolic Equivalent Task (MET) while in a sitting, reclining or lying posture (Tremblay et al., 2017), and regular PA, have been associated with better-perceived quality of life in older adults (Boberska et al., 2018; J. Kim et al., 2017; Su et al., 2019; Wilson et al., 2019; Withall et al., 2014). More active and less sedentary older adults have shown better self-rated health in several studies (Liposcki et al., 2019; Tew et al., 2017). Based on these findings, another recent study has suggested that higher levels of PA - and therefore, a better perception of HRQoL - were significantly associated with successful ageing measured with the Successful Aging Scale for older adults (Choi et al., 2017). Successful aging is considered a complex construct cluster of factors such as QoL, life-satisfaction and well-being, which includes movement behaviours (Ziółkowski et al., 2015). Higher levels of PA predicted further maintenance of functional status including functional capacity, increased muscle mass and strength which had also been related to HRQoL in this population (Cunningham et al., 2020). Another study suggested that higher amounts of PA could improve cognitive and physical functions, leading to a positive effect in successful aging in older adults (Yi-Hsuan et al., 2020). High levels of SB had also been associated with HRQoL among older adults. Kim and colleagues showed that higher SB levels as the older adults age were associated with poorer HRQoL (Y. Kim & Lee, 2019). A recent overview of systematic reviews showed that movement behaviours, including SB and PA levels, influenced heath status among adults (Saunders et al., 2020). SB and PA, and their relationship to HRQoL have been widely studied in younger age groups (e.g. adolescents, adults) (Y. Ge et al., 2019; Palomino-Devia et al., 2018). However, scientific literature in the older adult population is limited (Chigateri et al., 2018; Heesch et al., 2018), and even more scarce using device-based measures of PA and SB in large samples (Matthews et al., 2012).

Therefore, this study aimed to further investigate the associations between self-reported SB and PA and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries.

Material and methods

Participants

This study used a cross-sectional design using baseline data from the SITLESS study. Briefly, the SITLESS study is a multi-center pragmatic three-armed randomized controlled trial. The purpose of the study was to determine whether an exercise referral scheme, enhanced by self-management strategies to reduce SB, could increase PA levels and improve health in the long-term in community-dwelling European older adults (≥65 years old) from Spain, Germany, Denmark and United Kingdom (U.K.; in Northern Ireland). Included participants were insufficiently active (according to general guidelines) and/or reported being highly sedentary (>6 hours in SB) (Giné-Garriga et al., 2017). The SITLESS study was approved by the Ethics and Research Committee of each institution. Participation was voluntary and all participants signed informed consent before the first assessment. Out of 1360 community-dwelling older adults, a subsample of 1193 participants who fully completed the SF-12, the SBQ, the modified IPAQ and returned valid accelerometer data from the hip-worn ActiGraph were analysed for this cross-sectional study.

Data collection

Personal information including age, sex, and educational background was collected with an individual interview and the number of current medications was obtained through the health-care electronic registry. All demographic characteristics were collected during each assessment across all sites between 2016 and 2017. Weight and height were measured using a TANITA BC 420 and a SECA 213 portable stadiometer to obtain the participants' body mass index (BMI). Participants were asked to self-report their daily sedentary time using the SBQ (Rosenberg et al., 2010) and their total time spent walking (LPA; 3.3 METs per minute), in moderate PA (MPA; 4 METs per minute) and vigorous PA (VPA; 8 METs per minute) using the modified IPAQ

(Hurtig-Wennlf et al., 2010). Both questionnaires are valid to assess SB (Sansano-Nadal et al., 2021) and PA (Lines et al., 2020). Some limitations such as recall bias and poor correlation with objective measures are likely with self-reported measures of both behaviours in older adults (Aguilar-Farías et al., 2014; Gilbert et al., 2016; Hart et al., 2011; Sansano-Nadal et al., 2021; Urda et al., 2017). However, they have been widely used in large scale studies due to their low administration cost. Moreover, the SBQ provides relevant information regarding context of behaviour (Ainsworth et al., 2015). Self-rated HRQoL was assessed using the 12-Item Short-Form Health Survey (SF-12) to obtain the physical and mental composite scores (Ware et al., 1996). The SF-12 questionnaire has been used as an important tool to describe self-reported perception of HRQoL (Thiel et al., 2017). The SF-12 scoring method proposed by Ware et al. (1996) assumes that each item (from an 8-dimension profile including physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, limitations due to emotional problems and mental health) contributes to both the physical component score (PCS) or the mental component score (MCS), and that these two measures are uncorrelated (Ware et al., 1996). To overcome the aforementioned limitations of self-reported measures, participants were also asked to wear an ActiGraph wGT3X-BT triaxial accelerometer (ActiGraph, LLC, Pensacola, FL) on their dominant hip during waking hours for seven consecutive days. Participants were asked to remove the device only for water-based activities (e.g. bathing or swimming) and during sleep time. Wear time and non-wear time was calculated using the Choi 2011 algorithm (Choi et al., 2011). A small number of participants wore the device continuously (i.e. no removal during sleep). To reduce conflation of sleep and SB time, a pragmatic maximum daily wear time threshold of 19 hours was used. For relevant participants, their activity diary was used to record on/off times. The accelerometers were initialised to collect data at 30 Hz using the normal filter setting. A valid accelerometer dataset contained at least four valid days (including at least one weekend day), with a valid day defined as containing at least 600 minutes of wear time to be included in the analysis as in previous studies (Migueles et al., 2017). SB was defined as <100 counts per minute (CPM), LPA as 100-2019 CPM, and MVPA as ≥2020 CPM on the vertical axis (Troiano et al., 2008). Raw accelerometry data was analyzed using ActiLife v6.13.3 software summarized into 10-second epochs, as have been recommended for estimation of SB in clinical older adult populations (Byrom et al., 2016).

Statistical analysis

Demographic characteristics of the sample size were presented descriptively as mean and standard deviation (SD) for continuous variables and percentage for categorical variables separately by country and overall. The association between self-reported and objective measures of SB and PA, and HRQoL were quantified using non-parametric Spearman's Rho coefficients after all variables were examined for normality using the Kolmogorov-Smirnov Test. Correlations were interpreted as follows: coefficient value between +1 and -1: perfect positive/negative linear relationship or correlation; between +0.8 and -0.9: very strong positive/negative linear relationship or correlation; between +0.6 and -0.7: moderate positive/negative linear relationship or correlation; between +0.3 and -0.5 fair positive/negative linear relationship or correlation; between +0.1 and -0.2: poor positive/negative linear relationship or correlation; and 0: non-linear relationship or correlation (Akoglu, 2018). The strength of the association between self-reported time spent in PA and SB (model *a*) and device-measured daily time spent in PA and SB (model *b*) and self-rated HRQoL (SF-12: MCS and PCS) were assessed through multivariate multiple regression analysis. Model *c* and model *d* were adjusted for covariates: Country (Spain, Germany, Denmark and U.K.), age (years), sex (male / female), BMI categories (≤24.9 underweight and normal, 25.0 – 29.9 overweight, ≥30 obese), educational background (never attended school; primary education; secondary education; university; and unknown) and number of current medications. Each independent variable was investigated for collinearity using the variance inflation factor (VIF; collinearity: VIF > 4) which identifies correlation between independent variables and the strength of that correlation. All statistical analyses were performed using IBM SPSS Statistics 26 (SPSS, Inc, an IBM Company, Chicago, IL, USA) and the significance level was set at $p < 0.05$.

Results

Out of the 1360 participants in the SITLESS trial, 167 participants were excluded as they did not meet the pre-specified ActiGraph wear time criteria or did not complete the self-reported questionnaires. A final subsample of 1193 participants (75.1 ± 6.2 years old, 61% women) returned valid accelerometer data, completed the SF-12, the SBQ and the IPAQ.

Descriptive characteristics of the sample are presented in Table 1. Approximately 75% of the overall sample was overweight or obese (mean BMI = 28.8 ± 5.2 and ranged from 16.7 kg/m^2 to 51.5 kg/m^2). Women BMI ranged from 16.7 kg/m^2 to 51.5 kg/m^2 (mean women BMI = 28.9 ± 5.8) and men BMI ranged from 19.8 kg/m^2 to 45.8 kg/m^2 (mean men BMI = 28.7 ± 4.2). Of all participants, 54.1% reported having completed secondary education while 3.1% of the overall sample reported that they never attended school. The number of current medications ranged from 0 to 19 with a mean of 4.5 ± 3.2. Some 70% of the participants reported good to excellent general health. Nevertheless, a small percentage (3.9%) reported poor general health status with the SF-12 survey. The PCS across all participants (45.0 ± 9.1) ranged from 15.6 to 65.7. The MCS across all participants (51.9 ± 8.9) ranged from 18.4 to 71.1.

Descriptive characteristics of self-reported and device-measured SB and PA levels are shown in Table 1. No significant differences (p= 0.082) were found between countries regarding the self-reported average mean hours per day of SB (overall mean average 7.7 ± 2.8 h/d). Self-reported LPA differed (p< 0.05 using Bonferroni's test) between Spanish (1.0 ± 1.3 h/d) and U.K. participants (1.0 ± 1.0 h/d) versus Danish (1.3 ± 1.6 h/d) and German participants (1.3 ± 1.4 h/d). U.K. participants showed significant differences (p< 0.05 using Bonferroni's test) against other countries' participants regarding MVPA levels (overall 0.7 ± 1.1 h/d). Device-measured SB was 78.8% of daily awake time out of 14.4 hours of mean daily wear time in the overall sample. Danish participants showed the highest proportion of device-measured daily SB (81.0%). Device-measured daily LPA was 18.6% and MVPA was 2.6% in the overall sample. U.K. participants showed the highest levels on both PA intensities (19.8% and 3.7%, respectively).

Table 1. Descriptive variables of the sample.

	Overall (n = 1193)	**Spain** (n = 263)	**Germany** (n = 304)	**Denmark** (n = 318)	**UK** (n = 308)
Age (years), mean (SD)	75.2 (6.2)	75.9 (6.4)	74.7 (6.1)	77.3 (5.7)	72.6 (5.5)
Sex (women), n (%)	733 (61.4)	207 (78.7)	172 (56.6)	185 (58.2)	169 (54.9)
BMI, mean (SD)	28.8 (5.2)	28.9 (5.0)	29.2 (5.6)	27.3 (5.0)	28.9 (5.0)
BMI categories, n (%)					
Underweight and normal (≤24.9 kg/m^2)	274 (23.0)	39 (14.8)	61 (20.1)	106 (33.4)	68 (22.1)
Overweight (25 to 29.9 kg/m^2)	488 (40.9)	102 (38.8)	131 (43.1)	129 (40.7)	126 (40.9)
Obese (≥30 kg/m^2)	430 (36.1)	122 (46.4	112 (36.8)	82 (25.9)	114 (37.0)
Educational background, n (%)					
Never attended school	37 (3.1)	35 (13.4)	1 (0.3)	1 (0.3)	-
Primary education	232 (19.5)	112 (42.9)	9 (3.0)	93 (29.3)	18 (5.9)
Secondary education	642 (54.1)	84 (32.2)	217 (71.9)	182 (57.4)	159 (51.8)
University	272 (22.9)	29 (11.1)	74 (24.5)	40 (12.6)	129 (42.0)
Unknown	4 (0.4)	3 (0.4)	3 (0.3)	2 (0.3)	2 (0.3)
Number of current medications, mean (range)	4.5 (0-19)	4.8 (0-16)	4.3 (0-16)	3.9 (0-14)	4.8 (0-19)

	Overall (n = 1193)	**Spain** (n = 263)	**Germany** (n = 304)	**Denmark** (n = 318)	**UK** (n = 308)
Self-reported general health (SF-12), n (%)					
Excellent	35 (2.9)	1 (0.4)	1 (0.3)	16 (5.0)	17 (5.5)
Very good	216 (18.1)	19 (7.2)	24 (7.9)	69 (21.7)	104 (33.8)
Good	584 (49.0)	116 (44.1)	160 (52.6)	177 (55.7)	131 (42.5
Fair	311 (26.1)	106 (40.3)	107 (35.2)	51 (16.0)	47 (15.3)
Poor	47 (3.9)	21 (8.0)	12 (3.9)	5 (1.6)	9 (2.9)
Physical component (SF-12), mean (SD)	45.0 (9.1)	42.1 (9.4)	43.6 (8.7)	46.1 (8.6)	47.6 (8.9)
Mental component (SF-12), mean (SD)	51.9 (8.9)	49.7 (9.1)	50.1 (9.3)	54.1 (8.1)	53.2 (8.2)
Self-reported SB (h/d), mean (SD)					
Daily sedentary time	7.7 (2.8)	7.4 (3.2)	7.6 (2.4)	7.9 (2.7)	7.9 (2.8)
IPAQ (h/d), mean (SD)					
LPA	1.9 (1.3)	1.0 (1.0)	1.3 (1.4)	1.3 (1.6)	1.0 (1.0)
MVPA	0.6 (1.1)	1.1 (1.1)	0.6 (0.9)	0.5 (0.8)	1.1 (1.2)
Accelerometry (h/d), mean (SD)					
Daily sedentary time	11.3 (1.3)	11.3 (1.3)	11.2 (1.3)	11.7 (1.1)	10.9 (1.1)
Daily LPA	2.7 (0.9)	2.6 (0.8)	2.7 (0.9)	2.5 (0.9)	2.8 (0.8)
Daily MVPA	0.4 (0.3)	0.3 (0.3)	0.4 (0.3)	0.2 (0.2)	0.5 (0.4)
Total wear time (h/d), mean (SD)	14.4 (1.2)	14.2 (1.2)	14.3 (1.2)	14.5 (1.1)	14.3 (1.0)

BMI: body mass index; IPAQ: international physical activity questionnaire; LPA: light physical activity; MVPA: moderate-vigorous physical activity

Table 2 displays the association between self-reported and device-measured levels of PA and SB with PCS as well as MCS. PA and SB levels both device-measured and self-reported showed a poor-to-fair significant association ($p \leq 0.05$ across all PA and SB variables) with PCS. It is important to note that all SB-related measures (both device-based assessment and self-reported) showed a poor negative significant association with PCS in the model (e.g. the less sedentary an individual was, the better PCS was perceived) ($p < 0.05$). Nevertheless, when the association between self-reported and device-measured levels of PA and SB with MCS was analysed, significant associations were only found between self-reported LPA and MVPA ($p < 0.05$), but no significant associations were found between device-measured daily hours in LPA and MVPA or daily hours in SB with MCS.

Table 2. Relationship between self-reported and device-measured SB and PA, and the physical and mental component scores of the SF-12 (HRQoL). Spearman's Rho coefficients and *p* value.

	Physical Component SF-12		Mental Component SF-12	
	Spearman's Rho	***p* value**	**Spearman's Rho**	***p* value**
Self-reported SB (SBQ)				
Daily sedentary time	-0.078**	0.007	0.033	0.251
Self-reported PA (IPAQ)				
LPA	0.091**	0.002	0.058*	0.046
MVPA	0.204**	<0.001	0.072*	0.013
Accelerometry				
Daily Sedentary Time	-0.263**	<0.001	0.012	0.674
Daily LPA	0.168**	<0.001	-0.029	0.319
Daily MVPA	0.419**	<0.001	0.051	0.081

SBQ: sedentary behavior questionnaire; IPAQ: international physical activity questionnaire; MVPA: moderate-vigorous physical activity; LPA: light physical activity. ** $p \leq 0.001$; * $p \leq 0.05$.

Table 3 shows the multivariate multiple regression models for PCS and MCS unadjusted (models *a* and *b*) and adjusted for relevant covariates (models *c* and *d*). The full model *a* for the PCS adjusted by self-reported PA and SB time predicted 19% of the total variance ($p < 0.001$). The effect modification was significant ($p < 0.05$) in all explanatory self-reported variables except for LPA time (IPAQ). The same model for the MCS predicted 0.07% of the total variance ($p < 0.001$) with a significant effect modification in self-reported daily sedentary time (SBQ) ($p < 0.05$). No collinearity was identified between each independent variable of this model (VIF ranges from 1.02 to 1.15). The full model *b* for PCS adjusted by device-measured SB and PA (LPA and MVPA) predicted 14% of the total variance ($p < 0.001$) with a significant effect modification ($p < 0.05$) in device-measured LPA, MVPA and SB. On the other hand, the full model for MCS adjusted for device-measured SB and PA (LPA and MVPA) predicted 0.1% of the total variance ($p < 0.001$) with a significant effect modification ($p < 0.05$) in MVPA and sedentary time. No collinearity was identified between each independent variable of this model (VIF ranges from 1.10 to 1.47). The model *c* for PCS and MCS adjusted by self-reported PA and SB, and for covariates predicted 25% and 0.8% of the total variance ($p < 0.001$), respectively. The model *d* for the same dependent variables was adjusted by device-measured SB and PA, and for covariates predicted 29% of the total variance for PCS and 0.08% for MCS ($p < 0.001$).

Table 3. Multivariate multiple regression models for PCS and MCS adjusted by self-reported and device-measured PA and SB levels.

	PCS			MCS		
	R^2	**Non St. Beta**	***p* value**	**R^2**	**Non St. Beta**	***p* value**
Model *a*	0.19		<0.001	0.007		<0.001
LPA (IPAQ)		0.198	0.322		0.316	0.105
MVPA (IPAQ)		0.735	0.002		0.071	0.763
Daily sedentary time (SBQ)		-0.313	0.001		-0.200	0.028
Model *b*	0.148		<0.001	0.016		<0.001
LPA (ActiGraph)		0.793	0.019		0.161	0.647
MVPA (ActiGraph)		10.210	<0.001		2.564	0.003
Sedentary time (ActiGraph)		0.637	0.005		0.880	<0.001
Model *c*	0.258	-	<0.001	0.081	-	<0.001
LPA (IPAQ)		-0.047	0.797		0.297	0.133
MVPA (IPAQ)		0.412	0.063		-0.078	0.748
Daily sedentary time (SBQ)		-0.244	0.004		-0.220	0.017
Country (Denmark as reference)						
Spain		-2.284	0.002		-3.464	<0.001
UK		1.163	0.103		-0.919	0.237
Germany		-2.705	<0.001		-4.334	<0.001

	PCS			MCS		
	R^2	**Non St. Beta**	***p* value**	R^2	**Non St. Beta**	***p* value**
Model *c* (continuation)						
Age (years)		-0.197	<0.001		0.070	0.120
Sex (women as reference)						
Men		1.589	0.002		2.101	<0.001
BMI categories (obese as reference)						
Underweight and normal		2.666	<0.001		-1.515	0.038
Overweight		3.226	<0.001		-0.070	0.908
Educational background (university as reference)						
Never attended school and primary		-0.650	0.418		-1.778	0.042
Secondary		0.045	0.766		-0.225	0.173
Number of current medications		-0.976	<0.001		-0.213	0.010
Model *d*	0.293	-	<0.001	0.082	-	<0.001
LPA (ActiGraph)		0.389	0.244		0.493	0.187
MVPA (ActiGraph)		6.434	<0.001		1.825	0.011
Sedentary time (ActiGraph)		0.284	0.189		0.109	0.059
Country (Denmark as reference)						
Spain		-2.728	<0.001		-3.373	<0.001
UK		0.152	0.831		-1.056	0.184
Germany		-3.183	<0.001		-4.178	<0.001

	PCS			MCS		
	R^2	**Non St. Beta**	***p* value**	**R^2**	**Non St. Beta**	***p* value**
Model *d* (continuation)						
Age (years)		-0.088	0.040		0.101	0.034
Sex (women as reference)						
Men		1.368	0.007		2.123	<0.001
BMI categories (obese as reference)						
Underweight and normal		1.623	0.015		-1.663	0.026
Overweight		2.511	<0.001		-0.245	0.058
Educational background (university as reference)						
Never attended school and primary		-0.492	0.531		-1.667	0.058
Secondary		0.086	0.559		-0.218	0.186
Number of current medications		-0.832	<0.001		-0.180	0.035

Abbreviations: PCS, physical composite score; MCS, mental composite score; $R^{2,}$ r square; Non St Beta., Non Standardized Beta coefficient; SBQ, sedentary behaviour questionnaire; IPAQ, international physical activity questionnaire; LPA, light physical activity; MVPA, moderate to vigorous physical activity. *a* PCS and MCS adjusted by self-reported PA (LPA and MVPA) and SB. *b* PCS and MCS adjusted by device-measured PA (LPA and MVPA) and SB. *c* PCS and MCS adjusted by self-reported PA (LPA and MVPA), SB and covariates. *d* PCS and MCS adjusted by device-measured PA (LPA and MVPA), SB and covariates.

Discussion

This study aimed to analyse the association between self-reported and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries, assessing possible differences between the PCS and the MCS of the SF-12 questionnaire. Our results showed poor-to-fair significant associations between self-reported and device-measured SB and PA with the PCS. When assessing these associations with MCS, poor significant associations were found with self-reported LPA and MVPA. Our multivariate multiple regression models adjusted by self-reported and device-measured PA and SB predicted between 19% to 14% of the variance in the PCS by both self-reported and device-measured SB and PA. For MCS, the same models, self-reported and device-measured PA and SB, predicted between 0.07 and 0.1% of the variance.

A recent study that analysed self-reported PA levels with HRQoL using the SF-12 found that more active participants reported higher levels of HRQoL as well as significantly higher MCS ($p < 0.01$) (Su et al., 2019). This significant association of self-reported PA with MCS differed with our findings, and could be potentially explained due to a difference in the age of the sample and the use of a different questionnaire which assessed several types of PA on different intensities using METs (Su et al., 2019). Another recent study found that self-reported physical inactivity was significantly associated with diminished HRQoL, including physical and mental health composite scores (Wardoku et al., 2019). In our study, device-measured PA levels were only significantly associated with PCS. A recent study that aimed to assess the association of device-measured PA levels of different intensities (light, moderate and MVPA) in women with fibromyalgia found that all PA intensity levels were positively associated with HRQoL (Gavilán-Carrera et al., 2019). Our study found a higher association with device-measured MVPA and PCS than in the al-Ándalus project (Gavilán-Carrera et al., 2019). This higher association found in our study could be explained due to a worse baseline functional state in the al-Ándalus project's population (mean PCS 29.5 ± 6.9 versus PCS 45.0 ± 9.1 units), which may have prevent their participants from engaging in higher intensity PA. Davis and colleagues (2014) found that higher levels of device-based MVPA and greater SB were associated with greater and worse Short Physical Performance Battery scores, respectively in adults aged >70 years old (Davis et al., 2014). Previous research has suggested that engaging in MVPA could contribute to better physical function performance in older adults, which is related to some of the 8 dimensions assessed in the SF-12 to assess PCS, such as physical functioning or limitations due to physical problems (Gebel et al., 2014; Keevil et al., 2016; Lai et al., 2020). However, taking into account the cross-sectional nature of these data, such associations could reflect bi-directional causation, where a better physical function is needed to engaging in most types of MVPA.

Previous scientific literature suggests that PA and SB are independently associated with HRQoL, and that results regarding SB are still mostly inconsistent (Bampton et al., 2015). In our study, we found a significant, negative and poor association between self-reported SB and PCS. López-Torres and colleagues (2019) also concluded that higher self-reported SB levels were significantly associated with poorer

HRQoL. Likewise, Wilson and colleagues (Wilson et al., 2019) found that daily sitting time was negatively and significantly associated with HRQoL. Similarly, other recent studies found significant associations between device-measured SB and HRQoL (Cheak-Zamora et al., 2009; Davies et al., 2012; Gavilán-Carrera et al., 2019; L. Ge et al., 2019; Rosenberg et al., 2015). However, previous studies suggested that device-measured PA levels tend to be more valid and reliable than self-reported (Prince et al., 2008; Troiano et al., 2008). Therefore, the lower associations between self-reported SB and PA levels with PCS compared to device-measured SB and PA levels could be explain due to the accuracy to measure both behaviours. Nevertheless, when analysed the associations between SB and PA between MCS only significant but poor associations were found with self-reported PA levels.

