Clinical Interventions in Aging

Dovepress
open access to scientific and medical research

Open Access Full Text Article

REVIEW

The Association of Objectively Measured Physical Activity and Sedentary Behavior with (Instrumental) Activities of Daily Living in Community-Dwelling Older Adults: A Systematic Review

Elvira S Amaral Gomes [1]
Keenan A Ramsey [1]
Anna GM Rojer [1]
Esmee M Reijnierse [2]
Andrea B Maier [1–3]

[1]Department of Human Movement Sciences, @AgeAmsterdam, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, the Netherlands; [2]Department of Medicine and Aged Care, @AgeMelbourne, The Royal Melbourne Hospital, The University of Melbourne, Melbourne, Victoria, 3050, Australia; [3]Healthy Longevity Translational Research Program, Yong Loo Lin School of Medicine, National University of Singapore, Singapore; Centre for Healthy Longevity, @AgeSingapore, National University Health System, Singapore

Abstract: Up to 60% of older adults have a lifestyle characterized by low physical activity (PA) and high sedentary behavior (SB). This can amplify age-related declines in physical and cognitive functions and may therefore affect the ability to complete basic and instrumental activities of daily living (ADL and IADL, respectively), which are essential for independence. This systematic review aims to describe the association of objectively measured PA and SB with ADL and IADL in community-dwelling older adults. Six databases (PubMed, Embase, the Cochrane library, CINAHL, PsychINFO, SPORTDiscuss) were searched from inception to 21/06/2020 for articles meeting our eligibility criteria: 1) observational or experimental study, 2) participants' mean/median age ≥60 years, 3) community-dwelling older adults, 4) PA and SB were measured with a(n) accelerometer/pedometer, 5) PA and SB were studied in relation to ADL and/or IADL. Risk of bias was assessed in duplicate using modified versions of the Newcastle–Ottawa scale. Effect direction heat maps provided an overview of associations and standardized regression coefficients (βs) were depicted in albatross plots. Thirty articles (6 longitudinal; 24 cross-sectional) were included representing 24,959 (range: 23 to 2749) community-dwelling older adults with mean/median age ranging from 60.0 to 92.3 years (54.6% female). Higher PA and lower SB were associated with better ability to complete ADL and IADL in all longitudinal studies and overall results of cross-sectional studies supported these associations, which underscores the importance of an active lifestyle. The median [interquartile range] of βs for associations of PA/SB with ADL and IADL were, respectively, 0.145 [0.072, 0.280] and 0.135 [0.093, 0.211]. Our strategy to address confounding may have suppressed the true relationship of PA and SB with ADL or IADL because of over-adjustment in some included studies. Future research should aim for standardization in PA and SB assessment to unravel dose–response relationships and inform guidelines.

Keywords: accelerometry, independent living, aged

Correspondence: Andrea B Maier
Department of Human Movement Sciences, @AgeAmsterdam, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Van der Boechorststraat 7, Amsterdam, 1081 BT, the Netherlands
Tel +31 20 5982000
Email a.b.maier@vu.nl

Introduction

Physical activity (PA), defined as bodily movement produced by the contraction of skeletal muscle that requires energy,[1] has been linked to various health benefits with increasing age.[2] Up to 60% of older adults worldwide do not meet PA guidelines[3] due to physical impairments that arise with aging[4,5] or sedentary behavior (SB), which refers to waking activity (mainly performed while in a sitting, reclining, or lying posture) with little to no energy expenditure beyond the resting metabolic

Received: 5 July 2021
Accepted: 27 August 2021
Published: 28 October 2021

rate.[6] Low PA (volume, duration, or intensity) and high SB (duration) can be distinct behaviors[7] that independently amplify age-related decline in many physiological systems[8] and may therefore affect endurance, muscle strength, and flexibility[9] as well as cognition.[10] However, these capacities are necessary to autonomously function in daily life, including engaging in activities of daily living (ADL), referring to self-care tasks, such as transferring in and out of bed, feeding, and dressing, as well as instrumental activities of daily living (IADL), which involve more complex and cognitively demanding tasks, such as housekeeping, shopping, and medication use.[11]

Previous systematic reviews of longitudinal and cross-sectional studies have demonstrated that PA classified as of at least moderate intensity is positively associated with the ability to complete ADL and IADL,[12,13] whereas negative associations were found between SB and the ability to perform these activities.[14] An important limitation of these findings is that conclusions are predominantly based on self-reported measures of PA and SB (ie, questionnaires), which are especially susceptible in older adult populations to overestimation of PA and underestimation of SB[15] as a result of recall bias. Furthermore, self-reported measures of PA and SB often fail to capture activity at the lower end of the PA continuum, which comprises most of the PA in older adults (eg, light-intensity, short-duration tasks).[16] PA and SB can be most accurately quantified with wearable technology (accelerometers, pedometers), which allows for the objective assessment of PA as well as continuous monitoring of activity in daily life[17] (ie, frequency, intensity, duration). Objective measurements of PA and SB are therefore essential to advance knowledge by accurately quantifying the association of PA and SB with ADL and IADL, which can ultimately be targeted through public health clinical intervention.

This systematic review aimed to describe the association of objectively measured PA and SB with ADL and IADL in community-dwelling older adults.

Materials and Methods

The protocol of this review was registered in the PROSPERO International prospective register of systematic reviews with registration number CRD42018103910.

Information Sources and Search Strategy

Two assessors (the Vrije Universiteit librarian (RO) and AR) conducted a systematic literature search based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement,[18] consulting the following electronic databases from inception to June 21, 2020: PubMed, Embase, the Cochrane Library (via Wiley), CINAHL, PsychINFO, and SPORTDiscuss (via EBSCO). The search terms "active or inactive lifestyle", "motor activity", and "people over 60 years of age" were used to ascertain articles that studied PA and SB in relation to any health outcome in older adults; the full search strategy is presented in Appendix A. Articles that reported associations of PA and SB with ADL and IADL were organized and managed in the software Endnote (Version X8.2 Clarivate Analytics, Philadelphia, USA) and Rayyan QRCI.[19]

Inclusion Criteria

Full-text articles published in English or Dutch were considered eligible for this systematic review based on the following criteria: 1) observational or experimental study, 2) participants' mean or median age ≥60 years old, 3) study population consisted of community-dwelling older adults, 4) PA and SB were measured with an accelerometer or pedometer, 5) ADL was defined as any tool or questionnaire explicitly described as measuring ADL and/or IADL, and 6) PA and SB were studied in relation to ADL and/or IADL. For intervention studies, associations at baseline or control group data were included.

Article Selection

Search results were assessed for possible eligibility based on title and abstract screening by two independent assessors (KR and EvdR) using the Rayyan screening software.[19] Full-text screening was performed in duplicate by two independent assessors (KR and LD, or AR) and differences in opinion with regard to inclusion and exclusion decisions were resolved by another assessor (AM). The references of all included articles were screened for additional eligible articles.

Data Extraction

Data extraction was performed by two independent assessors (EG and WZ) and disagreement was settled by a third assessor (KR). The following data were extracted: first author; year of publication; country; cohort; study design with, if applicable, follow-up period; characteristics of study population (population selection), sample size, age (in years), sex (number and percentage of females), device used for objective assessment of PA/SB (accelerometer, pedometer), device name, wearing location of device, number of monitor days, mean device wear time, minimum duration of device wear to define a valid day, number of valid days required for analysis, reported measures of PA/SB and their definitions, PA/SB scores, tools and definitions used for ADL and IADL assessment, activities included in an ADL or IADL tool/questionnaire, ADL/IADL scores, adjustment model(s), statistical analysis to study association(s), effect size(s) with 95% confidence interval (95% CI) or standard error (SE), and significance level (p-value).

Assessment of Study Quality

Study quality and risk of bias were assessed by two independent assessors (EG and WZ) using modified versions of the Newcastle–Ottawa scale (NOS) for cross-sectional and longitudinal studies,[20] customized for this systematic review. Three domains, selection (representativeness of study cohort and ascertainment of exposure), comparability (adjustment model(s) and statistical analysis), and outcome (assessment of outcome and, if applicable, adequacy to follow-up), were assessed and the median of total possible stars (points) was set as the cut-off to determine high or low quality, defined as ≥ or < 4 out of 7 and ≥ or < 5 out of 9 for cross-sectional and longitudinal studies, respectively (Appendix B).

Data Analysis and Visualization

Extracted information and associations between PA/SB and ADL or IADL were reported in tables, visualized in effect direction heat maps,[21] and synthesized in albatross plots[22] according to the PRISMA[18] and Synthesis Without Meta-analysis (SWiM)[23] guidelines. Data were reported based on the following hierarchy of adjustment: 1) age and sex, 2) age and sex, and other factors (eg, cognitive function, number of chronic diseases, body mass index), 3) age or sex, and other factors, 4) other factors only, and 5) unadjusted (crude) model. When articles reported more than one type of statistical analysis for an association, the following hierarchy for reporting was considered: 1) adjusted linear regression, 2) adjusted logistic regression, 3) partial correlation, 4) unadjusted linear regression (including Pearson's and Spearman correlation), 5) analysis of variance (ANOVA), and 6) Mann–Whitney test, Student's *t*-test, or chi-squared test. Continuous measures of PA/SB were used if reported and categorical variables were used otherwise. P-values were calculated when these were not reported: for linear regression: the upper and lower limit of the 95% CI were used to acquire the SE, $SE=((\text{upper limit of 95\% CI} - \text{lower limit of 95\% CI})/(2*1.96))$, which was then used to obtain the absolute value (abs) of the z-statistic (z), $z=abs(\text{regression coefficient}/SE)$, and eventually calculate the p-value, p(calc) $=\exp((-0.717*z) - (0.416*(z^2)))$. The aforementioned formulae were also used for ratio measures (odds ratio (OR), hazard ratio (HR), and risk ratio (RR)), except for that the upper and lower limits of the 95% and effect sizes were transformed into logarithms using natural log(ln) first.[24] For correlations, sample size (n) and coefficients (including Pearson's R and Spearman's Rho) were used to calculate the t-statistic (t), $t=R*\sqrt{((n-2)/(1/R))}$, of which the absolute value (abs) was compared to the two-sided student's t-distribution using T.VERD.2T in Microsoft Excel to obtain p(calc). For comparison between groups, mean values and standard deviations (sd) were used to calculate t, $t=((mean_1-mean_2)/\sqrt{(((n_1-1)*((sd_1)^2))+((n_2-1)*((sd_2)^2)))/((n_1+n_2-2)*((1/n_1)+(1/n_2)))})$, which was then compared to the two-sided t-distribution using the earlier-mentioned function in Microsoft Excel. Associations with p-values that could not be calculated were conservatively estimated for effect direction heat maps as being ≥0.25 or the largest p-value derived from the reported information and excluded from albatross plots.[25]