The model used to predict MCS from the al-Ándalus project had higher predictive capability (R^2= 0.19) compared to our results in both SB and PA models with the MCS (Gavilán-Carrera et al., 2019). However, the PCS models with both self-reported and device-measured SB and PA showed higher prediction of the total variance compared to the al-Ándalus project (R^2 = 0.04). As previously stated, the different regression coefficients between studies could be explained by the different sample characteristics (e.g. the sample with women suffering from fibromyalgia included in the al-Ándalus project reported lower PCS than older adults from the SITLESS study) or the instrument used to assess HRQoL. Our results may not be clinically significant due to some of the correlations being poor. However, these findings may provide insight when designing strategies and interventions aimed at improving both physical and mental components of overall quality of life.

Furthermore, we must suggest that public resources should be allocated to strategies aimed at reducing SB and increasing PA levels to improve quality of life of older adults.

Strengths and limitations

Some limitations of the present cross-sectional study are worth noting. It is difficult to determine associations between physical behaviours and HRQoL due to the large number of factors related to HRQoL (Theofilou, 2013). The strengths of this study include the device-measured SB and PA of a large heterogeneous sample of community-dwelling older adults from four European countries as well as their association with HRQoL in both the physical and mental components.

Conclusions

In conclusion, the findings of this study suggest that both self-reported or device-measured PA intensity levels were positively and statistically significant associated with PCS of the SF-12. On the other hand, SB was negatively and statistically significant associated with the PCS of the SF-12. Those findings indicate the importance of increasing PA and reducing SB levels if the physical function component related to HRQoL is to be improved. Only self-reported LPA and MVPA were statistically significant with MCS. In general, some of the associations we found were very poor, but our results support the accumulating research of the benefits of increasing PA levels and reducing sitting time for better HRQoL among older adults. Further longitudinal studies are necessary to confirm the associations between the PCS and self-rated health and further explore associations between the MCS.

Author Contributions

Conceptualization, O.S.-N., M.G.-G. and C.M-B.; and methodology, O.S.-N., M.G.-G. and C.M.-B.; formal analysis, O.S.-N.; prepare device-based data, J.J.W.; investigation, O.S.-N., M.G.-G., B.R.-R., M.G.-B., K.F., J.J.W., P.C., P.O., N.E.B., D.R., D.D., M.R.-F., E.M. and C.M.-B.; writing—original draft preparation, O.S.-N., M.G.-G. and C.M.-B.; writing—review and editing, O.S.-N., M.G.-G., B.R.-R., M.G.-B., K.F., J.J.W., P.C., P.O., N.E.B., D.R., D.D., M.R.-F., E.M. and C.M.-B.. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and ap-proved by the Ethics and Research Committee of each intervention site: The Ethics and Research Committee of Ramon Llull University (Fundació Blanquerna, Spain), The Regional Committees on Health Research Ethics for Southern Denmark (University of Southern Denmark, Denmark), Of-fice for

Research Ethics Committees in Northern Ireland (ORECNI) (Queen's University of Bel-fast) and the Ethical Review Board of Ulm University (Ulm, Germany).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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Conflicts of interests

The authors declare no conflict of interest.

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RESULTATS I DISCUSSIÓ

Resultats i discussió

En aquest capítol descriurem breument els resultats dels tres estudis inclosos en aquesta tesi doctoral, així com un breu resum de les discussions dels mateixos. Sigui dit per endavant, que els resultats dels tres estudis s'han redactat al capítol anterior (material i mètodes).

Estudi I

A partir d'un disseny metodològic de RS de la literatura científica juntament amb meta-anàlisi, l'objectiu principal d'aquest primer estudi ha estat avaluar l'efecte de les intervencions basades en AF en l'augment dels nivells d'AF de les persones grans. Així mateix, també s'han descrit les estratègies específiques implementades en aquestes intervencions per a millorar l'adherència a l'AF en les persones grans que viuen a la comunitat.

Dels 12 estudis inclosos a la RS amb meta-anàlisi, en quatre s'ha comparat el grup experimental amb un GC actiu, mentre que en els altres nou s'ha comparat el grup experimental amb un GC no actiu. Els resultats obtinguts a partir del meta-anàlisi sobre l'efecte de les intervencions per a mantenir els beneficis de l'AF a llarg termini (més de 6 mesos) son força heterogenis. A grans trets, però, podem dir que les intervencions supervisades utilitzant estratègies específiques per a millorar l'adherència a l'AF tenen uns efectes estadísticament significatius sobre els nivells d'AF en finalitzar les intervencions comparat amb els GC, tant actius com no actius. Tot i això, a partir dels 12 mesos d'haver finalitzat les intervencions, els nivells d'AF tendeixen a minvar. Una RS amb meta-anàlisis recent, suggereix que les persones grans amb nivells d'AF més elevats, tenen més probabilitats de tenir un envelliment més saludable en comparació amb aquells que son físicament menys actius (Daskalopoulou et al., 2017).

A la literatura científica, hi ha identificades aproximadament unes 80 teories diferents relacionades amb les TCC (Davis et al., 2015). Per descriure les estratègies específiques més utilitzades en els estudis inclosos a la RS ens hem basat amb la TSC de Bandura (Bandura, 2001). A partir d'aquesta teoria, en 9 dels 12 estudis inclosos hem identificat diferents TCC. Algunes de les més utilitzades han estat l'educació (Nutbeam, 2000), la monitorització (Cohen et al., 2013) i la planificació d'accions (Pearson, 2012). Aquestes TCC no es poden aplicar de la mateixa manera a totes les poblacions. Per això, saber escollir quina és la millor TCC per incloure en el disseny d'una intervenció per augmentar o mantenir els nivells d'AF és un repte per als professionals de l'AF i la salut. En aquest sentit, Finegood i els seus col·laboradors (2011) proposen que en el disseny d'intervencions es tinguin en compte la combinació de bases teòriques, així com també posar el focus en les possibles solucions, sempre basades amb els interessos individuals, i també els *stakeholders*[11] (Finegood et al., 2011). De fet, Chase i els seus col·laboradors (2015) corroboren que les intervencions amb TCC combinades tenen més èxit per augmentar els nivells d'AF que no pas aquelles que es basen amb una única estratègia (Chase, 2015).

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[11] Entenem els *stakeholders* com les parts interessades. Son grups o individus que poden afectar o es veuen afectats per un problema. Les parts interessades son una font important d'informació en la investigació en salut, que ofereixen perspectives crítiques i noves idees sobre els complexos determinants de la salut (Schiller et al., 2013).

Estudi II

L'objectiu del segon estudi d'aquesta tesi doctoral ha estat avaluar la validesa de l'SBQ per mesurar el CS de les persones grans que viuen a la comunitat mitjançant els inclinòmetres ActivPAL i Axivity com a criteri de validesa. En aquest estudi s'ha utilitzat l'SBQ (Rosenberg et al., 2010) en la versió anglesa, danesa, alemanya i espanyola, en funció del centre d'intervenció del projecte SITLESS.

Els resultats obtinguts mostren una correlació estadísticament significativa entre les mesures auto-reportades a partir de l'SBQ i el temps sedentari a partir de l'acceleròmetre ($p < 0.001$). Tot i això, la correlació és feble (Rho= 0.25). Tanmateix, quan hem analitzat per separat cada versió de l'SBQ, la versió danesa ha mostrat una correlació moderada (Rho= 0.30) mentre que les versions anglesa, alemanya i espanyola han mostrat correlacions febles (Rho= 0.28; 0.23; 0.06, respectivament). Quan hem avaluat la correlació intraclasse (CIC) entre els minuts al dia en CS a partir de l'SBQ i la mateixa variable mitjançant l'accelerometria, aquesta ens suggereix una relació feble entre les mesures (CIC= 0.32).

Com ja hem comentat a l'apartat de mesures d'AF i CS del marc teòric, les mesures auto-reportades tendeixen a ser menys precises que les objectives, i generalment les persones grans infravaloren el temps en CS (Celis-Morales et al., 2012). Els nostres resultats mostren una infravaloració del temps en CS de 72.90 mins/dia entre el temps assegut avaluat amb l'SBQ i el registrat mitjançant l'accelerometria. Aquesta infravaloració del temps en CS també s'ha mostrat en altres estudis on s'han comparat mesures auto-reportades amb accelerometria (Clark et al., 2011; Hart et al., 2011; Harvey et al., 2015; Kastelic & Šarabon, 2019). La infravaloració del CS en la gent gran es pot explicar per la manca de consciència de l'elevada quantitat de temps que passen asseguts. La capacitat de memòria a l'hora de donar respostes precises davant d'instrument auto-reportats també és un factor determinant en aquesta infravaloració del CS.

Pel que fa als resultats obtinguts en la correlació entre mesures en aquest estudi, les nostres dades mostren coeficients de correlació lleugerament més alts que els que s'han mostrat en estudis anteriors on també s'ha utilitzat l'SBQ com a mesura auto-reportada (Bakar et al., 2018; Kastelic & Šarabon, 2019; Munguía-Izquierdo et al., 2013; Rosenberg et al., 2010). Aquestes diferències probablement es donen degut a que la mesura de validesa per comparar el temps en CS de l'SBQ no ha estat la mateixa que en el nostre estudi. Nosaltres hem utilitzat els inclinòmetres ActivPAL i l'Axivity que detecten els canvis posturals, donat que es col·loquen a la part mitja de la cuixa. En canvi, els estudis citats anteriorment, han utilitzat instruments com l'IPAQ, un instrument auto-reportat o el monitor SenseWear Pro3 Armband i l'ActiGraph que son acceleròmetres poc fiables a l'hora de distingir les postures i per tant el CS.

Per últim, també volem afegir que la feble correlació entre mesures també es podria donar a causa dels dominis limitats de CS que inclou l'SBQ, i que potser no donen resposta a algunes activitats habituals que solen fer les persones grans en els 4 països on s'han recollit les dades. Per exemple, les activitats fora del context dels seus domicilis com ara jugar a jocs de taula en centres d'oci, seure en un parc o en un bar amb amics, o fer sobretaula durant una llarga estona son activitats que creiem que s'haurien de considerar en les versions de l'SBQ específiques de cada país donat que les diferents condicions ambientals i culturals poden condicionar que aquests tipus d'activitats puguin ser més o menys freqüents.

Estudi III

L'objectiu del tercer estudi d'aquesta tesi doctoral ha estat analitzar la relació entre el CS i els nivells d'AF auto-reportats i mesurats mitjançant l'accelerometria amb la QVRS de les persones grans que viuen a la comunitat dels quatre països europeus que van participar en l'estudi SITLESS. En la variables de QVRS, mesurada amb el qüestionari SF-12, es va diferenciar entre els resultats en ambdós components de salut: el PCS i el MCS.

Els resultats obtinguts en aquest tercer estudi mostren una relació estadísticament significativa entre feble i acceptable del CS i els nivells d'AF (auto-reportats i mesurats mitjançant l'accelerometria) amb el PCS. En canvi, la relació amb el MCS només va ser estadísticament significativa però feble amb l'AFLL i l'AFMV auto-reportada. Un estudi anterior suggereix que l'AF i el CS s'associen de manera independent amb la QVRS (Bampton et al., 2015). En aquest sentit, Wardoku i els seus col·laboradors (2019), van concloure que la manca d'AF, en aquest cas auto-reportada, estava associada significativament amb la disminució de la QVRS, incloent-hi el PCS i el MCS (Wardoku et al., 2019). Su i els seus col·laboradors (2019) també van mostrar que els nivells d'AF auto-reportats estaven associats significativament amb la QVRS mesurada amb l'SF-12 (Su et al., 2019). Pel que fa a la relació del CS amb la QVRS, hi ha estudis recents on es mostra que el CS està associat negativament amb la QVRS, és a dir, a major temps en CS, pitjor QVRS (López-Torres et al., 2019; Wilson et al., 2019). De la mateixa manera, altres estudis també comparteixen aquestes troballes entre la relació del CS mesurat mitjançant accelerometria i la QVRS (Davies et al., 2012; Gavilán-Carrera et al., 2019; Ge et al., 2019; Rosenberg et al., 2015). Aquestes diferències amb els nostres resultats, es poden donar degut a les diferències entre l'edat de la mostra estudiada, els diferents instruments de mesura dels nivells d'AF auto-reportats, o també les diferències entre els nivells basals de salut física i mental de la mostra.

En relació als resultats dels models de regressió múltiple multivariant ajustats per l'AF i el CS auto-reportats i també mesurats mitjançant l'accelerometria, prediuen entre el 14% i el 19% els resultats del PCS. Per altra banda, les mateixes variables incloses al model prediuen entre el 0.1% i el 0.7% els resultats del MCS. Un estudi recent mostra els resultats del projecte al-Ándalus, on podem veure que els seus coeficients de regressió son més elevats (R^2= 0.19) respecte els nostres resultats en la predicció del MCS (Gavilán-Carrera et al., 2019). En canvi, el nostre model de regressió mostra coeficients més elevats en la predicció del PCS que els del projecte al-Ándalus (R^2= 0.04). Aquesta diferència entre els resultats d'ambdós estudis, tal i com ja hem avançat al paràgraf anterior, es poden donar degut a les diferències entre la mostra (en aquest cas, el projecte al-Ándalus es dirigeix a dones amb fibromiàlgia) o també pels instruments de mesurar de les variables independents i dependents incloses al model.

Discussió general

És important assenyalar que l'àmbit de la recerca en AF i CS encara es caracteritza per la manca de coneixement sobre quines estratègies son les més efectives i cal incloure en les intervencions per augmentar els nivells d'AF i reduir el CS; així com mantenir els efectes d'aquestes intervencions a llarg termini afavorint el canvi de comportament en un col·lectiu amb baixos nivells d'AF i que passen asseguts moltes hores al dia. Així mateix, cal tenir present que ambdós comportaments son complexos i multifactorials, i que cal disposar d'instruments de mesura assequibles, vàlids i fiables que es puguin emprar en la pràctica clínica diària. Finalment, també és important entendre la relació de l'AF i el CS en la QVRS de les persones grans.

Les intervencions d'AF semblen tenir un petit benefici clínic en els nivells d'AF de les persones grans que viuen a la comunitat. Tot i això, els estudis inclosos a la RS amb meta-anàlisi que estudien aquest benefici a llarg termini demostren que les millores tendeixen a minvar amb el pas del temps. És per això que es necessiten més estudis per concloure quines son les intervencions i les estratègies més efectives per a mantenir els nivells d'AF i per tant, els seus beneficis a llarg termini. Val a dir, que cal centrar els esforços en incorporar estratègies de canvi de comportament que afavoreixin canvis fàcils d'incorporar en les rutines diàries, afavorint que es puguin mantenir a llarg termini.

Els nivells de CS han esdevingut un indicador de salut ja que estar assegut o estirat durant períodes llargs de temps està associat negativament amb l'estat de salut. Aquestes conseqüències negatives sembla que fins i tot es donen en aquelles persones suficientment actives. Per aquest motiu l'avaluació del CS esdevé tant important com l'avaluació dels nivells d'AF. Els nostres resultats de validació de l'SBQ i també d'estudis epidemiològics anteriors, suggereixen que el qüestionari no pot proporcionar una estimació sòlida del temps en CS diari de les persones grans, ja que hi ha una infravaloració del CS en aquesta població. Per això, recomanem als investigadors i professionals sanitaris que intentin utilitzar de manera complementària instruments objectius per mesurar aquests comportaments físics ja que tendeixen a ser més precisos. Tot i la infravaloració observada del CS i la tendència a sobrevalorar l'AF, resulta important l'ús de qüestionaris que ens permetin avaluar els dominis específics dels temps en CS i del tipus d'AF.

Com dèiem anteriorment, l'AF i el CS tenen un impacte significatiu en la salut i, per tant, en la QVRS de les persones grans. Aquesta realitat justifica que molts investigadors posin el focus del seu estudi en el disseny d'intervencions d'AF i reducció del CS en aquesta població en un moment on l'esperança de vida va augmentant significativament. El repte ha de ser aconseguir que aquesta població envelleixi de manera saludable, acompanyant els anys de vida, d'una bona QVRS. Nous estudis que analitzin la relació entre els nivells d'AF i el CS amb la QVRS son importants per a donar suport a la investigació en aquest camp. Tot i que en el nostre estudi, algunes de les associacions que hem trobat entre ambdós comportaments i la QVRS son febles, és important fomentar els beneficis que aporta augmentar els nivells d'AF i reduir el CS per una millor QVRS entre les persones grans.

CONCLUSIONS

Conclusions

The main aim of this doctoral thesis was to investigate the relation of PA and SB, as well as interventions to modify both behaviours, with older adults' health. Based on the results of the three studies conducted, we conclude that both PA and SB could have a significant impact on older adults' health. Regarding PA, the impact was positive, while it was negative for SB. Moreover, we found a statistically significant effect on PA levels in PA-based interventions in which behaviour change techniques (BCT) where used.

Regarding the specific aims of the three studies, we conclude:

Study I

- *Aim 1: to assess the effect of exercise-based interventions on at least six months follow up PA measure in community-dwelling 65+ year-old adults.*

  Having analysed the effect of PA-based interventions to increase PA levels with a ≥6 months follow up of the 12 included studies in the systematic review (SR) as well as in the meta-analysis, we conclude that our results are quite heterogeneous. However, we could say that exercise-based interventions to improve PA adherence have statistically significant effects on PA levels at the end of the interventions when compared with a control group (CG), whether they were active or non-active CG. Nevertheless, we observed that PA levels declined after 6 months of the intervention cessation.

- *Aim 2: to describe the specific strategies implemented during the intervention to strengthen the sustainability of PA in community-dwelling 65+ year-old adults.*

  To describe these strategies, we have relied on the Bandura's Social Cognitive Theory (SCT). In 9 of the 12 included studies in the SR, we identified different BCT, being the most used education, monitoring, and action planning.

Study II

- *Aim 1: to assess the validity of the Sedentary Behaviour Questionnaire (SBQ) to measure SB among community-dwelling older adults using accelerometry as a gold standard.*

  Based on the results of this study, we conclude that SBQ tends to underestimate SB time in older adults. We could say that the SBQ is a valid tool to measure SB, but it shows a correlation between weak and acceptable with the device-measured SB.

Study III

- *Aim 1: to analyse the association between self-reported and device-measured PA and SB with health-related quality of life (HRQoL) in a cohort of community-dwelling older adults from four European countries.*

  Having analysed the relationship between self-reported and device-measured PA and SB, we conclude that they were positively and significantly associated with HRQoL, especially with the PCS. In contrast, only self-reported LPA and MVPA were significantly associated with the MCS. In terms of SB, both self-reported and device-measured were negatively and significantly associated with HRQoL, especially with the PCS. However, most of the significant associations were weak.

We hypothesize that both PA and SB, as well as exercise-based intervention to modify these behaviours, had a significant and relevant impact on community-dwelling older adults' health status. Having completed all three studies of the doctoral thesis, we conclude that our hypothesis was true. Both PA and SB can have a significant impact on older adults' health. Also, PA-based interventions have a statistically significant effect on this population PA levels once the interventions are completed.

Based on our specific hypotheses, we conclude:

Study I

- *Hypothesis 1: PA-based interventions have a significant effect on improving older adults' PA levels, even ≥6 months after the intervention cessation.*

  Based on our meta-analysis results, we conclude that despite showing quite heterogeneous results, PA interventions to improve older adults' adherence to PA have statistically significant effects on PA levels once interventions are completed. However, these improvements tend to decrease after 6 months.

- *Hypothesis 2: the most commonly used specific strategies to improve PA adherence among older adults are the once based on the Bandura's SCT or the Prochaska and DiClemente's Transtheoretical Model (TTM).*

  Analysing the most used strategies in the 9 studies included in the SR that specified different BCT, we identified that the most commonly used BCT in the different interventions were education, monitoring and action planning, based on Bandura's SCT.

Study II

- *Hypothesis 1: the Sedentary Behaviour Questionnaire (SBQ) is a valid tool to measure community-dwelling older adults' SB.*

  Based on our results, we conclude that older adults tend to underestimate their SB time when using the SBQ, despite being a valid tool to measure SB. Our results show a statistically significant correlation between weak and acceptable based on the SBQ sedentary time against thigh-based SB measure. However, the ICC between both measures suggests a weak agreement between them.

Study III

- *Hypothesis 1: there is a significant association between self-reported and device-measured PA and SB with HRQoL in a cohort of community-dwelling older adults from four European countries.*

  Based on our results, we conclude that there is a significant relationship between self-reported and device-measured PA and SB with older adults' HRQoL. However, this relationship is especially appreciated with the PCS; while with the MCS is only significantly associated with LPA and MVPA. In general, this association is weak among most of PA intensities and SB time.

Limitations and future research

In this section, we show the most relevant limitations of this doctoral thesis, based on the three studies included in the compendium of publications. It is worth noting that these limitations have already been pointed out in previous sections.

Study I

One of the limitations of the first study of this doctoral thesis, a SR design with a meta-analysis, is that our search strategy was restricted to three databases (MEDLINE, EMBASE and CENTRAL). Another limitation, directly related to the results, is the few included studies in the meta-analysis giving an inaccurate estimation, and therefore restricting the confidence of the obtained results. On the other hand, although it was intended to describe the long-term effects of current interventions on improving PA levels' adherence, very few studies reported this follow up. Therefore, the analysis focused on a six-month follow up period. Finally, it should also be noted that most of the RS included studies assessed PA using self-reported tools, which increased the possible data bias.

Having identified these limitations, we believe that further studies are needed to show the most effective strategies to improve PA levels and older adults' PA practice. In these studies, we suggest that self-reported PA intensities assessment should be complemented with device-based measures as we would avoid possible bias of self-reported instruments. Therefore, we believe it is necessary to specify the strategies or BCT used in the interventions to be able to replicate them in other studies and other populations. Finally, we emphasize the importance of assessing the participants of these studies not only when they completed the intervention but also with a follow-up beyond six months from the intervention cessation. That would allow us to see the effect of the long-term interventions.

Study II

In this study, the validity of the SBQ was assessed based on a subsample of the SITLESS study. The validity of the same instrument was assessed using the four different versions of the SBQ depending on the country. The number of Spanish participants was small compared to other countries, and the results of the study could be biased when the validity was assessed separately. The correlation between self-reported and device-measured SB should be considered as an exploratory analysis, as the sample could be considered small. Another limitation is that inclinometers measure both sitting and lying behaviours, while the SBQ only assesses sitting behaviours. This bias could potentially explain the weak correlation between both instruments. Finally, we also considered another limitation since we were not be able to use the same algorithm to classify SB time in the Axivity and ActivPAL3.

Based on our findings of the validation analysis of the four different SBQ versions, it is important to note that further studies are needed to assess the validity of the same instrument in other populations, as well as in larger cohorts to obtain more significant results. We also suggest using a single device-measured instrument (gold standard) as a criterion validity to avoid time-biased results.

Study III

In the third study, the cross-sectional design of the study should be highlighted as a limitation. In addition, it is worth noting the difficulty to determine associations between PA and SB with HRQoL due to many HRQoL-related factors in older adults' population.

As future research lines in this field, we emphasize the importance of new studies, longitudinal and experimental designs, to be able to highlight the significant associations between PA and SB with HRQoL, specially with the PCS and MCS from the SF-12. Further, it is important to explore whether there exist more correlations between PA and SB with MCS since no correlations between those components have been found.

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ANNEXOS

Annex 1. Fullet d'informació pel participant del projecte SITLESS

Projecte SITLESS

Fullet d'informació pel participant

Preparat per Dr Jason Wilson, Prof Frank Kee and Dr Mark Tully

Traduït per Javier Jerez Roig

Preparat amb finançament de la Comissió Europea

Continguts

Introducció a la Intervenció SITLESS

Ser actiu i ser sedentari: quina és la diferència?

Per què reduir el temps de seure és important per a mi?

Preguntes freqüents sobre la reducció de temps assegut

Com puc reduir el temps assegut?

Com puc aplicar aquests consells per reduir el temps assegut?

Ús del podòmetre

Introducció a la Intervenció SITLESS

Gràcies per acceptar participar voluntàriament en aquesta intervenció com a part del Projecte SITLESS. La seva participació és molt apreciada!

La intervenció SITLESS té com a objectiu millorar la seva experiència amb un programa d'exercici mitjançant la introducció a les estratègies d'autogestió encaminades a reduir el temps dedicat a ser sedentari (és a dir, estar assegut). Es preveu que aquestes estratègies d'autogestió l'ajudaran a desenvolupar gradualment alguns hàbits actius que, així mateix, l'ajudaran a mantenir els beneficis per a la salut obtinguts a partir del programa d'exercici durant un període de temps més llarg.

La informació que hi ha en aquest fullet l'ajudarà a tenir una idea de per què estar assegut massa temps és dolent per a la salut, tracta algunes preguntes que pugui tenir, suggereix alguns consells per reduir el temps d'estar assegut i com es poden aplicar a la seva vida diària, així com proporciona certa informació sobre com utilitzar el podòmetre per augmentar el seu nivell d'activitat.

Ser actiu i ser sedentari: quina és la diferència?

- L'activitat física és qualsevol moviment corporal que fa que els seus músculs treballin i requereix més energia que el repòs (és a dir, activitats que van des de estar de peu a córrer).

- El comportament sedentari es produeix quan es seu o s'està estirat (tombat) i requereix una despesa energètica molt baixa (per exemple, veure la televisió o seure per llegir un llibre).

- Una persona insuficientment activa pot ser considerada com algú que no està realitzant suficient activitat física moderada i vigorosa per setmana per assolir les metes de les guies d'activitat física (és a dir, 150 minuts d'activitat física moderada per setmana, 75 minuts d'activitat física vigorosa o una barreja de tots dos en sessions d'almenys 10 minuts de durada).

- Encara que un adult compleixi aquestes recomanacions de les guies d'activitat física, pot passar una gran quantitat de temps assegut, i això és perjudicial per a la seva salut i benestar.

Per què reduir el temps de seure és important per a mi?

La investigació ha demostrat que seure massa temps està relacionat amb un major risc de mort precoç, així com una sèrie de malalties cròniques, incloent:

- Malaltia cardíaca
- Diabetis
- Infart cerebral (ictus)
- Obesitat
- Alguns tipus de càncer, com ara el colorectal, d'ovaris i d'endometri (és a dir, del úter)
- Osteoporosis (és a dir, ossos fràgils)

Mitjançant la substitució d'estar assegut per estar en peu i activitats físiques lleugeres, és possible:

- Reduir la probabilitat de patir les malalties mencionades anteriorment
- Reduir la pressió arterial
- Reduir el colesterol
- Millorar la funció física (és a dir, augmentar l'habilitat per fer les tasques quotidianes)
- Millorar la creativitat i la funció mental

Les persones grans que han participat en programes anteriors dirigits a reduir el temps d'estar assegut han manifestat:

- Reducció de la rigidesa
- Millor maneig del dolor crònic
- Sentir-se més feliços
- Sentir-se amb més energia i menys fatiga
- Millor concentració
- Millora de la qualitat del son

Preguntes freqüents sobre la reducció de temps assegut

Per fer front a qualsevol preocupació o dubte que pugui tenir, a continuació hi ha algunes preguntes i respostes per aclarir alguns aspectes:

Què es considera com massa temps assegut?

- Per desgràcia, en l'actualitat no hi ha evidència suficient per establir un límit de temps diari en el comportament de seure de les persones grans. No obstant això, moltes persones grans solen passar 65-75% del seu dia en una posició asseguda; el qual es considera un nivell elevat de temps assegut.

M'estàs dient que mai hauria d'estar assegut?

- Clarament no! Seure és un comportament natural que dóna al cos temps per descansar i recuperar-se després de realitzar les activitats diàries. No obstant això, el que estem dient és que reduccions petites regulars en el temps assegut poden produir un impacte positiu en la salut.

Hauré de fer exercici tot el temps per reduir el meu temps de seure?

- Clarament no! Qualsevol activitat que no impliqui seure es pot fer. Això vol dir que l'activitat física molt lleugera, com pot ser estar de peu o passejar, podem usar-les per reduir el temps d'estar assegut, així com les activitats físiques moderades i vigoroses.

Hi ha cap activitat d’estar assegut o reclinat que no compten com comportament sedentari?

- Dormir, els exercicis físics i màquines d'exercicis en posició asseguda (per exemple, bicicletes estàtiques i màquines fixes de peses) NO es compten com a activitats sedentàries.

Quins son els millors mètodes per reduir el meu temps assegut?

- Això és molt personal segons cada individu. No obstant això, una bona regla d'or seria interrompre els períodes d’estar assegut moltes hores (és a dir, 1 hora o més) amb almenys 5 minuts d’activitat física lleugera, moderada o intensa.

Com puc reduir el tems de seure?

Els següents consells han estat utilitzats per altres persones per ajudar a reduir el temps que passen asseguts en diferents situacions. Per què no donar-li una oportunitat a alguns d'ells? Potser vostè pot pensar en alguns d’ells que siguin més apropiats pel seu cas?

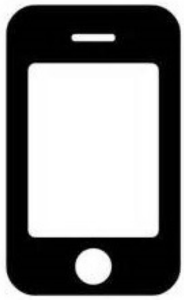
Temps davant de pantalles

Quan es veu la televisió, posar-se dempeus o caminar durant els anuncis entre programes.

Deixar el comandament a distància de banda del televisor, implica que vostè ha de aixecar-se per canviar de canal.

Quan estigui a l'ordinador, estableixi una alarma per aixecar-se cada hora i moure-s.

Quan es segui amb la tableta o el telèfon mòbil, programar una alarma perquè soni cada hora. Quan soni, aixecar-se i moure's.



Activitats domèstiques

En lloc d'afanyar-se en activitats com la jardineria i les compres, tracti de allargar els seus esforços per trigar més temps en finalitzar-les.

Intenti jugar més activament amb els seus nets.

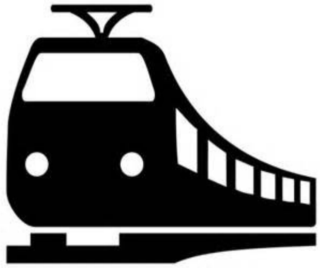
Està posposant fer certes tasques? Vostè podria fer algunes en el seu temps lliure (per exemple, posar en ordre l'àtic o netejar el garatge).

Quan recicli o llançi escombraries, llançi cada bossa a la galleda gran d'escombraries en lloc d'utilitzar galledes petites dins de la casa.

Sortir i socialitzar-se

Al parlar per telèfon amb amics, familiars i altres persones, aixecar-se i moure's durant la durada de la trucada.

Al viatjar en un tren, aixecar-se en lloc de seure a un seient almenys durant part del viatge.



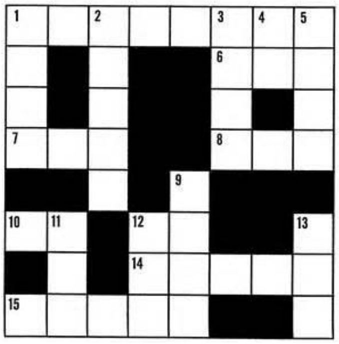
Quan està en un concert/teatre, aixecar-se i moure's durant l'interval (o durant la representació si és possible).

Durant la visita a amics o altres persones en reunions socials, ajudeu a fer descansos i animar-los a posar-se dempeus.

Aficions

T'agrada escoltar música? Posa't de peu i potser fins i tot balla mentre l'escolta!

Quan completi els seus mots encreuats / trencaclosques, aixecar-se cada tres respostes que completa.



Quan llegeixi un llibre o un diari, aixecar-se després de cada capítol / secció que finalitza.

Quan està pintant, estigui de peu davant del cavallet.

Com puc aplicar aquests consells per reduir el temps assegut?

L'aplicació pràctica d'aquests consells pot semblar desafiant, pel que aquí hi ha una guia ràpida sobre com aplicar aquests consells en la seva vida diària:

- Seleccioni només un o dos consells que s'apliquin a la major part del temps que vostè seu durant el dia.
- L'ús del podòmetre per controlar els seus passos diaris li donarà un bon indicador de si vostè està reduint el temps que passa assegut i es torna cada vegada més actiu/activa.
- Fer que els seus amics i familiars s'involucrin, pot animar-vos els uns als altres per seure menys i ser més actius!
- Intenti mantenir-se en contacte amb altres membres del grup, ja que li proporcionarà suport i estímul addicional per seure menys i ser més actiu..
- Intenti aplicar de manera realista i progressiva els consells a la seva pròpia situació. Per exemple, quan vegi la televisió opti per posar-se dret i moure's durant els anuncis durant dos o tres programes per dia en lloc de a cada programa.

- Posar-se a un lloc de la casa que li permeti realitzar algunes activitats en una posició de peu (per exemple, als fogons de la cuina).

- Portar o col·locar les targetes SITLESS en llocs visibles per recordar-li que ha de aplicar els consells.

- Si vostè pateix problemes de salut que no li permeten ser actiu durant llargs períodes de temps (per exemple, artritis), llavors tracti de realitzar les seves pauses actives després d'estar assegut durant un curt temps, però amb més freqüència durant el dia.

- No es senti incòmode o avergonyit sobre complir els consells del SITLESS. Vostè s'ha de sentir orgullós d'estar fent un esforç per ser menys sedentari i més actiu!

- El més important és seguir practicant els consells! Es necessitaran vàries setmanes o mesos per aplicar els nous hàbits saludables en el seu estil de vida

- Diari.

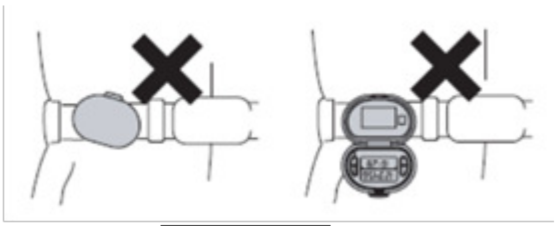
Ús del podòmetre

1. El podòmetre (veure Dibuix 1) ha de portar-se únicament durant les hores de vigília; treguis el podòmetre abans d'anar a dormir.

2. Vostè ha de portar el podòmetre a la zona dels malucs davant de la cintura del seu costat dominant (tingui en compte que el dispositiu pot ser usat per sobre o per sota de la roba, així que no és obligatori usar-lo contra la pell).

Dibuix 1

3. Si us plau, assegureu-vos que el podòmetre es troba en la seva cintura i no s'inclina cap endavant o cap a un costat (veure Dibuix 2).


Dibuix 2

4. Si us plau, poseu-vos el podòmetre cada matí al despertar. Vostè haurà d'assegurar-se que el podòmetre està col·locat en el mateix lloc del cos cada vegada que es treu. Pot ser útil deixar el podòmetre al costat de les seves claus / carpeta / telèfon per recordar de col·locar-se'l al dia següent.

5. Per esborrar el nombre de passos que es mostren a la pantalla del podòmetre, premi el botó "RESET" a l'interior del podòmetre,

NOMÉS després d'haver anotat els seus passos diaris al final del dia. La pantalla llavors mostrarà "0" passos.

6. Si habitualment fa una migdiada durant el dia, si us plau mantingui el podòmetre posat durant aquest temps.

Si us plau, retiri el podòmetre quan es va a dutxar/banyar o abans de participar en activitats aquàtiques, ja que no és resistent a l'aigua. Posis el podòmetre de nou immediatament després de la dutxa/bany o activitat aquàtica.

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Review

Exercise-Based Interventions to Enhance Long-Term Sustainability of Physical Activity in Older Adults: A Systematic Review and Meta-Analysis of Randomized Clinical Trials

Oriol Sansano-Nadal [1], Maria Giné-Garriga [1,2,3,*], Jennifer S. Brach [4], David M. Wert [4], Javier Jerez-Roig [1,2,5], Myriam Guerra-Balic [1], Guillermo Oviedo [1], Jesús Fortuño [1], Natàlia Gómara-Toldrà [3,6], Luis Soto-Bagaria [7,8], Laura Mónica Pérez [7,8], Marco Inzitari [7,8,9], Ivan Solà [10,11], Carme Martin-Borràs [1,3] and Marta Roqué [10,11,12]

1 Department of Physical Activity and Sport Sciences, Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Císter 34, 08022 Barcelona, Spain
2 School of Health and Life Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, UK
3 Department of Physical Therapy, Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Padilla 326-332, 08025 Barcelona, Spain
4 Department of Physical Therapy, School of Health and Rehabilitation Sciences, University of Pittsburgh, Forbes Tower, 3600 Atwood St, Pittsburgh, PA 15260, USA
5 Research group on Methodology, Methods, Models and Outcome of Health and Social Sciences (M3O), Faculty of Health Science and Welfare, University of Vic-Central University of Catalonia (UVIC-UCC), Sagrada Família 7, 08500 Vic, Spain
6 Department of Health Sciences, Faculty of Health Sciences and Welfare, University of Vic, Sagrada Família 7, 08500 Vic, Spain
7 Intermediate Care Hospital, Parc Sanitari Pere Virgili, Avinguda de Vallcarca 169-205, 08023 Barcelona, Spain
8 RE-FiT Barcelona Research Group, Vall d'Hebrón Institute of Research (VHIR), Passeig de la Vall d'Hebron 119-129, 08035 Barcelona, Spain
9 Department of Medicine, Universitat Autònoma de Barcelona, Plaça Cívica, 08193 Bellaterra, Barcelona, Spain
10 Iberoamerican Cochrane Centre, Institute of Biomedical Research Sant Pau (IIB-Sant Pau), Sant Antoni Marià Claret 167, pavilion 18, 08025 Barcelona, Spain
11 CIBER Epidemiology and Public Health, CIBERESP, 28029 Madrid, Spain
12 Institute on Health and Aging, Universitat Autònoma de Barcelona (UAB), Sant Antoni Marià Claret 171 (Casa Convalecencia), 08041 Barcelona, Spain
* Correspondence: mariagg@blanquerna.url.edu; Tel.: +34-932-533-000

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Abstract: Exercise is a form of physical activity (PA). PA is an important marker of health and quality of life in older adults. The purpose of this study was to conduct a systematic review of the literature to assess the effect of exercise-based interventions on an at least six-month follow up PA measure, and to describe the specific strategies implemented during the intervention to strengthen the sustainability of PA in community-dwelling 65+ year-old adults. We registered and conducted a systematic review and meta-analysis (PROSPERO: CRD42017070892) of randomized clinical trials (RCT). We searched three electronic databases during January 2018 to identify RCT assessing any type of exercise-based intervention. Studies had to report a pre-, post-, and at least 6-month post-intervention follow-up. To be included, at least one PA outcome had to be assessed. The effect of exercise-based interventions was assessed compared to active (e.g., a low-intensity type of exercise, such as stretching or toning activities) and non-active (e.g., usual care) control interventions at several time points. Secondary analyses were conducted, restricted to studies that reported specific strategies to enhance the sustainability of PA. The intervention effect was measured on self-reported and objective measures of time spent in PA, by means of standardized mean differences. Standardized mean differences of PA level were pooled. Pooled estimates of effect were computed with the DerSimonian–Laird method, applying a random effects model. The risk of bias was also assessed. We included 12 studies, comparing 18 exercise intervention groups to four active and nine non-active control groups. Nine studies reported specific strategies to enhance the long-term sustainability of PA. The strategies were mostly related to the self-efficacy, self-control, and behavior capability principles based on the social cognitive theory. Exercise interventions compared to active control showed inconclusive and heterogeneous results. When compared to non-active control, exercise interventions improved PA time at the six-months follow up (standardized mean difference (SMD) 0.30; 95%CI 0.15 to 0.44; four studies; 724 participants; I^2 0%), but not at the one- or two-years follow-ups. No data were available on the mid- and long-term effect of adding strategies to enhance the sustainability of PA. Exercise interventions have small clinical benefits on PA levels in community-dwelling older adults, with a decline in the observed improvement after six months of the intervention cessation.

Keywords: Older adults; physical activity; sustainability; adherence; meta-analysis; systematic review

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1. Introduction

Many health-oriented systems and organizations are faced with the challenge of implementing new health-related practices, and while many of these programs demonstrate initial success, they fail to become a habit or routine for the participants. Policy makers and other stakeholders are increasingly concerned with the long-term impact of their investment. Greenhalgh et al. [1] pointed out there was a near absence of studies focusing primarily on how to sustain health promotion interventions in the long term.

While intervention sustainability is defined as the continued use of intervention components and activities for the continued achievement of desirable health outcomes within the population of interest [2], determining how to foster the maintenance of health-related benefits acquired by the intervention's recipients once it ends is another great challenge [3]. Adherence, similarly, is defined as the extent to which a person's behavior (e.g., lifestyle changes) corresponds with agreed recommendations from a health care provider [4], based on completion (e.g., retention), attendance, duration, and intensity while undergoing a certain intervention.

The incidence rate of many chronic diseases increases with age [5,6]. Physical activity (PA) is a major aspect of chronic disease self-management [7–13], and higher levels of PA are associated with healthy ageing [14]. In particular, for older adults, balance and resistance training programs are an effective way to maintain mobility and independence [9]. People who undertake regular PA tend to experience better health and live longer [15,16], even with small increases each day [16]. However, insufficient amounts of PA remain one of the major behavioral burdens worldwide [17–19]. Older adults are the less active group, with only about 11% meeting the current PA recommendations [20,21], creating a ripe environment for PA intervention research. The road towards sustainable maintenance to PA might be the cornerstone of health promotion.

Interventions to promote maintenance of PA once the intervention ends in older adults have achieved limited success, particularly over the long term [14,22–27]. A clear definition of long-term sustainability is still lacking, so we will consider long-term as a person maintaining a recommended behavior over a 12-month period [4]. Most current studies thus far have focused on identifying the factors that are critical to the success of initial implementation efforts. The development of alternative approaches based on end-users' preferences, and which implement behavioral change concepts, have been repeatedly requested [28]. Some of the most used theories in health behavior change include psychological theories, such as the transtheoretical model [29] and the social cognitive theory (SCT) [30]. Behavioral change techniques (BCTs) include cognitive and behavioral processes of change, and had been associated with an increase in the effects of behavior change interventions [31]. There is a need for designing effective and sustainable interventions to promote PA in the long term in older adults [3].

The purpose of this study was to conduct a systematic review of the literature to assess the effect of exercise-based interventions, implemented in community-dwelling older adults (65+ years of age), on an at least six-month follow up of PA—and subsequently describe the specific strategies implemented to strengthen the long-term sustainability of PA. We hypothesized that interventions that described specific strategies to enhance the sustainability of PA practice would be more effective in PA maintenance, at least after the six-month post-intervention cessation. Our paper aimed to inform an agenda for research, funding, and policies on PA promotion in older adults.

2. Materials and Methods

2.1. Study Selection

We conducted a systematic review of the literature to assess the effect of exercise-based interventions, implemented in community-dwelling older adults, at least six-months post-intervention, on the sustainability of PA (PROSPERO: CRD42017070892). The guidelines for conduct and a report of systematic reviews in the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [32] and PRISMA statement [33] were followed. We searched MEDLINE, EMBASE, and CENTRAL up to January 2018 without language or date restrictions. We designed a search strategy adapted to the requirements of each database, combining their controlled vocabularies and text terms. We used, among others, keywords like older, elderly, ageing, aging, sustainable, sustainability, maintenance, adherence, long-term effects, and physical activity, exercise, rehabilitation (see Supplementary Materials Table S1). We approached other sources (references from relevant systematic reviews and meta-analyses, or personal communication with experts) to identify additional studies. Title words had to include 'exercise' or 'physical activity' or 'exercise referral schemes' and 'older adults'. Results from the search procedures were imported into Mendeley bibliographic software and duplicates were removed. Study titles and abstracts of identified studies were screened by pairs of authors independently (M.G.-G., N.G.-T., M.G.-B., L.S.-B., J.J.-R, O.S.-N., G.O., J.F., J.S.B., D.M.W.) to exclude studies that clearly did not meet the inclusion criteria. Full text versions of potentially eligible studies were retrieved and assessed independently by pairs of authors (M.G.-G., N.G.-T., J.S.B., D.M.W., L.S.-B., L.M.P., M.I., M.G.-B., J.J.-R., O.S.-N. G.O., J.F.) against the inclusion criteria, and agreements were reached by consensus. Articles were excluded at all stages of the review and the reasons for exclusion were recorded (see Figure 1: study flow chart).

Studies were included if they were randomized clinical trials (RCT) involving any type of exercise program (e.g., exercise referral scheme, aerobic and/or strength exercise programs, tai-chi) in community-dwelling older adults aged 65 years or older of both genders. Studies had to report at least pre-, post-, and at least six-month post-intervention follow-up exercise intervention measurements. Furthermore, at least one valid PA outcome had to be assessed (e.g., self-report, activity monitor) as a primary or secondary outcome measure. Studies were included if the exercise-based intervention was compared to either a non-active control, such as usual care, or an active control, if participants performed a low intensity type of exercise such as stretching or toning activities, or physiotherapy. We included studies aimed at assessing the sustainability of PA and studies that assessed PA as a health-related outcome measure.

Studies with participants younger than 65 years old were only included in the review if the mean age was over 65, and the study either mostly included participants over 65, or presented results specifically for the subgroup of 65+ participants.

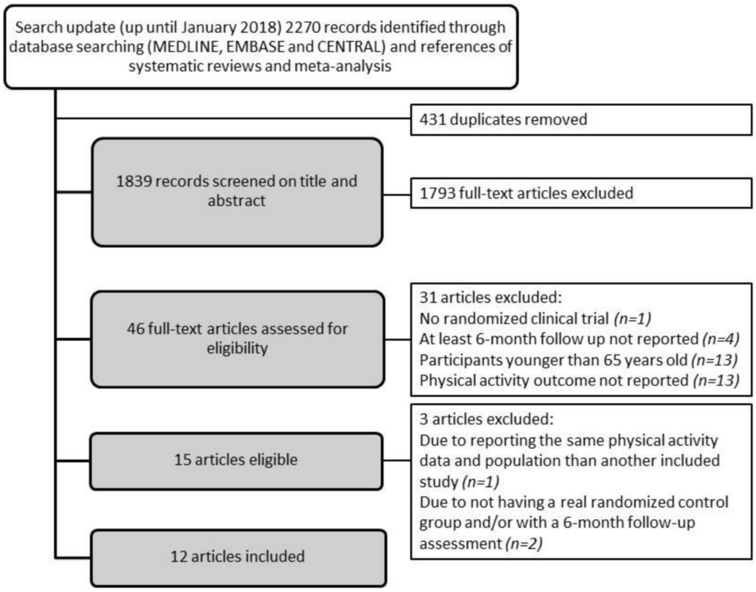

Figure 1. Flow chart of study inclusion.

2.2. Quality Assessment

The validity of the results provided by the studies was assessed using the Cochrane Collaboration's risk of bias tool [32] by two independent reviewers, with two added questions. The domains of selection bias, performance bias, outcome assessment bias, attrition bias, and selective reporting bias were assessed through the following measures: (1) random sequence generation; (2) allocation concealment; (3) adherence to intervention; (4) contamination; (5) objective PA assessment; (6) incomplete outcome data; and (7) incomplete or selective reporting, based on published papers and documentation in trial registries. The risk of bias for each item could be rated as 'high' (+), 'low' (−), or 'unclear' (?).

Performance bias items related to the blinding of participants and personnel were not included, as this is typically not feasible for exercise interventions. The assessments of both reviewers were compared, and disagreements were resolved by discussion (see Supplementary Materials Table S2).

2.3. Data Extraction

Pairs of independent reviewers (M.G.-G and N.G.-T., J.S.B. and D.M.W., L.S.-B. and L.M.P., M.I. and M.G.-B., J.J.-R. and O.S.-N., G.O. and J.F.) extracted information about the mean age, inclusion and exclusion criteria, setting, PA and physical function outcomes, instruments, and time point measured (Supplementary Materials Table S3). The extraction of specific details on intervention components included dose (frequency, intensity, time, and type), profile of the professional delivering it, control intervention description, compliance, and the specific strategies targeted to increase the sustainability of PA practices and its relevant theory background (Supplementary Materials Table S4).

Data regarding study characteristics was extracted into an electronic database. Three independent reviewers checked the accuracy of this procedure (M.G.-G., M.R., C.M.-B.) and if any discrepancy arose, consensus through discussion was sought.

2.4. Outcomes

The primary outcome of the review was time spent in PA, either assessed with valid objective measures with any kind of activity monitor (e.g., accelerometer or pedometer) or self-reported instruments. Information on the instruments used in each study (e.g., validation and recall periods of the self-reported measures) can be found in Supplementary Materials Table S3.

2.5. Statistical Analysis

We assessed the effect of exercise-based interventions on PA levels at several time-points (immediately after intervention, at mid-term (between 6 and 11 months after), and long-term (12 or more months after)). Data at three-months follow-up from a study [34] have been included in the mid-term category for comprehensiveness purposes.

The effect of exercise-based interventions was organized in two comparisons, defined by the type of control: exercise-based interventions compared to active control interventions (e.g., a low-intensity type of exercise, such as stretching or toning activities, or physiotherapy); and compared to a non-active control (e.g., usual care). We conducted secondary analyses restricted to those studies that reported specific strategies to enhance the sustainability of PA.

The effect of intervention on objective and self-reported time spent in PA was assessed with standardized mean differences, due to the variability of PA measures applied across trials. Pooled estimates of effect were computed with the DerSimonian–Laird method, applying a random effects model. Heterogeneity was assessed by means of the I^2 statistic, considering values over 50% to indicate serious inconsistency [32]. When high statistical or clinical heterogeneity was found, the pooled estimates of effect were unreliable.

Three studies comparing either two or three active interventions to one control arm [35–37] were included in the meta-analysis by merging their intervention arms into a single arm, to avoid double counting of data. Data from a four-arm study [38] was presented as two comparisons.

3. Results

3.1. Description of Study Inclusion (Figure 1)

The search update identified 2270 records, of which 46 were eligible after title and abstract screening. After the full-text assessment, 15 studies [34–48] remained eligible for inclusion, but three studies were later excluded [40,46,47], one for reporting the same PA measures and population as another included study [40], and two for not having a real randomized control group and/or not having a six-month follow up assessment [46,47]. The 12 studies that were included in the final analyses investigated a total of 18 exercise-based arms [34–39,41–45,48], compared to four active control groups [34,36,42,44] and nine non-active control groups (usual care) [35,37–39,41,43,45,48]. It is worth noting that the targeted older adults were heterogeneous in terms of comorbidities and functional status.

The principal investigators of four studies were contacted because of incomplete reporting of PA data [35,38,41,42]. Baseline data of one included study [38] were retrieved in a previous article [49]. After personal communication, we obtained additional information for two studies [35,38].

3.2. Characteristics of Exercise Arms Included in the Meta-Analysis

We described the exercise arms assessed in the included trials in Supplementary Materials Table S3, and the description of the interventions and strategies applied to enhance long-term sustainability of PA levels is presented in Supplementary Materials Table S4. Trials included a range of 52 to 422 participants, that were, on average, 75.8 years old and 73.7% were female. Only three trials reported specific information regarding the race/ethnicity of the participants, with between the 80% and 95% of the sample being Caucasian [36,42,44].

Intervention duration varied across the 12 studies, ranging from 8 weeks to 24 months. All interventions were supervised, the frequency of supervised exercise sessions was mainly two or three times a week, and session duration ranged from 30 to 90 minutes. Prescribed exercise intensity was not described in most of the included studies [36,37,39,41–43,45] (Supplementary Materials Table S4).

3.3. Comparison 1: Exercise-Based Intervention Versus Active Control

Three studies with 265 participants compared active interventions against active controls. Two of the studies assessed intervention effect on self-reported measures of PA [36,44], while the third study applied both self-reported and objective measures of PA [34]. Two of the studies implemented strategies to enhance sustainability [36,44] and one study [34] did not. The main analyses showed heterogeneity in self-reported estimates of PA, at all-time points. One of the studies showed a consistent effect of the intervention immediately and at the six-month and two-year follow ups [44], while the other two showed either no effect [36], or an initial immediate effect that disappeared during follow ups [34] (Figure 2). The secondary analyses restricted to the two trials with sustainability-enhancing strategies reached similar results and heterogeneity levels as the main analyses (Supplementary Materials Figure S1). The only study measuring PA objectively [36] showed no differences between intervention and active control, neither immediately post-intervention (SMD 0.16; 95%CI −0.30 to 0.62; 100 participants) nor at the six-month follow up (SMD 0.15; 95%CI −0.31 to 0.61).

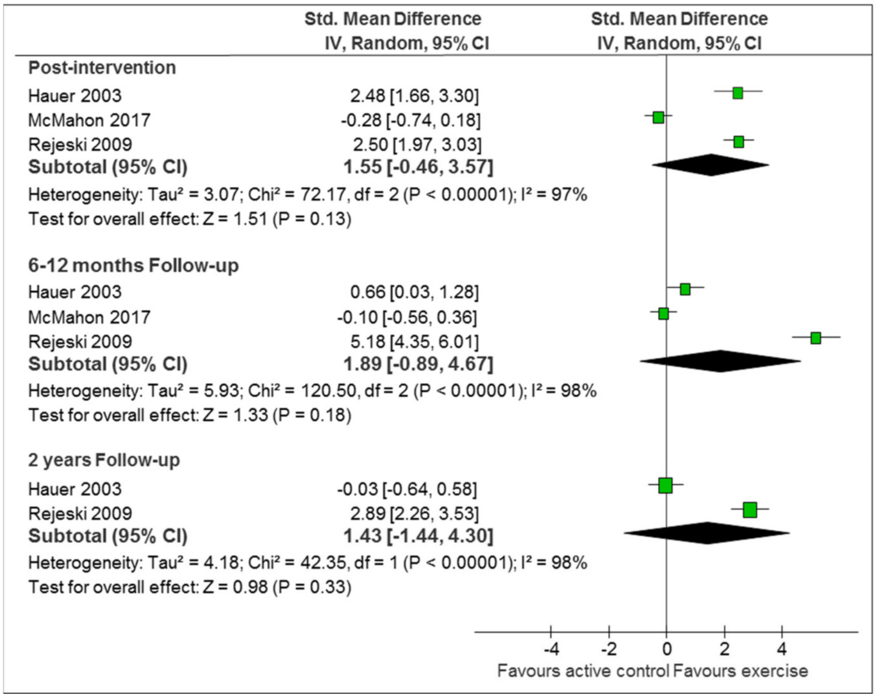

Figure 2. Exercise-based intervention versus active control (self-reported PA: physical activity). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: p value.

3.4. Comparison 2: Exercise-Based Intervention versus Non-Active Control

Eight studies with 1676 participants compared exercise-based interventions against non-active controls [35,37–39,41,43,45,48]. All but two studies implemented sustainability-enhancing strategies [35,37]. Five studies provided only on self-reported PA data [35,39,41,45,48], one study provided only objective PA data [43], and one study provided both types of data [38]. One additional study could not be included in the analysis for not presenting results data for the intervention and control groups separately [42].

Active interventions had a small effect on self-reported PA time compared to non-active control, both immediately post intervention (SMD 0.18; 95%CI −0.01 to 0.37; five studies [35,38,39,45,48]; 1257 participants; I^2 63%), and at the six-month follow up (SMD 0.30; 95%CI 0.15 to 0.44; four studies [39,41,45,48]; 724 participants; I^2 0%). The effect was gradually lost over time, with irrelevant long term results at the one-year follow up (SMD 0.27; 95%CI 0.05 to 0.48; one study [48]; 239 participants) and the two-year follow up (SMD 0.03; 95%CI −0.18 to 0.24; one study [38]; 350 participants) (Figure 3). When restricting the analyses to the four studies who applied some kind of strategy to enhance sustainability, the immediate post-intervention effect became significant and less heterogeneous (SMD 0.25; 95%CI 10.0 to 40.0; four studies [38,39,45,48]; 1108 participants; I^2 31%) (Supplementary Materials Figure S2).

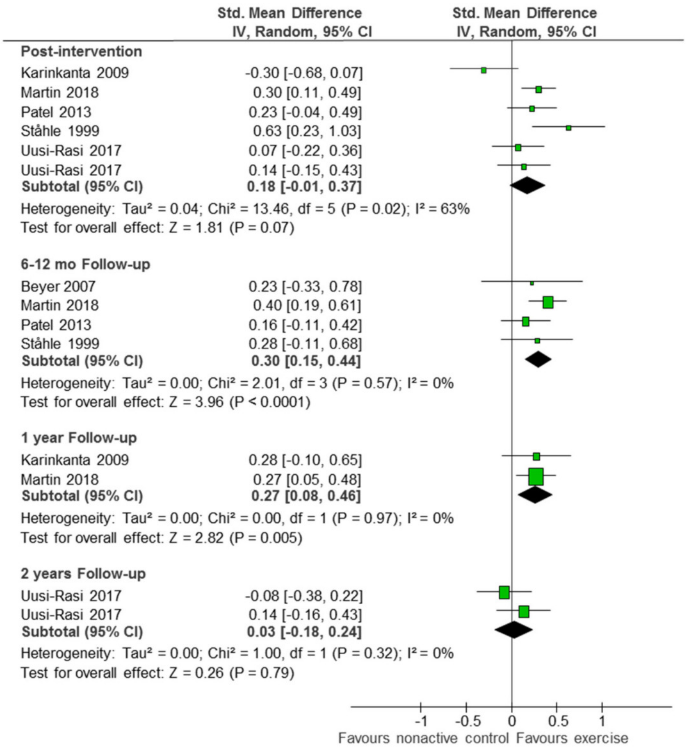

Figure 3. Exercise-based intervention versus non-active control (self-reported PA). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: p value.

The three studies which provided data with objective measures of PA were extremely heterogeneous, with two of them showing no differences between intervention and non-active control, either immediately or at any time point [36,37], and the third study showing significant differences in the changes between the baseline and the nine-month follow up [43] (Figure 4). The secondary analysis restricted to two studies which applied sustainability-enhancing strategies was still quite heterogeneous (Supplementary Materials Figure S3).

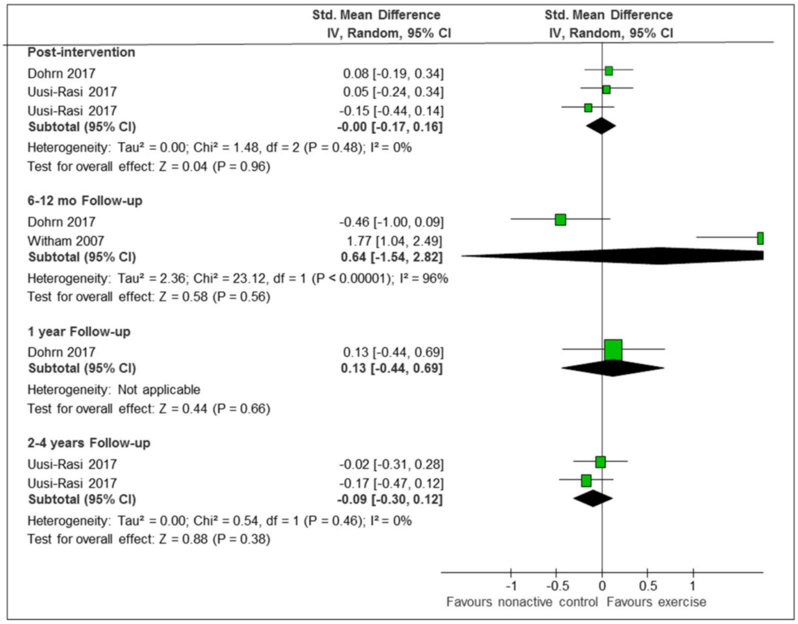

Figure 4. Exercise-based intervention versus non-active control (objective measures of PA). Abbreviations: Std. Mean Difference: standardized mean difference; IV, Random: a random-effects meta-analysis is applied, with weights based on inverse variances; 95% CI: 95% confidence interval; df: degrees of freedom; Tau^2 and I^2: heterogeneity statistics; Chi^2: the chi-squared test value; Z: Z-value for test of the overall effect; P: p value.

3.5. Reported Strategies to Enhance Long-Term Sustainable Maintenance of PA

In the present review, we classified the strategies according to the SCT (e.g., self-efficacy, behavioral capability, reinforcements, observational learning, expectations, expectancies, and self-control) [30]. Nine studies reported specific strategies to enhance the long-term sustainability of PA once the intervention had ended [36,38,39,41–45,48]. In one study, the authors offered for the intervention group to continue the PA sessions once a week, and informed the control group about a training program available in the community [39]. Similarly, in one study, researchers invited the participants to keep their PA monitors after the study, to favor sustaining the PA practice [36]. In another study, the person delivering the intervention applied the principles of self-efficacy, regular performance feedback, and positive reinforcement to enhance the motivation for exercise progression and maintenance [41]. McAuley et al. used self-efficacy as the guiding theoretical construct, and participants were sent feedback on their measures by mail as a reinforcement strategy, so that they could see their improvements in health outcomes [42]. In two studies, patients kept an activity diary and agreed to establish weekly goals for increased activity with the training provider [43,45]. In another study, each participant engaged in weekly group-mediated behavioral counselling sessions that focused on self-regulatory skills central to promoting PA, for the first 10 weeks [44]. In the study that assessed outcomes two years post-intervention, participants were encouraged to keep their pedometers and were invited to continue with the exercise training, or encouraged to participate in any other preferred PA [38]. In the most recent study, the exercise specialist identified a leader in each exercise group to organize a third session each week on their own, to enhance the autonomy of the participants and the sustainable maintenance of PA practice [48]. All participants were offered a personalized exercise program and visits with all participants were made to the nearest community resources (e.g., sport facilities) [48]. This latest intervention included mechanisms to enhance social support during the cool-down phase of each session, such as social influence/social comparison, social control, self-esteem, sense of control and belonging, and companionship [48].

The sustainability-enhancing strategies most associated with success were two behavioral strategies: self-control and behavioral capability. Self-control strategies used by participants to maintain self-motivation and achieve personal goals were the use of tracking monitors, daily step diaries, and individualized step-based goals. Behavioral capability strategies included individualized counselling on the role of PA in disability prevention, designed to promote PA, and visits to community resources (e.g., sport facilities) where the regular PA practice could be continued.

4. Discussion

The current systematic review synthesized the data from 12 RCTs, including 18 exercise-based arms, compared to four active control and nine non-active control groups that evaluated the effects of exercise-based interventions implemented in older adults to sustain the maintenance of PA increases for the mid- and long-term, and to describe the strategies used in the interventions to enhance the sustainability of PA in this population.

Results of the effect of exercise interventions on the sustainability of PA were heterogeneous in the present study. The results of a recent meta-analysis also revealed a high heterogeneity associated with the pooled treatment, with a significant small effect favoring exercise interventions over control [25,26]. As the authors included non-randomized trials, it is possible that the effect reported was overestimated [25,26]. Supervised exercise interventions with specific strategies to enhance sustainability had statistically significant beneficial effects on PA levels at the end of intervention compared to non-active controls or active controls. However, at 12 months post-intervention cessation, benefits subsided. Unclear effects on maintenance beyond 12 months were noted in other reviews of PA promotion, due to a lack of high-quality longitudinal studies, heterogeneity of interventions, and a high chance of bias [27].

Researchers tended to describe some strategies to enhance PA sustainability in the intervention, although most researchers failed to design the intervention bearing sustainability in mind [3]. Approximately 80 theories related to behavior change had been identified in the literature, and one of the most used is the SCT [50]. The specific strategies described to enhance sustainability in the included studies might not be applicable to all populations, or might not be explicitly based on theory. Choosing a relevant theory can be a challenging task for intervention designers, especially given the large number of theories.

4.1. Mechanisms that Underpin our Main Finding

Insufficient PA is a modifiable lifestyle factor that leads to an increasing pressure to deal with additional health care costs associated with an ageing population and chronic disease burden [18]. A recent systematic review suggested that participants who engaged in PA had their odds of living a healthy life in older age increased compared to participants that were physically less active [14]. The present systematic review does not show a successful picture of exercise-based interventions to increase PA levels in older adults in the long-term, as only one intervention that added specific strategies to sustain PA maintenance showed better effects in the long-term [43]. Public health interventions targeting insufficient PA levels are usually developed without the involvement of end-users, which seems to be the case for all the studies included in the present review. One promising way to develop effective PA-based interventions (e.g., exercise-based) is to combine theory-based with solution-based approaches, characterized by considering individuals' interests, forming cooperative teams of stakeholders, and distributing actions and decisions [51]. Patient and public involvement (PPI) has developed into an integral part of research practice over the last 25 years. It is thought that involving end-users in the development of solution-based interventions using key elements derived from participatory methodologies such as PPI may increase the likelihood of producing sustainable change [52]. However, none of the studies included in our review reported any approach of PPI in the design of the exercise-based intervention.

Behavioral-type components, such as self-monitoring, goal setting, and prompting, engage participants in actively changing physical behaviors [53]. Cognitive-type components, such as education, problem solving, or counselling, promote change in cognitive processes, attitudes, or beliefs [54]. Some of the most cited strategies used in the included studies were education [55], self-monitoring [56], and action planning [57]. These have all been acknowledged in the literature as important theoretical constructs for successful behavior change, however, in the included studies they might not have been sufficiently addressed in the intervention design and across the intervention period [50]. A recent narrative systematic review supports combination strategies as more successful in changing PA behavior [58] than interventions that target a standalone behavioral strategy. However, none of the strategies described in the present review suggested the inclusion of the end-user themselves, which may be one of the most vital components for finding the right motivating factors to improve long-term exercise/PA participation among older adults. The behavioral capability strategies reported in some of the included studies aimed at engaging participants in existing community resources. Community-based resources to facilitate health behavior change may include a wide range of available opportunities, such as city-based exercise programs [59], referral to fitness professionals, or fitness centers [60]. Referrals to specific community programs, such as exercise for adults, have shown a positive effect on patient behavior [60,61]. Self-control strategies are aimed at providing regular performance feedback to enhance the motivation for activity maintenance (e.g., pedometer, daily steps diary). Several studies have shown the positive effects of activity trackers for enhancing PA levels. However, while some short-term studies support success, more recent data question the longer-term effects on PA change [62,63].

It is important to note that this area of PA research is characterized by a dearth of knowledge of the effects of exercise interventions on long-term sustainability, particularly among older adults [64]. Brawley et al. highlighted the need for longitudinal research investigating not only the factors associated with activity maintenance after the program ends, but also the psychological strategies that were most effective for attenuating the rate of declining activity levels beyond program completion [64]. A whole system-oriented approach is required that is tailored to meet the needs of older adults and aligns with social, individual, and environmental factors [31]. A patient-centered approach supporting clinical reasoning to detect needs, limitations, and strengths in both the participant and the physical and social environment and choosing evidence-based interventions to enhance behavior change was described in one study, which had to be excluded from the present review for not reporting a six-month follow-up [47]. Mechanisms to enhance social support and participation might be effective for battling social isolation and enhancing adherence [48].

PA is continuously ubiquitous throughout the day [65], so understanding usual PA patterns might help turn daily routines into opportunities for exercising rather than performing specific exercise programs [66]. Interventions should be developed in coherence with their daily routine, tailored to an individual's context and circumstances to improve adherence [67].

4.2. Strengths and Limitations

To our knowledge, this is the first systematic review focusing on the sustainability of exercise-based interventions to maintain increases in PA levels in older adults, in the mid- and long-term. The strengths of the current meta-analysis are the extensive search strategy, the inclusion of RCTs, and the number of exercise arms, as well as the description of specific strategies to enhance sustainability of PA practice. However, the present systematic review is restricted to three databases. In addition, two studies could not be included due to not being able to contact the main author. The meta-analyses were performed on few studies, which caused estimates to be more imprecise. This imprecision, added to the observed heterogeneity, limits our confidence in the results. On the other hand, even though we aimed at describing the long-term effects of current interventions on enhancing PA sustainability, very few studies reported this, so the analysis had to focus on the six-month follow up period.

Besides this, most of the studies included in the review assessed PA with a self-report instrument, increasing the impact of recall bias [68]. There was also lack of consistency regarding the way frequency, intensity, and duration of PA were reported. Similar problems are also mentioned in other systematic reviews of PA [14,24,26,28].

5. Conclusions

Exercise interventions are statistically significant but translate to a small clinical benefit on PA levels in community-dwelling older adults. Among those studies that reported longer-term follow up (six months after the intervention cessation) improvements have been shown to decline. Only one intervention that added specific strategies to enhance sustainability demonstrated maintenance of PA practice in the long term. Further research is needed to conclude the most effective strategies to enhance the sustainability of PA for older adults.

This review could be of interest to clinical or institutional leaders and administrators, as well as to health professionals and researchers in order to inform clinical decisions and policies.

Data Statement

The data will be made available to interested researchers. Please contact the corresponding author.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/16/14/2527/s1, Supplementary S1. Search Strategy, Supplementary S2. Risk of bias, Supplementary S3. Description of included studies, Supplementary S4. Description of the interventions and strategies to enhance long-term adherence of PA levels, Supplementary Figure S1. Exercise-based intervention vs active control (self-reported PA) restricted to studies with adherence-enhancing strategies. Supplementary Figure S2. Exercise-based intervention vs non-active control (self-reported PA) restricted to studies implementing adherence-enhancing strategies. Supplementary Figure S3. Exercise-based intervention vs non-active control (objective measures of PA) restricted to studies implementing adherence-enhancing strategies.

Author Contributions: M.G.-G., J.S.B., M.I., M.R. and O.S.-N. contributed to the concept and design of the study. I.S. conducted the literature search. M.G.-G., N.G.-T., M.G.-B., L.S.B., J.J.-R., O.S.-N, G.O., J.F., J.S.B., D.M.W. conducted the title and abstract screening for eligibility. M.G.-G., N.G.-T., J.S.B., D.M.W., L.S.B., L.M.P., M.I., M.G.-B., J.J.R., O.S.-N., C.M.B., G.O., J.F., C.M.-B. gathered and conducted the full text data extraction. M.R. performed the data analysis. All authors have revised the manuscript and approved the final version.

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Abbreviations

PA, physical activity; RCT, randomized clinical trials; SCT, social cognitive theory; BCTs, behavioral change techniques.

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Annex 3. Search Strategy (Estudi I)

Estudi I: Supplementary Table S1. Search Strategy.

MEDLINE (PubMed)
January 2018

#1 "Aging"[MeSH Terms] OR "Nursing Homes"[MeSH] OR "Long-term care" [MeSH] OR "Caregivers" [MeSH] OR "Homebound Persons"[MeSH] OR "Home care services"[MeSH] OR old[Title/Abstract] OR olds[Title/Abstract] OR senior[Title/Abstract] OR seniors[Title/Abstract] OR ageing[Title/Abstract] OR aging[Title/Abstract] OR aged[Title/Abstract] OR nursing home*[Title/Abstract] OR community dwelling[Title/Abstract] OR care home*[Title/Abstract] OR carer[Title/Abstract] OR carers[Title/Abstract] OR long-term care[Title/Abstract] OR caregiver[Title/Abstract] OR care giver[Title/Abstract] OR caregivers[Title/Abstract] OR care givers[Title/Abstract] OR homebound[Title/Abstract] OR resident*[Title/Abstract] 1828945

#2 ("Adult"[MeSH] OR "Middle Aged"[MeSH] OR "Young Adult"[MeSH] OR Child[MeSH] OR "Child, Preschool"[MeSH] OR Infant[MeSH] OR "Infant, Newborn"[MeSH] OR "Internship and Residency"[MeSH OR adolescent*[tiab] OR youth*[tiab] OR young[tiab] OR child*[tiab] OR pediatric[tiab] OR paediatric[tiab]) NOT "Aged"[MeSH] 1582329

#3 #1 NOT #2 1482560

#4 "Aged"[MeSH] OR “Geriatrics” [MeSH] OR older[tiab] OR oldest[tiab] OR elder[tiab] OR elderly[tiab] OR elders[tiab] OR eldership[tiab] 2929284

#5 #3 OR #4 3908325

#6 “Exercise”[Majr] 101919

#7 “Exercise Therapy”[Mesh] 39343

#8 "Physical Fitness"[Mesh] 24808

#9 exercise[ti] 92365

#10 physical activity[tiab] 81156

#11 physical train*[ti] 2088

#12 fitness[ti] 15182

#13 aerobic[ti] 15348

walking

#14 #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 265270

#15 #5 AND #14 71955

#16 sustain*[tiab] 272669

#17 continued[ti] 4396

#18 continuation[ti] 1902

#19 maintained[ti] 4914

#20 maintenance[ti] 33877

#21 long term[ti] 171647

#22 intensity[ti] 33089

#23 follow up[ti] 84979

#24 #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 580225

#25 #15 AND #24 4709

#28 systematic[sb] 328193

#29 #25 AND #28 123

#30 #25 NOT #29 4586

#31 (randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized[tiab] OR placebo[tiab] OR drug therapy[sh] OR randomly[tiab] OR trial[tiab] OR groups[tiab]) NOT (animals [mh] NOT humans [mh]) 3505571

#32 #30 AND #31 2146

#34 #25 NOT (#29 OR #32) 2440

#35 #34 AND 28648951[uid] 0

#36 28648951[uid] 1

#37 longitudinal[tiab] OR cohort*[tiab] 576315

#38 #15 AND #37 7562

#40 longitudinal[ti] OR cohort*[ti] 110398

#41 #15 AND #40 1923

OVID Embase <1974 to 2017 November 16>

January 2018

1 aged/ (2671375)

2 older.ti,ab. (476520)

3 elderly.ti,ab. (295651)

4 1 or 2 or 3 (3015661)

5 *exercise/ (103420)

6 exp fitness/ (35889)

7 exercise.ti. (118971)

8 physical activity.ti,ab. (112787)

9 5 or 6 or 7 or 8 (275973)

10 sustain*.ti,ab. (369026)

11 continued.ti. (5147)

12 continuation.ti. (2440)

13 maintained.ti. (5703)

14 maintenance.ti. (43899)

15 long term.ti. (233163)

16 follow up.ti. (117109)

17 10 or 11 or 12 or 13 or 14 or 15 or 16 (737794)

18 4 and 9 and 17 (2692)

19 random:.tw. or placebo:.mp. or double-blind:.tw. (1507141)

20 18 and 19 (777)

The Cochrane Library <Cochrane Central Register of Controlled Trials : Issue 10 of 12, October 2017>
January 2018

#1 MeSH descriptor: [Aged] explode all trees 1180

#2 older:ti,ab 29155

#3 elderly:ti,ab 19950

#4 #1 or #2 or #3 45696

#5 MeSH descriptor: [Exercise] explode all trees 19952

#6 MeSH descriptor: [Exercise Therapy] explode all trees 11092

#7 MeSH descriptor: [Physical Fitness] explode all trees 2760

#8 exercise:ti 23253

#9 (physical next activity):ti,ab 12479

#10 #5 or #6 or #7 or #8 or #9 47148

#11 sustain*:ti,ab 25133

#12 continued:ti 472

#13 continuation:ti 517

#14 maintained:ti 546

#15 maintenance:ti 6675

#16 (long next term):ti 21386

#17 (follow next up):ti 12898

#18 #11 or #12 or #13 or #14 or #15 or #16 or #17 62408

#19 #4 and #10 and #18 384

Annex 4. Risk of bias (Estudi I)

Estudi I: Supplementary Table S2. Risk of bias.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Adherence (performance bias)	Contamination (performance bias)	Self-reported assessment of PA (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Beyer 2007	+	?	+	?	−	+	?
Dohrn 2017	+	+	?	?	+	+	?
Hauer 2003	?	?	+	?	−	+	?
Karinkanta 2009	+	+	?	?	−	?	?
Martin 2018	+	+	+	?	−	+	+
McAuley 2007	+	+	+	?	−	+	?
McMahon 2017	+	+	+	+	+	+	+
Patel 2013	+	+	?	?	−	?	?
Rejeski 2009	+	?	?	?	−	+	+
Ståhle 1999	?	?	+	?	−	+	?
Uusi-Rasi 2017	+	+	+	?	+	+	+
Witham 2007	+	+	+	?	+	−	?

Annex 5. Description of included studies (Estudi I)

Estudi I:

- Supplementary Table S3. Description of included studies.

Annex 6. Description of the interventions and strategies to enhance long-term adherence of PA levels

Estudi I:

- Supplementary Table S4. Description of the interventions and strategies to enhance long-term adherence of PA levels.

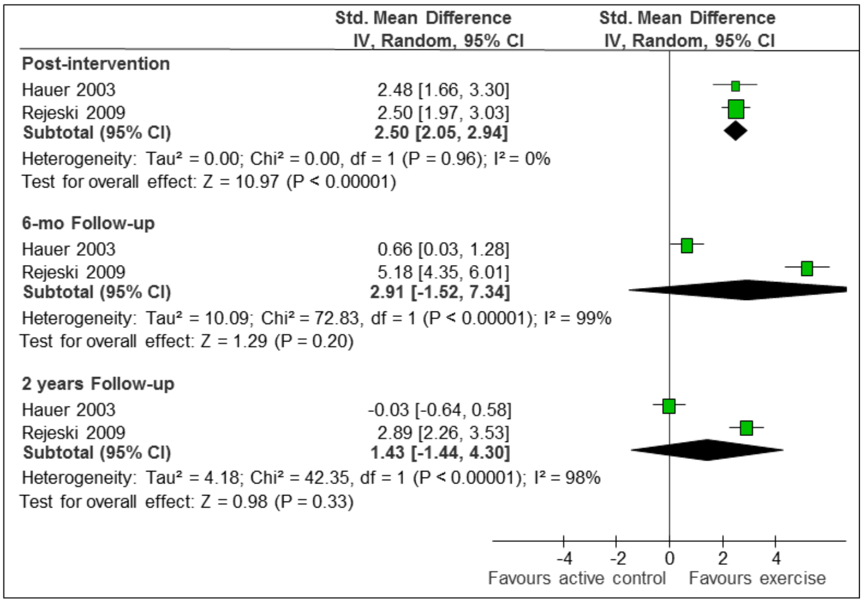
*Ambdós annexos es poden recuperar de manera *online* a:

http://www.mdpi.com/1660-4601/16/14/2527/s1

Annex 7. Exercise-based intervention vs active control (self-reported PA) restricted to studies with adherence-enhancing strategies (Estudi I)

Estudi I:

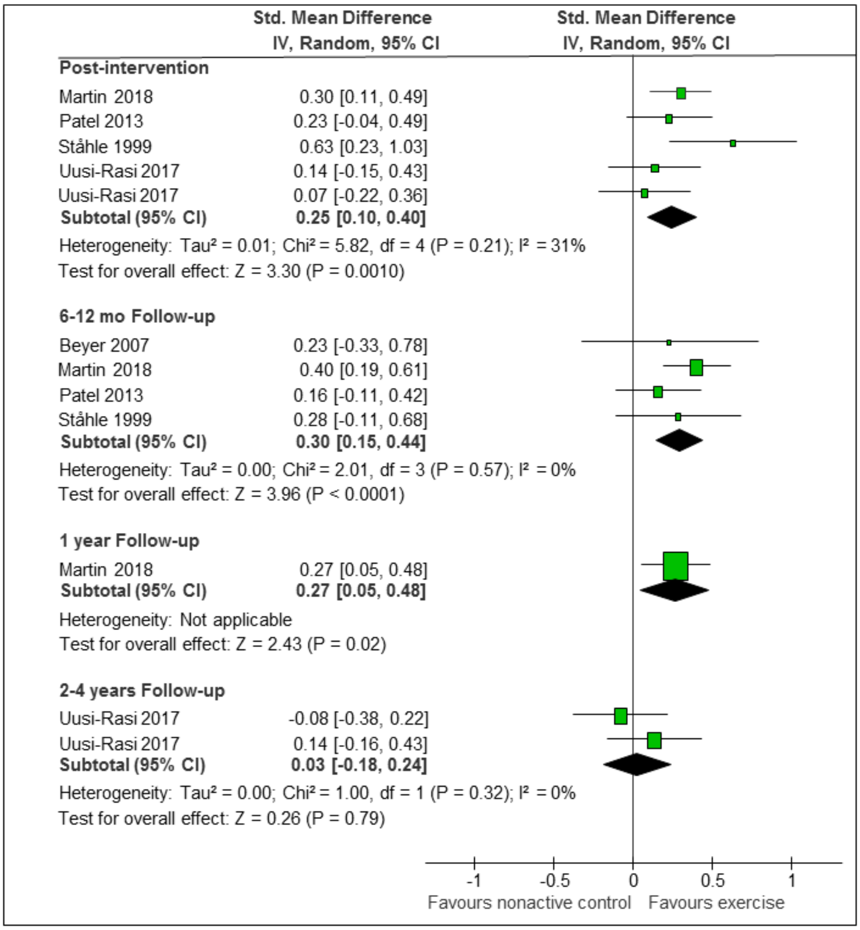
- Supplementary Figure 1. Exercise-based intervention vs active control (self-reported PA) restricted to studies with adherence-enhancing strategies.



Annex 8. Exercise-based intervention vs non-active control (self-reported PA) restricted to studies implementing adherence-enhancing strategies (Estudi I)

Estudi I:

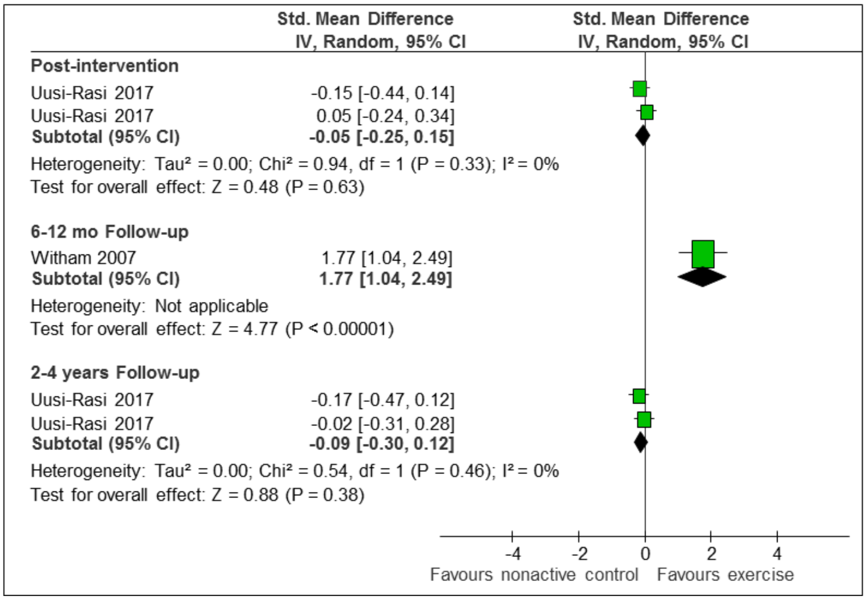
- Supplementary Figure 2. Exercise-based intervention vs non-active control (self-reported PA) restricted to studies implementing adherence-enhancing strategies.

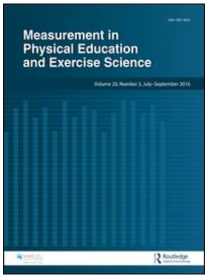


Annex 9. Exercise-based intervention vs non-active control (objective measures of PA) restricted to studies implementing adherence-enhancing strategies

Estudi I:

- Supplementary Figure 3. Exercise-based intervention vs non-active control (objective measures of PA) restricted to studies implementing adherence-enhancing strategies.





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Validity of the Sedentary Behavior Questionnaire in European Older Adults Using English, Spanish, German and Danish Versions

Oriol Sansano-Nadal [a], Jason J. Wilson [b,c], Carme Martín-Borràs [a,d], Jan Christian Brønd [e], Mathias Skjødt[e], Paolo Caserotti[e], Marta Roqué I Figuls [f], Nicole E. Blackburn [g], Jochen Klenk [h], Dietrich Rothenbacher [h], Myriam Guerra-Balic [a], Manel Font-Farré [a], Michael Denkinger [i], Laura Coll-Planas [f], Manuela Deidda [j], Emma McIntosh [j], Maria Giné-Garriga [a,d], and Mark A. Tully [b]

[a]Department of Physical Activity and Sport Sciences, Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Barcelona, Spain; [b]Institute of Mental Health Sciences, School of Health Sciences, Ulster University, Newtownabbey, UK; [c]School of Sport, Ulster Univeristy, Newtownabbey, UK; [d]Department of Physical Therapy, Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Barcelona, Spain; [e]Department of Sports Science and Clinical Biomechanics, Center for Active and Healthy Ageing (CAHA), Syddansk Universitet, Odense, Denmark; [f]Fundació Salut I Envelliment (Foundation on Health and Ageing)- UAB, Universitat Autònoma De Barcelona, Barcelona, Spain; [g]Institute of Nursing and Health Research, School of Health Sciences, Ulster University, Newtownabbey, UK; [h]Institute of Epidemiology and Medical Biometry, Ulm University, Ulm, Germany; [i]Agaplesion Bethesda Clinic, Geriatric Research Unit Ulm University and Geriatric Center, Ulm, German; [j]Health Economics and Health Technology Assessment (HEHTA), Institute of Health and Wellbeing (IHW), University of Glasgow, Glasgow, UK

ABSTRACT

The main aim of this study was to assess the criterion validity of the Sedentary Behavior Questionnaire (SBQ) to measure SB in community-dwelling older adults using thigh-measured accelerometry as the criterion method. 801 participants (75.6 ± 6.1 years old, 57.6% females) provided valid thigh-based accelerometer data (activPAL/Axivity) and completed the SBQ. Criterion validity was assessed using Spearman's Rho coefficients. Bland–Altman plots, including 95% limits of agreement and Intraclass Correlation Coefficient (ICC), were used to assess the agreement between self-report and device-measured daily SB time. Strength of the association was examined using multiple linear regression. There was a weak correlation (Rho = 0.25, $p < .001$) between self-reported and device-based SB measures. The SBQ under-estimated daily SB time compared to accelerometry. Our results highlighted an overall weak-to-moderate correlation between measures, with significant differences between each country's version. Researchers should be cautious when using the SBQ to provide an estimation of SB time in older adults.

KEYWORDS
Sedentary behavior; activpal; Axivity; older adults

Introduction

Reducing sedentary behavior, defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting, reclining or lying posture (Tremblay et al., 2017), has been recognized as an important public health target in older adults (De Rezende et al., 2014; Sparling et al., 2015). Older adult populations exhibit the highest levels of sedentary behavior, spending up to 80% of their waking hours sitting (Giné-Garriga et al., 2020; Harvey et al., 2015; Wullems et al., 2016). Researchers have demonstrated that sitting or lying for prolonged periods of time is negatively associated with health status (Ku et al., 2018; Wilson et al., 2019). Pavey and colleagues (2015) highlighted that older women who sat 8 to 11 hours/day and those who sat ≥11 hours/day had 1.45 and 1.65 times higher risk of all-cause mortality respectively, compared to older women who sat less than 4 hours per day. High levels of sedentary behavior have also been associated with increased levels of social isolation in older adults (Tully et al., 2019). Though the cost of sedentary behavior to the UK national health service has been estimated as £0.8 billion in the 2016–2017 financial year (Heron et al., 2019), the actual burden is likely to be higher, considering the broader societal costs associated with sedentary behavior. The negative health consequences of high levels of sedentary behavior appear to hold true even for those who meet the physical

CONTACT Oriol Sansano-Nadal oriolsn@blanquerna.url.edu Facultat De Psicologia, Ciències De l'Educació I De l'Esport Blanquerna, (Universitat Ramon Llull), C/Císter 34, Barcelona, 08022, Spain

*Dr. Maria Giné-Garriga and Dr. Mark A. Tully should be considered joint senior author.
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activity recommendations of the World Health Organization (WHO), of at least 150 minutes per week of moderate-intensity physical activity, but higher levels of physical activity may ameliorate this effect (Ekelund et al., 2016; Katzmarzyk et al., 2009; Keith P. Gennuso et al., 2013; Patel et al., 2010; Van Der Ploeg et al., 2012; Van Uffelen et al., 2010).

Accurate measurement of sedentary behavior is important in order to facilitate rigorous scientific evaluations of interventions designed to reduce sedentary behavior. Device-based (e.g. hip-worn ActiGraph accelerometer; wrist-worn Axivity accelerometer; and thigh-worn activPAL accelerometer) and self-reported measures (e.g. Sedentary Behavior Questionnaire (SBQ); Measuring Older Adults Sitting Time (MOST); International Physical Activity Questionnaire (IPAQ); LASA Sedentary Behavior Questionnaire) are available. Self-report questionnaires have been predominantly used in large scale studies due to low administration cost and due to providing more information about the context of behavior (e.g. watching television, reading, playing computer/video games, driving/riding in a car). Nevertheless, some limitations such as recall bias and the underestimation of sedentary time are likely with self-reported measures (Aguilar-Farías, Brown, Olds et al., 2014a). The SBQ is a self-report instrument developed to evaluate the amount of time doing nine context-specific behaviors on weekdays and weekend days. The English-language version has been validated in overweight adults (Rosenberg et al., 2010); an adapted Spanish-language version was validated in patients with fibromyalgia (Munguía-Izquierdo et al., 2013); and a Turkish-language version in an adult population (Bakar et al., 2018). A recent study compared the Slovenian version of the SBQ (weekdays) against the activPAL3 micro also in an adult population (Kastelic & Šarabon, 2019). However, there are currently no studies that have validated the use of the SBQ in older

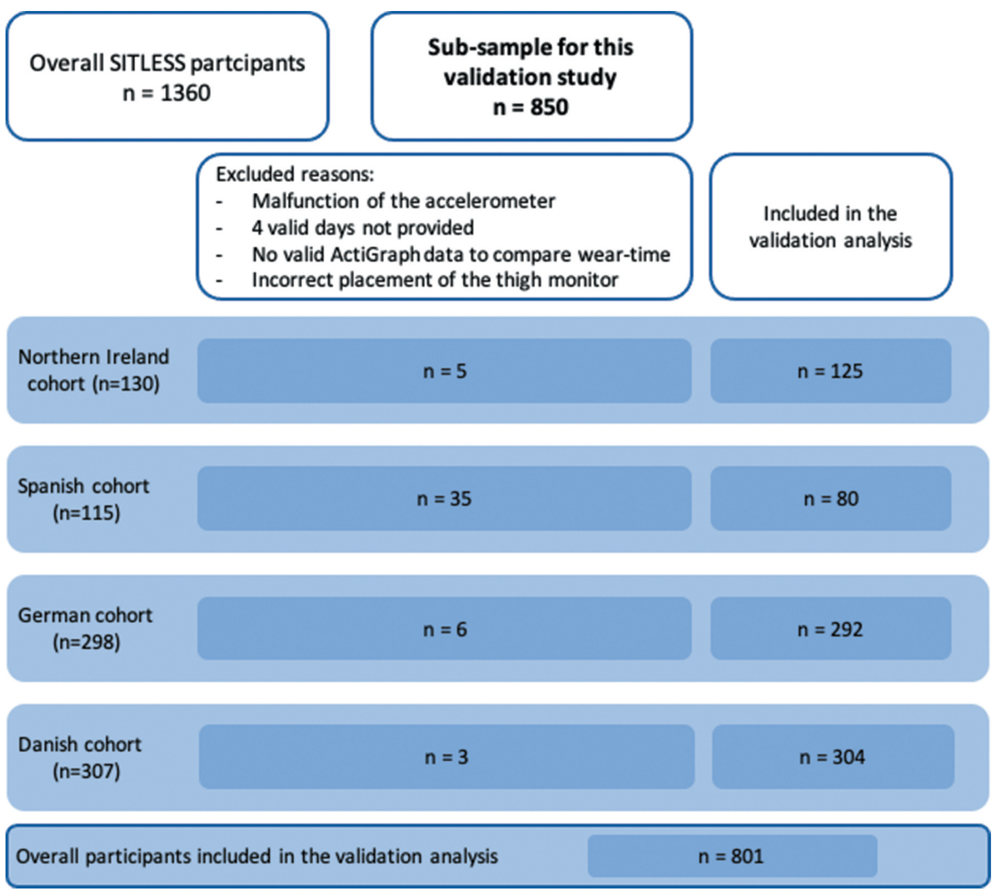

Figure 1. Sample flowchart.

adults. There has also been a lack of validation studies of self-reported sedentary behavior measures in languages other than in English in older adults.

Authors of a recent study have shown minor differences assessing different physical behaviors, as well as both sitting and lying, between three different accelerometers placed at the thigh (ActiGraph GT3X, activPAL micro and the Axivity AX3). Researchers suggested that raw data should be processed and analyzed in an identical manner (Crowley et al., 2019). However, some limitations for using accelerometers include their high cost and the added complexity when using them in large cohort studies, including participant's responsibility to wear the device for at least seven days to provide representative data as shown in previous studies (Hart et al., 2011). Older adults have reported additional challenges such as mild skin irritation with continuous wear (Van Der Berg et al., 2016), forgetting to replace the belt in the morning after removing it for sleeping and finding the device uncomfortable (Schrack et al., 2014). Thus, assessing the validity of self-report questionnaires such as the SBQ is especially relevant in the older adult population.

Therefore, the main aim of this study was to assess the criterion validity of the SBQ to measure sedentary behavior in community-dwelling older adults using thigh and hip accelerometry. Our secondary aim was to validate the English, Spanish, German and Danish versions of the SBQ in the same population.

Materials and methods

Study design & participants

This validation study used a cross-sectional design using baseline data collected from the SITLESS study. Briefly, the SITLESS study was a multi-center pragmatic three-armed randomized controlled trial which aimed to determine whether exercise referral schemes could be enhanced by self-management strategies to reduce sedentary behavior, increase physical activity levels and improve health in the long-term in community-dwelling European older adults (≥65 years old). Full details of the study were described elsewhere (Giné-Garriga et al., 2017). All participants gave their informed consent prior to participation. From the overall SITLESS participants (N = 1360), a subsample of 801 participants (mean age 75.6 ± standard deviation 6.1 years old and 57.6% females) who answered all items in the SBQ and provided valid thigh-based accelerometry data in the baseline assessment were included in this validation study (see Figure 1)

Measurements & procedures

Sedentary behavior questionnaire (SBQ)

The SBQ version used was previously validated against self-reported measures by Rosenberg et al. (2010) in overweight male adults. Data showed an acceptable intraclass correlation coefficient (ICC) for all items and the total scale (range = 0.51–0.93), and significant relationships between SBQ items and the International Physical Activity Questionnaire (IPAQ) sitting time and body mass index (BMI). The SBQ assessed the amount of time spent doing nine context-specific behaviors during weekdays and weekend days, with the question 'on a typical weekday or weekend day, how much time do you spend (from when you wake up until you go to bed) doing the following?': watching television; playing computer/video games; sitting while listening to music; sitting and talking on the phone; doing paperwork or office work; sitting and reading a book or magazine; playing a musical instrument; doing arts and crafts; and sitting and driving/riding in a car or train. The possible responses options were: none, 15 minutes or less, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours, or 6 hours or more. To obtain daily time sitting or lying, weekday hours were multiplied by five and weekend hours were multiplied by two; summed hours per week were divided by seven and finally multiplied by 60 to give minutes in sedentary behavior per day.

Translation process

The translation and adaptation from English language to Spanish, German and Danish was completed following the recommendations of Hambleton (2005). The direct and inverse translation method in each language was completed by two independent bilingual translators to identify any discrepancies between the meaning of the translation and the original questionnaire. After a final consensus, researchers and translators generated the final versions of the questionnaires in Spanish, German and Danish.

Accelerometry

Participants were asked to wear an accelerometer on their dominant thigh continuously (24 hours/day) for seven consecutive days after completion of the SBQ. Two types of thigh accelerometers were used according to their availability at each site. The cohorts from Spain and Germany (n = 372) wore the activPAL3c (PAL technologies, Glasgow, Scotland) and the cohort from Northern Ireland and Denmark (n = 429) wore the Axivity AX3 (AXIVITY Ltd., Newcastle, UK). The activPAL (weighing 9 g and measuring 25x45x5mm) was initialized using activPAL Professional Software (version 7.2.38.2) with a sampling frequency of 20 Hz and a g range of ±2 g and the Axivity (weighing 11 g and measuring 23x32,5x7,6 mm) was initialized using Open Movement OmGui Software (version 1.0.0.43) with a sampling frequency of 50 Hz and a g range of ±8 g. The activPAL and Axivity accelerometers were positioned on the dominant thigh midway between the anterior superior iliac spine and the patellar tendon and attached using a waterproof transparent film (hypoallergenic Tegaderm foam adhesive dressing, 3 M, USA). For the purposes of determining accelerometer wear time for this specific study, participants were also asked to simultaneously wear the ActiGraph wGT3X-BT + (ActiGraph LLC, Pensacola, FL, USA) alongside the thigh accelerometer. The ActiGraph device was placed on the dominant hip using an elastic belt, just above the iliac crest, during waking hours only (removed during nighttime sleep and water-based activities) for seven consecutive days. The ActiGraph wGT3X-BT (weighing 19 g and measuring 46x33x15 mm) was initialized using the ActiLife (version 6.13.4) software with a sampling frequency of 30 Hz and a g range of ±6 g (Robusto & Trost, 2012).

Data from both thigh-based accelerometers were pooled together and harmonized. Sedentary behavior time (i.e. combined sitting/lying time) for the Axivity AX3 data was classified using the method described by Skotte et al. (2014). This method uses threshold values of standard deviation of acceleration, angle and also inclination to determine different types of activities, including sedentary behavior (Skotte et al., 2014). This method has demonstrated an excellent sensitivity and specificity (93 to 100%) in semi-standardized and free-living settings (Crowley et al., 2019). Sedentary behavior time from the activPAL was classified by the activPAL Professional Software (version 7.2.38.2) algorithm because the activPAL3 uses a lower sampling frequency compared to the Axivity (i.e. 20 vs 50 Hz). The activPAL3 also covers a more limited g range (±2 g) compared to the Axivity (±8 g). The assessment of daily sedentary behavior time from each thigh-worn accelerometer was restricted to wear time extracted from the .agd files generated by the hip-worn ActiGraph. Wear time information in the .agd files was identified using the Choi 2011 wear time algorithm using the ActiLife software (Giné-Garriga et al., 2020). With a small number of participants, it was observed that while the ActiGraph had been worn, the thigh-based accelerometer had not been worn in conjunction or suffered from a malfunction. In order to exclude these days from the analysis, the output derived from the harmonization process were subsequently manually cleaned by two authors (JJW and MS). The cleaning process ensured only valid days were included (at least four valid days (including one weekend day) and ≥600 minutes/day wear time) as suggested in previous studies (Migueles et al., 2017). Daily sedentary time, normalized at a daily level, was then calculated from the thigh-based monitors once the cleaning process had been completed.

Additional data

Additional data were included to describe the sample including age (years), sex (male and female), country (Northern Ireland, Spain, Germany and Denmark), BMI (kg/m^2; using the Tanita BC 420 bioelectrical impedance scales and a Seca 213 portable stadiometer) to categorize weight status (normal and underweight: <25 kg/m^2; overweight: 25–29.9 kg/m^2; obese: >30 kg/m^2), Short Physical Performance Battery (SPPB) score to determine low or high physical function (<10 SPPB score or ≥10 SPPB score, respectively) (Guralnik et al., 1994) and the Trail Making Test (TMT) (Soukup et al., 1998) time to determine cognitive (TMT A; intact <78 seconds; deficient ≥78 seconds)/executive (TMT B; intact ≤180 seconds; mildly reduced ≥181 seconds) function used in several studies (Bowie & Harvey, 2006; Roy & Molnar, 2013), as well as with an older adult population (Cangoz et al., 2009).

Statistical analysis

The chosen analytical approach has been guided by recommendations for validating self-reported behavior (Welk et al., 2019). Before conducting analyses, all variables where examined for normality using SShapiro–WilkTest or KKolmogorov–SmirnovTest.

Paired samples t-tests were used to assess the differences in the mean values for daily sitting time between self-reported and device-measured daily sedentary behavior time. Correlations were interpreted as follows: coefficient value between ± 0.50 and ± 1: strong positive/negative linear relationship or correlation; between ± 0.30 and ± 0.49: moderate positive/negative linear relationship or correlation; below ± 0.29: weak positive/negative linear relationship or correlation (Rumsey, 2005). Criterion validity was assessed using nonparametric Spearman's Rho coefficients.

To assess the agreement between daily sedentary behavior time measured by the SBQ compared to the accelerometer estimated sedentary time, Bland–Altman plots (including the 95% limits of agreement) and Intraclass Correlation Coefficients (ICC) were utilized. The mean difference ± 1.96 x the standard deviation of the mean difference was added to the plot to derive the limits of agreement. These limits defined the interval in which differences between methods could be expected for 95% of future measurements in comparable people (Bland & Altman, 2007). Differences of the two measures were checked to be normally distributed (Giavarina, 2015). Accelerometer estimated sedentary time was used as the criterion measure; a mean difference close to y = 0 was a good indicator of agreement, as was a confidence interval encompassing y = 0, thus indicating higher levels of agreement with the daily sitting time from the SBQ. We considered wide limits of agreement having a mean difference of more than 240 minute/day of sedentary time according to two previous research studies (Aguilar-Farías et al., 2014b; Gilbert et al., 2016).

The strength of the association between daily sedentary time measured by the SBQ compared to the accelerometer estimated sedentary time was examined using multiple linear regression with age, gender, country of origin, BMI, SPPB score and TMT times for cognitive and executive functioning as adjustment covariates in the same model.

Additional sub-group analyses were conducted to explore possible differences in the validity of SBQ in different languages (English versus Spanish versus German versus Danish); sex (males versus females); age groups (young-old: 65 to 74 years versus middle-old: 75 to 84 versus oldest-old: >85 years); weight status (normal and underweight versus overweight versus obese); physical functioning (low function versus high function); executive and cognitive functioning (intact executive/cognitive function versus reduced executive/cognitive function).

All statistical analyses were performed using IBM SPSS Statistics 26 (SPSS, Inc, an IBM Company, Chicago, IL, USA) and the significance level was set at $p < .05$.

Results

Out of 850 participants from the SITLESS study who were asked to wear a thigh accelerometer for seven consecutive days, 801 participants (57.6% female and 75.6 ± 6.1 years old) provided valid data for the SBQ and the thigh-based accelerometers. N = 49 participants were excluded as their data did not meet the pre-specified wear time criteria or there were technical problems with data processing.

Demographic characteristics are presented overall and by country in Table 1. Approximately 75% of the overall sample size was overweight or obese. The German cohort had the highest percentage of participants with low physical function (male: 71.5% and female: 77.8%) compared to the other three countries (Table 1). Executive and cognitive functions were similar across German, Danish and Northern Irish participants, but Spanish participants had lower executive and cognitive function (21.6% and 50.7%, respectively) (Table 1).

The criterion validity of the self-report daily minutes spent in sedentary behavior assessed with the SBQ against accelerometer estimated sedentary behavior is shown in Table 2. There was a weak correlation (Rho = 0.25, $p < .001$) between self-reported and device-based measures. Overall, participants reported an average of 472.9 ± 168.5 mins/day of sedentary behavior with the SBQ. Accelerometers measured an average of 545.9 ± 112.9 mins/day from 865.0 ± 68.0 mins/day of wear time during waking hours. The difference between self-reported and accelerometers was 72.90 mins/day (95% CI −85.45, −60.32; $p < .001$) with the SBQ underestimating sedentary behavior time compared to the accelerometer estimated sedentary behavior.

Bland–Altman plots were used to graphically compare the differences between device-based and self-reported measurements (Figure 2). Overall, participants reported lower daily sitting time using the SBQ with a mean difference of −73.4 mins/day and a wide range of limits of agreement (LoA) (upper LoA = 278.8 mins/day, lower LoA = −425.6 mins/day) compared to the same outcome assessed with the device-based instruments. Divided by country, Northern Irish, German and Danish participants under-reported their time spent in sedentary behavior with a mean difference of −60.7, −62.7 and −108.0 mins/day, respectively (range of upper LoA = 273.4 mins/day, lower LoA = −434.1 mins/day) (Figure 3). Spanish participants self-reported daily sitting time using the SBQ with a mean difference of 10.75 mins/day although with a wide range of LoA (upper LoA = 508.1 mins/day, lower LoA = −486.6 mins/day) compared to the device-based measured values (Figure 3). Participants with higher levels of accelerometer measured sedentary behavior tended to overreport their sedentary time in the SBQ; while participants with lower levels of sedentary behavior tended to underreport their sedentary time. This feature can be seen in Figure 3, markedly for Danish and Northern Irish participants. Overall, ICC data showed a weak agreement between both measures (ICC = 0.32, 95% CI 0.19, 0.43). Weak agreement between measures were also found across each language version (Table 2).

Table 3 shows the multiple linear regression model with daily sedentary behavior time measured with the

Table 1. Descriptive characteristics of the sample by gender and country.

	All participants			N. Ireland		Spain		Germany		Denmark	
	N (%)	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
N	801	340	461	65	60	16	64	130	162	129	175
Gender (%)	801 (100)	42.4	57.6	52	48	20	80	44.5	55.5	42.4	57.6
Mean age (years ± SD)	75.6 ± 6.1	75.8 ± 6.2	75.4 ± 6.1	71.8 ± 5.3	72.9 ± 5.7	78.7 ± 4.4	77.1 ± 6.4	74.9 ± 6.4	74.6 ± 6.0	78.5 ± 5.2	76.3 ± 5.8
Age (years) (%)											
65 to 74	427 (53.3)	178 (52.4)	249 (54.0)	83.1	71.7	18.8	42.2	59.2	56.2	34.1	50.3
75 to 84	307 (38.3)	133 (39.1)	174 (37.7)	13.8	25.0	81.3	43.8	30.8	37.0	55.0	40.6
≥ 85	67 (8.4)	29 (8.5)	38 (8.2)	3.1	3.3	-	14.1	10.0	6.8	10.9	9.1
Mean BMI (kg/m^2 ± SD)	28.5 ± 5.3	28.7 ± 4.1	28.5 ± 6.0	29.2 ± 4.6	28.6 ± 5.4	28.4 ± 4.0	29.6 ± 4.9	29.4 ± 4.4	29.3 ± 6.4	27.6 ± 3.5	27.2 ± 6.0
BMI (%)											
Normal and underweight (<25)	200 (25.0)	58 (17.1)	142 (30.8)	20.0	28.3	18.8	18.8	10.8	25.3	21.9	41.1
Overweight (25 to 29.9)	325 (40.6)	174 (51.3)	151 (32.8)	41.5	30.0	50.0	32.8	52.3	38.3	55.5	28.6
Obese (>30)	275 (34.4)	107 (31.6)	168 (36.4)	38.5	41.7	31.3	48.4	36.9	36.4	27.7	30.3
SPPB (%)											
Low function (<10 SPPB Score)	515 (64.3)	201 (59.1)	314 (68.1)	24.6	43.3	43.8	73.4	71.5	77.8	65.9	65.7
High function (>10 SPPB Score)	286 (35.7)	139 (40.9)	147 (31.9)	75.4	56.7	56.3	26.6	28.5	22.2	34.1	34.3
TMT (%)											
Executive function											
Mildly reduced	190 (24.2)	75 (22.6)	115 (25.3)	1.5	8.3	27.3	55.2	25.4	31.7	30.2	15.4
Intact	596 (75.8)	257 (77.4)	339 (74.7)	98.5	91.7	72.7	44.8	74.6	68.3	69.8	84.6
Cognitive function											
Deficient	84 (10.7)	32 (9.7)	52 (11.4)	1.5	-	9.1	32.2	12.3	16.1	11.2	4.0
Intact	702 (89.3)	299 (90.3)	403 (88.6)	98.5	100.0	90.9	67.8	87.7	83.9	88.8	96.9
Average Daily Wear Time (mins ± SD)	865.0 ± 68.0	863.1 ± 69.6	866.4 ± 66.9	861.8 ± 57.7	862.6 ± 61.7	860.0 ± 74.1	845.0 ± 71.6	857.7 ± 76.1	866.6 ± 66.6	896.4 ± 68.1	875.4 ± 65.7

SD = standard deviation; BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test

Table 2. Daily average minutes spent in sedentary behavior overall and by country from the SBQ and activPAL/Axivity [mean ± standard deviation]; 95% CI; Intraclass Correlation Coefficient (Confidence intervals 95%); Rho Spearman's correlation; and *p* value.

	SBQ	activPAL/Axivity	95% CI	ICC (95% CI)	Rho	p value
N. Ireland (n = 125)	486.6 ± 173.2	547.3 ± 87.9	−91.02, −30.41	0.34 (0.08, 0.53)	0.28**	0.001
Spain (n = 80)	472.1 ± 236.0	461.3 ± 121.3	−49.75, 71.26	0.15 (−0.36, 0.48)	0.06	0.613
Germany (n = 292)	463.8 ± 149.1	526.5 ± 121.6	−82.20, −43.22	0.36 (0.18, 0.50)	0.23**	<0.001
Denmark (n = 304)	476.2 ± 165.6	583.0 ± 95.7	−125.48, −88.12	0.32 (0.06, 0.50)	0.30**	<0.001
Total (n = 801)	472.9 ± 168.5	545.9 ± 112.9	−85.48, −60.32	0.32 (0.19, 0.43)	0.25**	<0.001

SBQ = Sedentary Behavior Questionnaire; ICC = Intraclass Correlation Coefficient; ** *p* ≤ 0.001

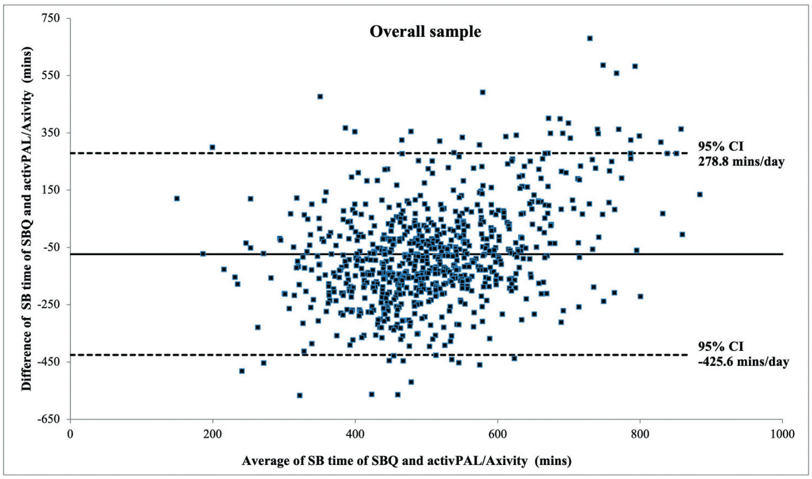

Figure 2. Overall Bland-Altman plot. solid line shows the mean different between the two measures; dash lines represent the 95% CI.

SBQ and covariates (country, age, gender, BMI, physical function and executive and cognitive functions) that predicted the response variable: accelerometer-measured daily sedentary time. The full model predicted 19% of the total variance. The effect modification was significant in all explanatory variables except for age and cognitive function (TMT A) (*p*< .05). After adjusting the model separately for each country, the model for the Danish cohort (R^2 = 0.23, *p*< .001), followed by those for German and Northern Irish participants (R^2 = 0.16, *p*< .001; R^2 = 0.16, *p* = .003, respectively) were able to explain the accelerometer-measured daily sedentary time better than the model for the Spanish cohort (R^2 = 0.10, *p*= .567).

Criterion validity of each version of the SBQ with the matching language was analyzed separately (Table 2). Data from the Danish version showed a moderate correlation (Rho = 0.30, *p*≤ 0.001) and data from the English, German and Spanish versions showed weak correlations (Rho = 0.28, *p*< .001; Rho = 0.23, *p*< .001 and Rho = 0.06, *p*= .613, respectively).

Correlations between SBQ and the accelerometer estimated sedentary time measures across countries and sub-groups are presented separately. In the Northern Irish cohort (see Supplementary Material 1), higher significant associations were found in the female subgroup (Rho = 0.35, *p*= .006) and the obese participants (Rho = 0.30, *p*= .032). Spanish participants (see Supplementary Material 2) showed no significant associations divided by subgroups. However, males and participants with intact executive function showed slightly higher associations than the other subgroups (Rho = 0.39, *p*= .076; Rho = 0.30, *p*= .223, respectively). Although associations were weak in the German version, moderate associations were found in different subgroups (see Supplementary Material 3). Those groups that showed slightly higher significant associations were participants with normal and underweight (Rho = 0.45, *p*< .001) and high physical function (Rho = 0.45, *p*< .001). The association was weak-to-moderate and almost equivalent in each Danish subgroup (see Supplementary Material 4) but showed slightly higher significant association in female (Rho = 0.39, *p*< .001) and the low function participants subgroup (Rho = 0.34, *p*< .001).

Discussion

This is the first study to assess the validity of the SBQ in four different languages (English, Spanish, German and

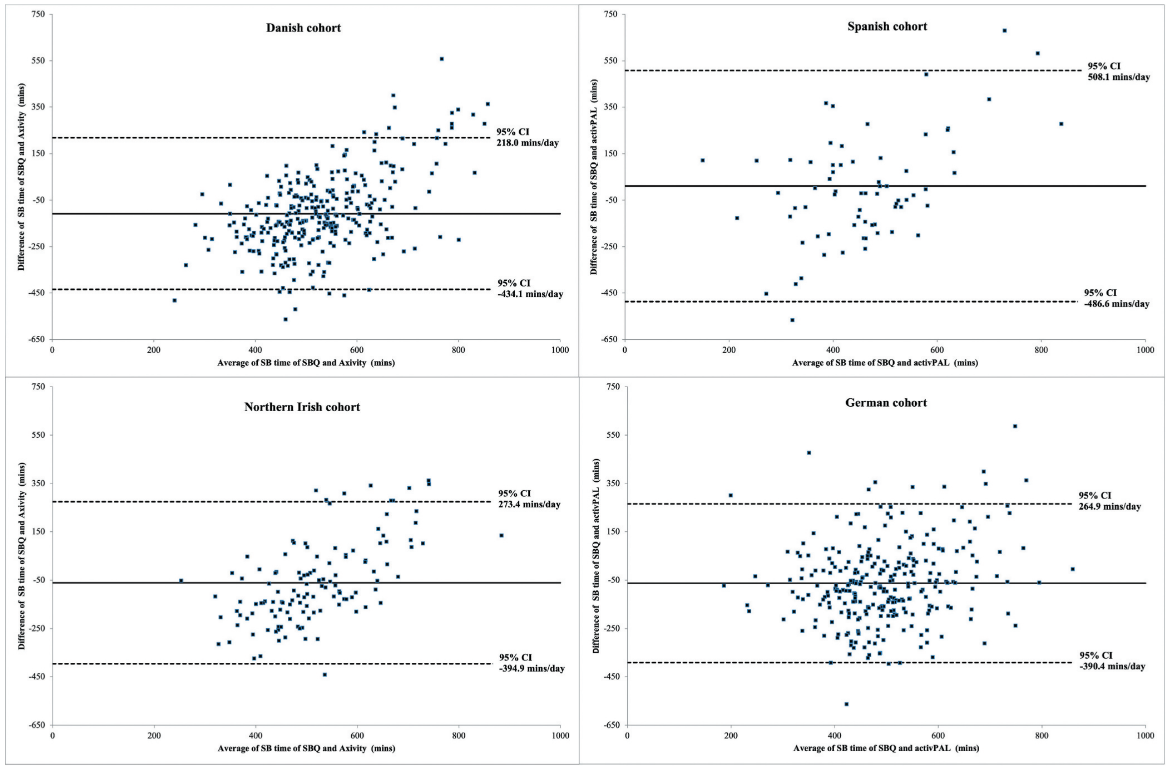

Figure 3. Bland-Altman plot panel by country. Solid line shows the mean different between the two measures; dash lines represent the 95% CI.

Table 3. Multiple linear regression model for daily sedentary time measured with accelerometry adjusted by average minutes spent in sedentary behavior measured with SBQ, center of study, age, gender, BMI, physical function and executive and cognitive functioning in the same model.

	Overall			N. Ireland			Spain			Germany			Denmark		
	R^2	St. Beta	p value	R^2	St. Beta	p value	R^2	St. Beta	p value	R^2	St. Beta	p value	R^2	St. Beta	p value
Model	0.19	-	<0.001	0.16	-	0.003	0.10	-	0.567	0.16	-	<0.001	0.23	-	<0.001
Average minutes spent in sedentary time (SBQ)		0.217	<0.001		0.255	0.005		0.066	0.649		0.259	<0.001		0.246	<0.001
Center of study		−0.222	<0.001		-	-		-	-		-	-		-	-
Age		0.005	0.904		−0.021	0.839		0.092	0.528		−0.004	0.947		0.049	0.385
Gender		−0.280	<0.001		−0.202	0.026		−0.152	0.307		−0.311	<0.001		−0.211	<0.001
BMI		0.076	0.031		0.129	0.179		−0.050	0.728		0.032	0.577		0.217	<0.001
Physical function (SPPB Score)		−0.107	0.006		−0.180	0.095		0.047	0.782		0.014	0.827		−0.129	0.032
Executive functioning (TMT B)		−0.147	0.001		−0.026	0.830		−0.297	0.077		−0.054	0.486		−0.098	0.126
Cognitive functioning (TMT A)		0.050	0.260		−0.001	0.994		0.231	0.172		0.034	0.656		0.142	0.023

Dependent variable: Daily sedentary time measured with accelerometry
R^2 = R Squared; St = Standardized coefficient; SBQ = Sedentary Behavior Questionnaire; BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test.

Danish) in an older adult population. Our results showed an overall weak positive correlation between the self-reported measures and the accelerometer estimated sedentary time. However, whenever each version of the SBQ with the matching language was analyzed separately, data of the Danish version showed a moderate correlation while the English, German and Spanish versions showed weak correlations. When overall absolute agreement was assessed, daily minutes in sedentary behavior of the SBQ with the equivalent variable derived from the accelerometer data, suggested a weak agreement between measures.

Similar to other studies, our findings showed an underestimation of 72.90 mins/day between self-reported and accelerometer measures. Kastelic and Šarabon (2019) compared the Slovenian version of SBQ (weekdays) against the activPAL in an adult population and showed an underestimation of the SBQ with a mean difference between measures of −181 mins/day (Kastelic & Šarabon, 2019). The Bouchard Activity Record, which is a self-report instrument used to assess all levels of the physical activity spectrum from lying and sitting to vigorous-intensity activity, detected significantly less time in sedentary behavior (487.0 ± 194.3 mins/day) than the activPAL (518.5 ± 147.8 mins/day) (Hart et al., 2011). Another questionnaire specific to older adults (e.g. the MOST questionnaire), also underestimated daily sedentary behavior time by 3.6 hours compared to accelerometer-based measures (Gardiner et al., 2011). Self-reported measures appear to have poor accuracy and generally provide an underestimation of the time spent in sedentary behavior, especially in older adults (Celis-Morales et al., 2012). According to Harvey et al. (2013), 58.9% of the participants (n = 372,550 older adults from seven countries) included in a meta-prevalence analysis of sitting time reported sitting >4 hours per day, 26.6% reported >6 hours per day and just 5% reported over 10 h per day; whereas 67% of these participants were sedentary for more than 8.5 hours per day using objective measures (Harvey et al., 2013).

The Bland-Altman plot of overall absolute agreement of daily minutes in sedentary behavior of the different SBQ versions with the equivalent variable derived from the accelerometers data showed a mean difference of −73.45 minutes, and the limits of agreement were (−425 mins to 278 mins), suggesting an overall weak agreement (ICC = 0.32, 95% CI 0.19, 0.43). Our study showed slightly higher agreement between measures compared to another study that found a ICC = 0.014 (95% CI −0.21, 0.26) (Kastelic & Šarabon, 2019).

In comparison with other studies, our data displayed slightly higher correlation coefficients than shown in previous SBQ validation-based studies (Bakar et al., 2018; Kastelic & Šarabon, 2019; Munguía-Izquierdo et al., 2013; Rosenberg et al., 2010). Bakar et al. (2018) used the self-reported IPAQ as a validity criterion (Craig et al., 2003) showing a weak correlation (Rho between −0.026 to 0.144 on weekdays and −0.083 to 0.175 on weekends) (Bakar et al., 2018). However, it is important to consider that using another subjective measure as a criterion measure was not ideal. The Slovenian version of the SBQ (weekdays) showed a weak correlation (Rho = 0.01) compared to the activPAL among adult population (Kastelic & Šarabon, 2019). Similarly, the Spanish version of the SBQ validated among fibromyalgia patients (Munguía-Izquierdo et al., 2013) showed a weak correlation (Rho = 0.06) compared with the SenseWear Pro3 Armband monitor. Rosenberg et al.

(2010) showed no correlation for males but a higher association for females (Rho = 0.26) compared to the ActiGraph accelerometer measure. Similarly, Nelson et al. (2019) compared the IPAQ sedentary time question against the ActiGraph device in undergraduate students and also showed a weak correlation (Rho = 0.26). However, these validation studies have used hip-worn accelerometers that are poor at distinguishing between postures. Our study used well-accepted thigh-based accelerometry to measure postural changes which could potentially explain the differences when compared to the other validation studies.

Underestimation of sedentary behavior in older adults could be explained due to a lack of awareness of the many occasions which require time spent sitting down. Memory capacity may also be reduced in some older adults, making it difficult to accurately provide relevant answers for self-reported instruments. A 10-item questionnaire developed for older adults (e.g. LASA Sedentary Behavior Questionnaire), correlated moderately (Rho = 0.35, $p< .001$) with total objective sedentary time (Visser & Koster, 2013). Activities such as napping, hobbies or talking with friends were included in this questionnaire and could explain some of the difference with our results since the SBQ does not include such activities. Time spent in activities such as afternoon napping or chatting after eating could potentially explain the weak association found in the Spanish cohort. Despite some studies highlighting poor associations between questionnaire and accelerometry-measured sedentary behavior, others have shown more moderate correlations. Aguilar-Farías, Brown, Olds et al. (2014a) showed a weak-to-moderate correlation (Rho = 0.28 to 0.33) against the activPAL accelerometer worn by older adults using one single question on weekdays and weekend days: "How many hours each day do you typically spend sitting down while doing things like visiting friends, driving, etc.?".

In the present study, some differences between versions were apparent. For our analysis, the English, German and Danish versions (Rho = 0.28, 0.25 and 0.30, respectively) showed higher correlations between self-reported and device-based measures than the Spanish version (Rho = 0.06). Differences between versions could potentially be explained due to the small Spanish sample size included in the analysis compared to the other countries. In the current study, higher associations in females in the Danish, English and German versions (Rho = 0.39, 0.35, 0.27, respectively) were found compared to males except in the Spanish version (Rho<0.01). Likewise, in Rosenberg et al.'s (2010), these findings suggest that females report their sedentary behaviors with greater accuracy.

To accurately self-report sedentary behavior, cognitive function, concentration and memory should be intact (Rikli, 2000). Munguía-Izquierdo et al. (2013) used the Spanish version of the Mini-Mental State Examination (Blesa et al., 2001) to screen cognitive function and excluded those participants with moderate-to-severe cognitive decline. In the current study, the TMT (Soukup et al., 1998) was used to assess cognitive functions. The low association found between measures in participants with deficient cognitive function could be explained due to the small percentage of participants in this group (10.7% overall). However, our findings suggest that self-reported sedentary behavior may not be suitable for individuals classified in the 'cognitively deficient' group on the TMT.

Assessing sedentary behavior in older adult populations may be challenging (Wullems et al., 2016). It is important to accurately measure sedentary behavior to determine its association with health status, to planning effective interventions, and to informing public health policy makers. Capturing its two primary components (posture and energy expenditure) can be challenging. Moreover, there are many factors that can bias the assessment such as an inappropriate criterion measure (e.g. motion sensors instead of direct observation), mode of administration (e.g. interview or self-report), the recall period, and the population being assessed (e.g. children, adults or older adults) (Kang & Rowe, 2015). Sedentary behavior is not commonly structured and purposive like physical activity; and it tends to be scattered throughout the day. This may negatively impact participants' ability to recall accurately the amount of time spent in sedentary

Behaviors (Healy et al., 2011). It may also be challenging for researchers and health professionals to design robust strategies to reduce sedentary behavior based on total daily sedentary time (e.g. basic summary measures obtained with objective and self-report instruments). Because the SBQ describes time in sedentary behavior in several context-specific behaviors throughout an entire week (i.e. also including weekend days alongside weekdays), individualized and targeted interventions can more effectively target time spent in these sedentary activities. It is also worth noting that accelerometry assesses both sitting and lying behaviors whereas the SBQ asks specifically for sitting time spent in 4/9 context-specific activities, three of which could be completed lying down and would not be captured with this questionnaire (sitting while listening to music; sitting and talking on the phone; sitting and reading a book or magazine; sitting and driving/riding in a car or train). This would be counted as a limitation of the questionnaire.

Furthermore, the weak correlation could also be explained due to the limited sedentary behavior domains that the SBQ includes, which may not completely align with some daily common activities that older adults tend to do in these countries. Outdoor activities such as playing board games in leisure centers, sitting in a park or in a bar with friends and having long meals in restaurants, should be considered in country-specific SBQ versions due to different environmental conditions (e.g. weather) and cultures.

This is the first study that has attempted to validate the SBQ in older adults. Our results provide initial evidence of the English, Spanish, German and Danish SBQ versions showing a weak relationship against the thigh-based accelerometry measures, a well-accepted criterion standard used to assess sedentary behavior across many studies. However, given the overall weak correlation, further research is needed to include other sedentary behavior-related daily activities older adults may spend time in to get more accurate estimates of total daily sedentary time. Napping (in some cultural-specific domains), eating breakfast, lunch and dinner could be one of the reasons for under-reporting. Also, the SBQ includes some questions that may not be suitable for most older adults, such as playing computer or video games.

The findings of this study suggest that the SBQ may not provide a robust estimation of daily sedentary time in older adults in population-based studies. It is important to consider that older adult populations have generally tended to underestimate their levels of daily sedentary time (Celis-Morales et al., 2012; Gardiner et al., 2011). The under-reporting of sedentary behavior also suggests that epidemiological studies assessing the relationship between self-reported sedentary time and health outcomes may underestimate the true relationship. Therefore, it is recommended that researchers and clinicians should try to concurrently utilize device-based measures to provide a more accurate estimation of sedentary behavior as well as questionnaires to evaluate specific domains of sedentary time in this population.

Strengths and limitations

The large sample size from four different European countries and the use of thigh-based accelerometry as a criterion measure should be considered strengths of this study. However, when criterion validity was assessed separately by country, the small sample size of the Spanish cohort compared to the other countries should be considered as a limitation that could be biasing the study results. Additionally, several subgroups, such as participants over 85 years old or participants with deficient cognitive function at the TMT, were low percentage in some cohorts. Associations between self-reported and objective measures in those groups should be considered an exploratory analysis due to small sample sizes. Another limitation was that accelerometers account for both sitting and lying behaviors whereas the SBQ specifically assesses sitting time in 4/9 context-specific behaviors, which could partially explain the weak correlation between both tools. Finally, being unable to use the same algorithm to classify sedentary behavior time for both the Axivity and activPAL3 was not ideal.

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ORCID

Oriol Sansano-Nadal http://orcid.org/0000-0002-1767-7443
Jason J. Wilson http://orcid.org/0000-0001-5558-8399
Carme Martín-Borràs http://orcid.org/0000-0002-4479-5410
Jan Christian Brønd http://orcid.org/0000-0001-6718-3022
Marta Roqué I Figuls http://orcid.org/0000-0003-0043-1364
Nicole E. Blackburn http://orcid.org/0000-0003-4379-6312
Jochen Klenk http://orcid.org/0000-0002-5987-447X
Dietrich Rothenbacher http://orcid.org/0000-0002-3563-2791
Myriam Guerra-Balic http://orcid.org/0000-0002-9197-3179
Manel Font-Farré http://orcid.org/0000-0001-8373-0460
Michael Denkinger http://orcid.org/0000-0002-8097-060X
Laura Coll-Planas http://orcid.org/0000-0001-5204-8717
Manuela Deidda http://orcid.org/0000-0002-0921-6970
Emma McIntosh http://orcid.org/0000-0001-6340-3083
Maria Giné-Garriga http://orcid.org/0000-0003-4449-3524
Mark A. Tully http://orcid.org/0000-0001-9710-4014

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Annex 11. Supplementary table S1 (Estudi II)

Estudi II: Supplementary Table S1. Table that shows daily average in minutes spent in sedentary behaviour from the SBQ and Axivity [mean ± standard deviation]; 95%CI; Rho Spearman's correlation; and *p* value of the Northern Ireland cohort using partial covariates for sub-groups.

N. Ireland (n=125)	SBQ	Axivity	95% CI	Rho	*p* value
Gender					
Male (n=65)	474.6 ± 143.79	560.3 ± 84.56	-123.16, -48.23	0.25*	0.041
Female (n=60)	499.4 ± 200.45	533.5 ± 89.93	-82.52, 14.36	0.35**	0.006
Age					
65 to 74 years old (n=97)	486.2 ± 170.18	547.6 ± 88.96	-96.37, -26.57	0.25*	0.013
75 to 84 years old (n=24)	484.1 ± 198.63	538.6 ± 88.75	-112.49, 31.32	0.33	0.118
≥ 85 years old (n=4)	431.2 ± 98.31	589.5 ± 51.24	-343.55, 26.94	0.40	0.600
BMI					
Normal and underweight (<25kg/m^2) (n=30)	458.9 ± 166.07	539.0 ± 86.46	-143.43, -16.77	0.28	0.133
Overweight (25 to 29.9kg/m^2) (n=45)	464.0 ± 165.75	527.6 ± 84.65	-114.47, -12.67	0.22	0.148
Obese (>30kg/m^2) (50)	523.1 ± 180.66	569.7 ± 88.15	-96.53, 3.37	0.30*	0.032
SPPB					
Low function (<10 SPPB Score) (n=42)	512.8 ± 170.28	562.5 ± 89.22	-100.56, 1.14	0.27	0.075
High function (≥10 SPPB Score) (n=83)	473.2 ± 174.27	539.6 ± 86.70	-104.77, -27.94	0.27*	0.013
TMT					
Executive function					
Mildly reduced (n=6)	570.7 ± 232.11	546.9 ± 81.67	-228.46, 275.91	0.42	0.397
Intact (n=119)	482.3 ± 169.93	547.3 ± 88.50	-95.36, -34.66	0.29**	0.001
Cognitive function					
Deficient (n=1)	295.7	595.8	-	-	-
Intact (n=124)	488.1 ± 173.10	546.9 ± 88.12	-89.08, -28.46	0.29**	0.001

Note. BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test; *$p \leq 0.05$; **$p \leq 0.001$

Annex 12. Supplementary table S2 (Estudi II)

Estudi II: Supplementary Table S2. Table that shows daily average in minutes spent in sedentary behaviour from the SBQ and ActivPAL [mean ± standard deviation]; 95%CI; Rho Spearman's correlation; and *p* value of the Spanish cohort using partial covariates for sub-groups.

Spain (n=80)	SBQ	ActivPAL	95% CI	Rho	*p* value
Gender					
Male (n=16)	465.4 ± 218.42	521.8 ± 94.84	-163.16, 50.28	0.39	0.146
Female (n=64)	473.8 ± 242.49	444.8 ± 123.13	-42.98, 101.14	0.00	0.973
Age					
65 to 74 years old (n=30)	425.8 ± 188.91	453.4 ± 111.61	-111.75, 56.52	0.01	0.925
75 to 84 years old (n=41)	467.2 ± 208.74	479.2 ± 124.60	-93.37 - 69.33	0.03	0.867
≥ 85 years old (n=9)	654.6 ± 399.14	412.8 ± 138.62	-56.59 - 540.26	0.23	0.570
BMI					
Normal and underweight (<25kg/m^2) (n=30)	470.5 ± 232.66	462.1 ± 104.95	-152.38, 169.21	-0.36	0.245
Overweight (25 to 29.9kg/m^2) (n=29)	497.4 ± 293.73	477.5 ± 101.69	-112.71, 152.50	0.02	0.905
Obese (>30kg/m^2) (n=36)	454.7 ± 193.73	449.6 ± 139.76	-68.44, 78.69	0.20	0.235
SPPB					
Low function (<10 SPPB Score) (n=54)	487.0 ± 234.77	460.3 ± 126.94	-45.49, 98.82	0.11	0.452
High function (≥10 SPPB Score) (n=26)	439.4 ± 240.98	463.4 ± 110.65	-142.53, 94.62	-0.04	0.844
TMT					
Executive function					
Mildly reduced (n=35)	469.3 ± 298.22	437.3 ± 118.64	-94.70, 158.64	-0.29	0.115
Intact (n=34)	473.9 ± 181.36	485.0 ± 101.95	-79.69, 57.48	0.30	0.093
Cognitive function					
Deficient (n=20)	408.4 ± 256.09	456.0 ± 114.72	-202.15, 107.07	-0.35	0.152
Intact (n=50)	492.0 ± 236.08	455.8 ± 124.67	-38.24, 110.76	0.26	0.089

Note. BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test.

Annex 13. Supplementary table S3 (Estudi II)

Estudi II: Supplementary Table S3. Table that shows daily average in minutes spent in sedentary behaviour from the SBQ and ActivPAL [mean ± standard deviation]; 95%CI; Rho Spearman's correlation; and *p* value of the German cohort using partial covariates for sub-groups.

Germany (n=292)	SBQ	ActivPAL	95% CI	Rho	*p* value
Gender					
Male (n=130)	457.8 ± 152.26	567.2 ± 113.50	-137.65, -81.13	0.24**	0.005
Female (n=162)	468.6 ± 146.87	493.8 ± 118.24	-50.81, 0.43	0.27**	<0.001
Age					
65 to 74 years old (n=168)	470.1 ± 144.50	533.1 ± 120.70	-88.33, -37.64	0.23**	0.002
75 to 84 years old (n=100)	470.9 ± 155.85	518.9 ± 127.11	-84.01, -12.09	0.22*	0.028
≥ 85 years old (n=24)	392.0 ± 140.24	510.9 ± 105.49	-174.46, -63.20	0.26	0.213
BMI					
Normal and underweight (<25kg/m^2) (n=55)	439.0 ± 142.94	491.7 ± 106.41	-88.49, -16.84	0.45**	<0.001
Overweight (25 to 29.9kg/m^2) (n=130)	464.4 ± 151.48	539.4 ± 109.02	-105.01, -44.98	0.15	0.085
Obese (>30kg/m^2) (n=107)	476.2 ± 149.26	529.3 ± 139.74	-88.12, -18.16	0.19*	0.046
SPPB					
Low function (<10 SPPB Score) (n=219)	469.5 ± 159.95	521.9 ± 126.00	-76.35, -28.36	0.16*	0.014
High function (≥10 SPPB Score) (n=73)	446.5 ± 129.48	540.5 ± 106.68	-123.45, -64.39	0.45**	<0.001
TMT					
Executive function					
Mildly reduced (n=84)	447.5 ± 155.29	520.5 ± 121.73	-107.88, -38.11	0.34**	0.001
Intact (n=207)	470.3 ± 146.45	528.9 ± 121.71	-82.17, -34.94	0.17*	0.004
Cognitive function					
Deficient (n=42)	461.5 ± 164.71	540.8 ± 98.09	-133.67, -24.91	0.13	0.403
Intact (n=249)	464.1 ± 146.71	524.1 ± 125.09	-80.92, -38.93	0.24**	<0.001

Note. BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test; $*p \leq 0.05$; $**p \leq 0.001$

Annex 14. Supplementary table S4 (Estudi II)

Estudi II: Supplementary Table S4. Table that shows daily average in minutes spent in sedentary behaviour from the SBQ and Axivity [mean ± standard deviation]; 95%CI; Rho Spearman's correlation; and *p* value of the Danish cohort using partial covariates for sub-groups.

Denmark (n=304)	**SBQ**	**Axivity**	**95% CI**	**Rho**	***p* value**
Gender					
Male (n=129)	463.4 ± 159.18	607.0 ± 92.20	-172.65, -114.5	0.21*	0.014
Female (n=175)	485.5 ± 170.02	565.4 ± 94.71	-103.72, -56.05	0.39**	<0.001
Age					
65 to 74 years old (n=132)	485.5 ± 177.25	577.1 ± 97.93	-121.94, -61.11	0.30**	<0.001
75 to 84 years old (n=142)	429.2 ± 157.92	590.1 ± 90.16	-136.94, -84.83	0.31**	<0.001
≥ 85 years old (n=30)	420.6 ± 140.40	575.4 ± 111.50	-209.70, -99.82	0.36*	0.046
BMI					
Normal and underweight (<25kg/m^2) (n=100)	449.7 ± 149.89	551.3 ± 90.99	-132.65, -70.6	0.22*	0.026
Overweight (25 to 29.9kg/m^2) (n=121)	464.3 ± 159.00	587.2 ± 80.41	-150.15, -95.58	0.34**	<0.001
Obese (>30kg/m^2) (n=82)	525.9 ± 183.79	615.3 ± 110.25	-131.76, -47.02	0.27*	0.013
SPPB					
Low function (<10 SPPB Score) (n=200)	474.8 ± 172.32	591.1 ± 99.71	-139.65, -92.85	0.34**	<0.001
High function (≥10 SPPB Score) (n=104)	478.8 ± 152.55	567.2 ± 85.80	-119.57, -57.30	0.23*	0.018
TMT					
Executive function					
Mildly reduced (n=65)	462.1 ± 170.92	595.1 ± 95.73	-177.39, -88.62	0.16	0.204
Intact (n=236)	482.2 ± 163.28	580.7 ± 95.24	-119.26, -77.92	0.33**	<0.001
Cognitive function					
Deficient (n=21)	438.0 ± 154.76	623.9 ± 110.09	-265.08, -106.70	-0.06	0.771
Intact (n=279)	480.5 ± 165.71	580.7 ± 93.86	-119.54, -80.92	0.32**	<0.001

Note. BMI = Body Mass Index; SPPB = Short Physical Performance Battery; TMT = Trail Making Test; *$p \leq 0.05$; **$p \leq 0.001$

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Article

Association of Self-Reported and Device-Measured Sedentary Behaviour and Physical Activity with Health-Related Quality of Life among European Older Adults

Oriol Sansano-Nadal [1,*], Maria Giné-Garriga [1,2], Beatriz Rodríguez-Roca [3], Myriam Guerra-Balic [1], Kelly Ferri [1], Jason J. Wilson [4,5], Paolo Caserotti [6], Pia Øllgaard Olsen [6], Nicole E. Blackburn [7], Dietrich Rothenbacher [8], Dhayana Dallmeier [9,10], Marta Roqué-Fíguls [11], Emma McIntosh [12] and Carme Martín-Borràs [1,2]

[1] Department of Physical Activity and Sport Sciences, Faculty of Psychology, Education and Sport Sciences (FPCEE) Blanquerna, Ramon Llull University, Císter 34, 08022 Barcelona, Spain; mariagg@blanquerna.url.edu (M.G.-G.); myriamgb@blanquerna.url.edu (M.G.-B.); kellyprisciladf@blanquerna.url.edu (K.F.); mariacarmenmb@blanquerna.url.edu (C.M.-B.)
[2] Department of Physical Therapy, Faculty of Health Sciences (FCS) Blanquerna, Ramon Llull University, Padilla 326-332, 08025 Barcelona, Spain
[3] Department of Physiatry and Nursing, Faculty of Health Sciences, University of Zaragoza, Domingo Miral, 50009 Zaragoza, Spain; brodriguez@posta.unizar.es
[4] Sport and Exercise Sciences Research Institute, School of Sport, Ulster University, Newtownabbey BT37 0QB, UK; jj.wilson@ulster.ac.uk
[5] Institute of Mental Health Sciences, School of Health Sciences, Ulster University, Newtownabbey BT37 0QB, UK
[6] Center for Active and Healthy Ageing (CAHA), Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark; PCaserotti@health.sdu.dk (P.C.); pollgaard@health.sdu.dk (P.Ø.O.)
[7] Institute of Nursing and Health Research, School of Health Sciences, Ulster University, Newtownabbey BT37 0QB, UK; ne.blackburn@ulster.ac.uk
[8] Institute of Epidemiology and Medical Biometry, Ulm University, Helmholtztr 22, 89081 Ulm, Germany; Dietrich.Rothenbacher@uni-ulm.de
[9] Research Unit on Aging, Agaplesion Bethesda Clinic, Zollernring 26, 89073 Ulm, Germany; dhayana.dallmeier@agaplesion.de
[10] Department of Epidemiology, Boston University School of Public Health, 715 Albany Street, Boston, MA 02118, USA
[11] Fundació Salut i Envelliment (Foundation on Health and Ageing)—UAB, Universitat Autònoma de Barcelona, Sant Antoni Maria Claret 171, 08041 Barcelona, Spain; Marta.Roque@uab.cat
[12] Health Economics and Health Technology Assessment (HEHTA), Institute of Health and Wellbeing (IHW), University of Glasgow, Glasgow G12 8QQ, UK; Emma.McIntosh@glasgow.ac.uk
* Correspondence: oriolsn@blanquerna.url.edu; Tel.: +34-932533000 (ext. 5332)

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Abstract: Human movement behaviours such as physical activity (PA) and sedentary behaviour (SB) during waking time have a significant impact on health-related quality of life (HRQoL) in older adults. In this study, we aimed to analyse the association between self-reported and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries. A subsample of 1193 participants from the SITLESS trial (61% women and 75.1 ± 6.2 years old) were included in the analysis. The association between self-reported and objective measures of SB and PA with HRQoL were quantified using Spearman's Rho coefficients. The strength of the associations between self-reported and device-measured PA and SB with self-rated HRQoL (mental composite score, MCS; physical composite score, PCS) were assessed through multivariate multiple regression analysis. Self-reported and device-measured PA and SB levels showed significant but poor associations with PCS ($p < 0.05$). The association with MCS was only significant but poor with self-reported light PA (LPA) and moderate-to-vigorous PA (MVPA). In conclusion, the findings of this study suggest that both self-reported and device-measured PA of all intensities were positively and significantly associated, while SB was negatively and significantly associated with the PCS of the SF-12.

Keywords: sedentary behaviour; physical activity; accelerometer; health-related quality of life; older adults

1. Introduction

Human movement behaviours such as physical activity (PA) and sedentary behaviour (SB) have a significant impact on health and quality of life (QoL) in older adults [1,2]. Health-related quality of life (HRQoL) in the older adult population is gaining the attention of researchers and policy makers since life expectancy worldwide, especially in European countries, is increasing. In 2015, the older adult population (≥65 years old) was 17.4% worldwide [3]; this percentage is expected to increase, reaching 33% by 2060 [4].

Low levels of SB, defined as any waking behaviour with an energy expenditure ≤1.5 Metabolic Equivalent Task (MET) while in a sitting, reclining or lying posture [5], and regular PA, have been associated with better-perceived quality of life in older adults [6–10]. More active and less sedentary older adults have shown better self-rated health in several studies [11,12]. Based on these findings, another recent study has suggested that higher levels of PA—and therefore, a better perception of HRQoL—were significantly associated with successful ageing measured with the Successful Ageing Scale for older adults [13]. Successful ageing is considered a complex construct cluster of factors such as QoL, life satisfaction and well-being, which includes movement behaviours [14]. Higher levels of PA predicted further maintenance of functional status including functional capacity, increased muscle mass and strength, which had also been related to HRQoL in this population [15]. Another study suggested that higher amounts of PA could improve cognitive and physical functions, leading to a positive effect on successful ageing in older adults [16]. High levels of SB had also been associated with HRQoL among older adults. Kim and colleagues showed that higher SB levels as older adults age were associated with poorer HRQoL [17]. A recent overview of systematic reviews showed that movement behaviours, including SB and PA levels, influenced heath status among adults [18]. SB and PA and their relationship to HRQoL have been widely studied in younger age groups (e.g., adolescents, adults) [19,20]. However, scientific literature on the older adult population is limited [21,22], and even more scarce using device-based measures of PA and SB in large samples [23].

Therefore, this study aimed to further investigate the associations between self-reported SB and PA and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries.

2. Materials and Methods

2.1. Participants

This study used a cross-sectional design using baseline data from the SITLESS study. Briefly, the SITLESS study is a multi-centre, pragmatic, three-armed, randomised controlled trial. The purpose of the study was to determine whether an exercise referral scheme, enhanced by self-management strategies to reduce SB, could increase PA levels and improve health in the long term in community-dwelling European older adults (≥65 years old) from Spain, Germany, Denmark and United Kingdom (U.K.; in Northern Ireland). Included participants were insufficiently active (according to general guidelines) and/or reported being highly sedentary (>6 h in SB) [24]. The SITLESS study was approved by the Ethics and Research Committee of each institution. Participation was voluntary and all participants signed informed consent before the first assessment. Out of 1360 community-dwelling older adults, a subsample of 1193 participants who fully completed the SF-12, the SBQ, the modified IPAQ and returned valid accelerometer data from the hip-worn ActiGraph were analysed for this cross-sectional study.

2.2. Data Collection

Personal information including age, sex and educational background was collected with an individual interview and the number of current medications was obtained through the healthcare electronic registry. All demographic characteristics were collected during each assessment across all sites between 2016 and 2017. Weight and height were measured using a TANITA BC 420 and a SECA 213 portable stadiometer to obtain the participants' body mass index (BMI). Participants were asked to self-report their daily sedentary time using the SBQ [25] and their total time spent walking (LPA; 3.3 METs per minute), in moderate PA (MPA; 4 METs per minute) and in vigorous PA (VPA; 8 METs per minute) using the modified IPAQ [26]. Both questionnaires are valid to assess SB [27] and PA [28]. Some limitations such as recall bias and poor correlation with objective measures are likely with self-reported measures of both behaviours in older adults [27,29–32]. However, they have been widely used in large-scale studies due to their low administration cost. Moreover, the SBQ provides relevant information regarding context of behaviour [33]. Self-rated HRQoL was assessed using the 12-Item Short-Form Health Survey (SF-12) to obtain the physical and mental composite scores [34]. The SF-12 questionnaire has been used as an important tool to describe self-reported perception of HRQoL [35]. The SF-12 scoring method proposed by Ware et al. (1996) assumes that each item (from an 8-dimension profile including physical functioning, role limitations due to physical problems, bodily pain, general health, vitality, limitations due to emotional problems and mental health) contributes to both the physical component score (PCS) or the mental component score (MCS), and that these two measures are uncorrelated [34]. To overcome the aforementioned limitations of self-reported measures, participants were also asked to wear an ActiGraph wGT3X-BT triaxial accelerometer (ActiGraph, LLC, Pensacola, FL, USA) on their dominant hip during waking hours for seven consecutive days. Participants were asked to remove the device only for water-based activities (e.g., bathing or swimming) and during sleep time. Wear time and non-wear time was calculated using the Choi 2011 algorithm [36]. A small number of participants wore the device continuously (i.e., no removal during sleep). To reduce conflation of sleep and SB time, a pragmatic maximum daily wear time threshold of 19 h was used. For relevant participants, their activity diary was used to record on/off times. The accelerometers were initialised to collect data at 30 Hz using the normal filter setting. A valid accelerometer dataset contained at least four valid days (including at least one weekend day), with a valid day defined as containing at least 600 min of wear time to be included in the analysis as in previous studies [37]. SB was defined as <100 counts per minute (CPM), LPA as 100–2019 CPM and MVPA as ≥2020 CPM on the vertical axis [38]. Raw accelerometry data were analysed using ActiLife v6.13.3 software summarised into 10 s epochs, as has been recommended for estimation of SB in clinical older adult populations [39].

2.3. Statistical Analysis

Demographic characteristics of the sample size were presented descriptively as mean and standard deviation (SD) for continuous variables and percentage for categorical variables, separately by country and overall. The association between self-reported and objective measures of SB and PA and HRQoL were quantified using non-parametric Spearman's Rho coefficients after all variables were examined for normality using the Kolmogorov–Smirnov test. Correlations were interpreted as follows: coefficient value between +1 and −1, perfect positive/negative linear relationship or correlation; between +0.8 and −0.9, very strong positive/negative linear relationship or correlation; between +0.6 and −0.7, moderate positive/negative linear relationship or correlation; between +0.3 and −0.5, fair positive/negative linear relationship or correlation; between +0.1 and −0.2, poor positive/negative linear relationship or correlation; 0, non-linear relationship or correlation [40]. The strength of the association between self-reported time spent in PA and SB (model *a*) and device-measured daily time spent in PA and SB (model *b*) and self-rated HRQoL (SF-12: MCS and PCS) were assessed through multivariate multiple regression analysis. Model *c* and model *d* were adjusted for covariates: country (Spain, Germany, Denmark and U.K.), age (years), sex (male/female), BMI categories ($\leq$24.9 underweight and normal, 25.0–29.9 overweight, $\geq$30 obese), educational background (never attended school, primary education, secondary education, university, unknown) and number of current medications. Each independent variable was investigated for collinearity using the variance inflation factor (VIF; collinearity: VIF > 4), which identifies correlation between independent variables and the strength of that correlation. All statistical analyses were performed using IBM SPSS Statistics 26 (SPSS, Inc., an IBM Company, Chicago, IL, USA) and the significance level was set at $p < 0.05$.

3. Results

Out of the 1360 participants in the SITLESS trial, 167 participants were excluded as they did not meet the pre-specified ActiGraph wear time criteria or did not complete the self-reported questionnaires. A final subsample of 1193 participants (75.1 $\pm$ 6.2 years old, 61% women) returned valid accelerometer data, completed the SF-12, the SBQ and the IPAQ.

Descriptive characteristics of the sample are presented in Table 1. Approximately 75% of the overall sample was overweight or obese (mean BMI = 28.8 $\pm$ 5.2 and ranged from 16.7 kg/m^2 to 51.5 kg/m^2). Women BMI ranged from 16.7 kg/m^2 to 51.5 kg/m^2 (mean women BMI = 28.9 $\pm$ 5.8) and men BMI ranged from 19.8 kg/m^2 to 45.8 kg/m^2 (mean men BMI = 28.7 $\pm$ 4.2). Of all participants, 54.1% reported having completed secondary education while 3.1% of the overall sample reported that they never attended school. The number of current medications ranged from 0 to 19 with a mean of 4.5 $\pm$ 3.2. Some 70% of the participants reported good to excellent general health. Nevertheless, a small percentage (3.9%) reported poor general health status with the SF-12 survey. The PCS across all participants (45.0 $\pm$ 9.1) ranged from 15.6 to 65.7. The MCS across all participants (51.9 $\pm$ 8.9) ranged from 18.4 to 71.1.

Descriptive characteristics of self-reported and device-measured SB and PA levels are shown in Table 1. No significant differences (p = 0.082) were found between countries regarding the self-reported average mean hours per day of SB (overall mean average 7.7 $\pm$ 2.8 h/d). Self-reported LPA differed ($p < 0.05$ using Bonferroni's test) between Spanish (1.0 $\pm$ 1.3 h/d) and U.K. participants (1.0 $\pm$ 1.0 h/d) versus Danish (1.3 $\pm$ 1.6 h/d) and German participants (1.3 $\pm$ 1.4 h/d). U.K. participants showed significant differences ($p < 0.05$ using Bonferroni's test) against other countries' participants regarding MVPA levels (overall 0.7 $\pm$ 1.1 h/d). Device-measured SB was 78.8% of daily awake time out of 14.4 h of mean daily wear time in the overall sample. Danish participants showed the highest proportion of device-measured daily SB (81.0%). Device-measured daily LPA was 18.6% and MVPA was 2.6% in the overall sample. U.K. participants showed the highest levels on both PA intensities (19.8% and 3.7%, respectively).

Table 2 displays the association between self-reported and device-measured levels of PA and SB with PCS as well as MCS. PA and SB levels, both device-measured and self-reported, showed a poor-to-fair significant association ($p \leq 0.05$ across all PA and SB variables) with PCS. It is important to note that all SB-related measures (both device-based assessment and self-reported) showed a poor negative significant association with PCS in the model (e.g., the less sedentary an individual was, the better PCS was perceived) ($p < 0.05$). Nevertheless, when the association between self-reported and device-measured levels of PA and SB with MCS was analysed, significant associations were only found between self-reported LPA and MVPA ($p < 0.05$), but no significant associations were found between device-measured daily hours in LPA and MVPA or daily hours in SB with MCS.

Table 1. Descriptive variables of the sample.

	Overall (n = 1193)	Spain (n = 263)	Germany (n = 304)	Denmark (n = 318)	U.K. (n = 308)
Age (years), mean (SD)	75.2 (6.2)	75.9 (6.4)	74.7 (6.1)	77.3 (5.7)	72.6 (5.5)
Sex (women), n (%)	733 (61.4)	207 (78.7)	172 (56.6)	185 (58.2)	169 (54.9)
BMI, mean (SD)	28.8 (5.2)	28.9 (5.0)	29.2 (5.6)	27.3 (5.0)	28.9 (5.0)
BMI categories, n (%)					
Underweight and normal ($\leq$24.9 kg/m^2)	274 (23.0)	39 (14.8)	61 (20.1)	106 (33.4)	68 (22.1)
Overweight (25 to 29.9 kg/m^2)	488 (40.9)	102 (38.8)	131 (43.1)	129 (40.7)	126 (40.9)
Obese ($\geq$30 kg/m^2)	430 (36.1)	122 (46.4	112 (36.8)	82 (25.9)	114 (37.0)
Educational background, n (%)					
Never attended school	37 (3.1)	35 (13.4)	1 (0.3)	1 (0.3)	-
Primary education	232 (19.5)	112 (42.9)	9 (3.0)	93 (29.3)	18 (5.9)
Secondary education	642 (54.1)	84 (32.2)	217 (71.9)	182 (57.4)	159 (51.8)
University	272 (22.9)	29 (11.1)	74 (24.5)	40 (12.6)	129 (42.0)
Unknown	4 (0.4)	3 (0.4)	3 (0.3)	2 (0.3)	2 (0.3)
Number of current medications, mean (range)	4.5 (0–19)	4.8 (0–16)	4.3 (0–16)	3.9 (0–14)	4.8 (0–19)
Self-reported general health (SF-12), n (%)					
Excellent	35 (2.9)	1 (0.4)	1 (0.3)	16 (5.0)	17 (5.5)
Very good	216 (18.1)	19 (7.2)	24 (7.9)	69 (21.7)	104 (33.8)
Good	584 (49.0)	116 (44.1)	160 (52.6)	177 (55.7)	131 (42.5
Fair	311 (26.1)	106 (40.3)	107 (35.2)	51 (16.0)	47 (15.3)
Poor	47 (3.9)	21 (8.0)	12 (3.9)	5 (1.6)	9 (2.9)
Physical component (SF-12), mean (SD)	45.0 (9.1)	42.1 (9.4)	43.6 (8.7)	46.1 (8.6)	47.6 (8.9)
Mental component (SF-12), mean (SD)	51.9 (8.9)	49.7 (9.1)	50.1 (9.3)	54.1 (8.1)	53.2 (8.2)
Self-reported SB (h/d), mean (SD)					
Daily sedentary time	7.7 (2.8)	7.4 (3.2)	7.6 (2.4)	7.9 (2.7)	7.9 (2.8)
IPAQ (h/d), mean (SD)					
LPA	1.9 (1.3)	1.0 (1.0)	1.3 (1.4)	1.3 (1.6)	1.0 (1.0)
MVPA	0.6 (1.1)	1.1 (1.1)	0.6 (0.9)	0.5 (0.8)	1.1 (1.2)
Accelerometry (h/d), mean (SD)					
Daily sedentary time	11.3 (1.3)	11.3 (1.3)	11.2 (1.3)	11.7 (1.1)	10.9 (1.1)
Daily LPA	2.7 (0.9)	2.6 (0.8)	2.7 (0.9)	2.5 (0.9)	2.8 (0.8)
Daily MVPA	0.4 (0.3)	0.3 (0.3)	0.4 (0.3)	0.2 (0.2)	0.5 (0.4)
Total wear time (h/d), mean (SD)	14.4 (1.2)	14.2 (1.2)	14.3 (1.2)	14.5 (1.1)	14.3 (1.0)

BMI: body mass index; IPAQ: international physical activity questionnaire; LPA: light physical activity; MVPA: moderate-vigorous physical activity.

Table 2. Relationship between self-reported and device-measured SB and PA, and the physical and mental component scores of the SF-12 (HRQoL). Spearman's Rho coefficients and p-values.

	Physical Component SF-12		Mental Component SF-12	
	Spearman's Rho	p-Value	Spearman's Rho	p-Value
Self-reported SB (SBQ)				
Daily sedentary time	−0.078 **	0.007	0.033	0.251
Self-reported PA (IPAQ)				
LPA	0.091 **	0.002	0.058 *	0.046
MVPA	0.204 **	<0.001	0.072 *	0.013
Accelerometry				
Daily Sedentary Time	−0.263 **	<0.001	0.012	0.674
Daily LPA	0.168 **	<0.001	−0.029	0.319
Daily MVPA	0.419 **	<0.001	0.051	0.081

SBQ: sedentary behaviour questionnaire; IPAQ: international physical activity questionnaire; MVPA: moderate-vigorous physical activity; LPA: light physical activity. ** $p \leq 0.001$; * $p \leq 0.05$.

Table 3 shows the multivariate multiple regression models for PCS and MCS, unadjusted (models a and b) and adjusted for relevant covariates (models c and d). The full model a for the PCS adjusted by self-reported PA and SB time predicted 19% of the total variance ($p < 0.001$). The effect modification was significant ($p < 0.05$) in all explanatory self-reported variables except for LPA time (IPAQ). The same model for the MCS predicted 0.07% of the total variance ($p < 0.001$) with a significant effect modification in self-reported daily sedentary time (SBQ) ($p < 0.05$). No collinearity was identified between each independent variable of this model (VIF ranges from 1.02 to 1.15). The full model b for PCS adjusted by device-measured SB and PA (LPA and MVPA) predicted 14% of the total variance ($p < 0.001$) with a significant effect modification ($p < 0.05$) in device-measured LPA, MVPA and SB. On the other hand, the full model for MCS adjusted for device-measured SB and PA (LPA and MVPA) predicted 0.1% of the total variance ($p < 0.001$) with a significant effect modification ($p < 0.05$) in MVPA and sedentary time. No collinearity was identified between each independent variable of this model (VIF ranges from 1.10 to 1.47). The model c for PCS and MCS adjusted by self-reported PA and SB, and for covariates predicted 25% and 0.8% of the total variance ($p < 0.001$), respectively. The model d for the same dependent variables was adjusted by device-measured SB and PA, and for covariates predicted 29% of the total variance for PCS and 0.08% for MCS ($p < 0.001$).

Table 3. Multivariate multiple regression models for PCS and MCS adjusted by self-reported and device-measured PA and SB levels.

	PCS			MCS		
	R^2	**Non St. Beta**	**p-Value**	**R^2**	**Non St. Beta**	**p-Value**
Model *a*	0.19		<0.001	0.007		<0.001
LPA (IPAQ)		0.198	0.322		0.316	0.105
MVPA (IPAQ)		0.735	0.002		0.071	0.763
Daily sedentary time (SBQ)		−0.313	0.001		−0.200	0.028
Model *b*	0.148		<0.001	0.016		<0.001
LPA (ActiGraph)		0.793	0.019		0.161	0.647
MVPA (ActiGraph)		10.210	<0.001		2.564	0.003
Sedentary time (ActiGraph)		0.637	0.005		0.880	<0.001
Model *c*	0.258	-	<0.001	0.081	-	<0.001
LPA (IPAQ)		−0.047	0.797		0.297	0.133
MVPA (IPAQ)		0.412	0.063		−0.078	0.748
Daily sedentary time (SBQ)		−0.244	0.004		−0.220	0.017
Country (Denmark as reference)						
Spain		−2.284	0.002		−3.464	<0.001
UK		1.163	0.103		−0.919	0.237
Germany		−2.705	<0.001		−4.334	<0.001
Age (years)		−0.197	<0.001		0.070	0.120
Sex (women as reference)						
Men		1.589	0.002		2.101	<0.001
BMI categories (obese as reference)						
Underweight and normal		2.666	<0.001		−1.515	0.038
Overweight		3.226	<0.001		−0.070	0.908
Educational background (university as reference)						
Never attended school and primary		−0.650	0.418		−1.778	0.042
Secondary		0.045	0.766		−0.225	0.173
Number of current medications		−0.976	<0.001		−0.213	0.010

Table 3. *Cont.*

	PCS			MCS		
	R^2	Non St. Beta	*p*-Value	R^2	Non St. Beta	*p*-Value
Model *d*	0.293	-	<0.001	0.082	-	<0.001
LPA (ActiGraph)		0.389	0.244		0.493	0.187
MVPA (ActiGraph)		6.434	<0.001		1.825	0.011
Sedentary time (ActiGraph)		0.284	0.189		0.109	0.059
Country (Denmark as reference)						
Spain		−2.728	<0.001		−3.373	<0.001
UK		0.152	0.831		−1.056	0.184
Germany		−3.183	<0.001		−4.178	<0.001
Age (years)		−0.088	0.040		0.101	0.034
Sex (women as reference)						
Men		1.368	0.007		2.123	<0.001
BMI categories (obese as reference)						
Underweight and normal		1.623	0.015		−1.663	0.026
Overweight		2.511	<0.001		−0.245	0.058
Educational background (university as reference)						
Never attended school and primary		−0.492	0.531		−1.667	0.058
Secondary		0.086	0.559		−0.218	0.186
Number of current medications		−0.832	<0.001		−0.180	0.035

Abbreviations: PCS, physical composite score; MCS, mental composite score; R^2, r square; Non St Beta., non-standardised beta coefficient; SBQ, sedentary behaviour questionnaire; IPAQ, international physical activity questionnaire; LPA, light physical activity; MVPA, moderate to vigorous physical activity. *a* PCS and MCS adjusted by self-reported PA (LPA and MVPA) and SB. *b* PCS and MCS adjusted by device-measured PA (LPA and MVPA) and SB. *c* PCS and MCS adjusted by self-reported PA (LPA and MVPA), SB and covariates. *d* PCS and MCS adjusted by device-measured PA (LPA and MVPA), SB and covariates.

4. Discussion

This study aimed to analyse the association between self-reported and device-measured SB and PA with HRQoL in a cohort of community-dwelling older adults from four European countries, assessing possible differences between the PCS and the MCS of the SF-12 questionnaire. Our results showed poor-to-fair significant associations between self-reported and device-measured SB and PA with the PCS. When assessing these associations with MCS, poor significant associations were found with self-reported LPA and MVPA. Our multivariate multiple regression models adjusted by self-reported and device-measured PA and SB predicted between 19% and 14% of the variance in the PCS by both self-reported and device-measured SB and PA. For MCS, the same models, self-reported and device-measured PA and SB, predicted between 0.07% and 0.1% of the variance.

A recent study that analysed self-reported PA levels with HRQoL using the SF-12 found that more active participants reported higher levels of HRQoL as well as significantly higher MCS ($p < 0.01$) [8]. This significant association of self-reported PA with MCS differs from our findings, and could be potentially explained due to a difference in the age of the sample and the use of a different questionnaire which assessed several types of PA and different intensities using METs [8]. Another recent study found that self-reported physical inactivity was significantly associated with diminished HRQoL, including physical and mental health composite scores [41]. In our study, device-measured PA levels were only significantly associated with PCS. A recent study that aimed to assess the association of device-measured PA levels of different intensities (light, moderate and MVPA) in women with fibromyalgia found that all PA intensity levels were positively associated with HRQoL [42]. Our study found a higher association with device-measured MVPA and PCS than in the al-Ándalus project [42]. This higher association found in our study could be explained due to a worse baseline functional state in the al-Ándalus project's population (mean PCS 29.5 ± 6.9 versus PCS 45.0 ± 9.1 units), which may prevent their participants from engaging in higher-intensity PA. Davis and colleagues (2014) found that higher levels of device-based MVPA and greater SB were associated with greater and worse Short Physical Performance Battery scores, respectively, in adults >70 years old [43]. Previous research has suggested that engaging in MVPA could contribute to better physical function performance in older adults, which is related to some of the eight dimensions assessed in the SF-12 to assess PCS, such as physical functioning or limitations due to physical problems [44–46]. However, taking into account the cross-sectional nature of these data, such associations could reflect bi-directional causation, where a better physical function is needed to engage in most types of MVPA.

Previous scientific literature suggests that PA and SB are independently associated with HRQoL, and that results regarding SB are still mostly inconsistent [47]. In our study, we found a significant, negative and poor association between self-reported SB and PCS. López-Torres and colleagues (2019) also concluded that higher self-reported SB levels were significantly associated with poorer HRQoL. Likewise, Wilson and colleagues [10] found that daily sitting time was negatively and significantly associated with HRQoL. Similarly, other recent studies found significant associations between device-measured SB and HRQoL [42,48–51]. However, previous studies suggested that device-measured PA levels tend to be more valid and reliable than self-reported [38,52]. Therefore, the lower associations between self-reported SB and PA levels with PCS compared to device-measured SB and PA levels could be explained by the accuracy in measuring both behaviours. Nevertheless, having analysed the associations between SB and PA between MCS, only significant but poor associations were found with self-reported PA levels.

The model used to predict MCS from the al-Ándalus project had higher predictive capability (R^2 = 0.19) compared to our results in both SB and PA models with the MCS [42]. However, the PCS models with both self-reported and device-measured SB and PA showed higher prediction of the total variance compared to the al-Ándalus project (R^2 = 0.04). As previously stated, the different regression coefficients between studies could be explained by the different sample characteristics (e.g., the sample with women suffering from fibromyalgia included in the al-Ándalus project reported lower PCS than older adults from the SITLESS study) or the instrument used to assess HRQoL. Our results may not be clinically significant due to some of the correlations being poor. However, these findings may provide insight when designing strategies and interventions aimed at improving both physical and mental components of overall quality of life. Furthermore, we must suggest that public resources should be allocated to strategies aimed at reducing SB and increasing PA levels to improve quality of life of older adults.

Strengths and Limitations

Some limitations of the present cross-sectional study are worth noting. It is difficult to determine associations between physical behaviours and HRQoL due to the large number of factors related to HRQoL [53]. The strengths of this study include the device-measured SB and PA of a large heterogeneous sample of community-dwelling older adults from four European countries as well as their association with HRQoL in both the physical and mental components.

5. Conclusions

In conclusion, the findings of this study suggest that both self-reported or device-measured PA intensity levels were positively and statistically significant associated with PCS of the SF-12. On the other hand, SB was negatively and statistically significant associated with the PCS of the SF-12. These findings indicate the importance of increasing PA and reducing SB levels if the physical function component related to HRQoL is to be improved. Only self-reported LPA and MVPA were statistically significant with MCS. In general, some of the associations we found were very poor, but our results support the accumulating research of the benefits of increasing PA levels and reducing sitting time for better HRQoL among older adults. Further longitudinal studies are necessary to confirm the associations between the PCS and self-rated health and further explore associations between the MCS.

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