Effect Direction Heat Maps

Effect direction heat maps[21] were created to provide a qualitative overview of all associations between PA/SB measures and ADL or IADL and were stratified by study design (longitudinal versus cross-sectional) and ordered by sample size. Articles that included combined measures of ADL and IADL were categorized as IADL because inability to carry out more complex and cognitively demanding activities precedes difficulty in ADL.[26] The observed direction of effect was determined based on whether higher PA and lower SB were associated with better (positive effect) or worse (negative effect) ADL and IADL, indicated by an upwards or downwards triangle, respectively. The following color scheme was used to present significance: $p<0.001$ (dark blue filled triangle), $0.001\leq p<0.01$ (blue filled triangle), $0.01\leq p<0.05$ (light blue filled triangle), $0.05\leq p<0.1$ (light grey empty triangle), $0.01\leq p<0.25$ (grey empty triangle), and $p\geq0.25$ (dark grey empty triangle).

Albatross Plots

Albatross plots are scatter plots of sample size plotted against two-sided p-values, stratified by the observed effect direction to graphically present the estimated magnitude of associations[22] (expressed as median with corresponding interquartile range, [IQR]). Each data point represents an association and based on whether higher PA and lower SB were associated with better (positive effect) or worse (negative effect) ADL and IADL, data points fall on the right or left side of albatross plots, respectively. Contour lines were superimposed on the plot to examine hypothetical effect sizes, here selected as standardized regression coefficients (βs), and derived from the following equation: $N=(((1-\beta^2)/\beta^2)*(Z_p)^2)$ in which Z_p denotes the z-value associated with given two-sided p-values. Separate albatross plots were made for ADL and IADL using the Stata Statistical Software, Release 16.0 (StataCorp LLC, College Station, Texas, United States), each stratified by measures of PA and SB. Sensitivity analyses were performed by stratifying albatross plots using population selection (disease versus general), study design (cross-sectional versus longitudinal), adjustment (adjusted versus unadjusted associations), device type (accelerometer versus pedometer), and device wearing location. For the latter sensitivity analysis, device wearing locations were entered into the albatross plots if reported for ≥5 associations to obtain an IQR.

Results

The literature search identified 18,806 articles of which 9660 articles were left after duplicate removal. Of the 1017 full texts assessed for eligibility, 30 articles[27–56] were included in this systematic review (Figure 1).

Characteristics of Studies

A total of 24,959 (range: 23 to 3749) community-dwelling older adults were included with mean or median age ranging from 60.0 to 92.3 years and, on average, populations were 54.6% female. In 11 articles, specific disease groups were studied: osteoarthritis (OA),[34,36,44,54] chronic obstructive pulmonary disease (COPD),[28,39,45,56] cirrhosis,[37] Parkinson's disease,[38] and stroke survivors.[40] Longitudinal associations were reported in six articles[27,31,34,36,53,54] (mean follow-up period of 3.1 years) and represented 7554 older adults with mean or median age ranging from 62.4 to 80.6 years (56.8% female); remaining articles reported cross-sectional associations (Table 1). The NOS categorized 26 out of 30 articles as high quality (Table 2).

Measures of Physical Activity and Sedentary Behavior

Accelerometers were used in 28 studies, while two studies-[27,28] used pedometers to objectively measure PA/SB (Table 3). The following measures of PA/SB were included: number of steps (or walking duration),[27,28,37,38,41,44,45,50,55] activity counts (or accelerations, movement intensity),-[29,33,42,43,45,49,53,55,56] energy expenditure (EE),[31,37,45,50] duration (in different units of time) of total PA (TPA) (or mobile duration),[45,47,51,56] moderate to vigorous PA (MVPA) (or moderate PA (MPA) or vigorous PA (VPA) individual),[30–32,34,36–40,46–49,51,52,54,55] light PA (LPA),[34,40,47,49,52,55] and SB (or lying duration, immobile time),[30–32,35,37,38,40,43,45,47,49,52,55] breaks per sedentary hour (SB break rate),[52] and breaks in sedentary time (BST).[32,52,55]

Assessment of Activities of Daily Living and Instrumental Activities of Daily Living

The association of PA/SB measures and ADL was studied in 20 articles using the following tools: London Chest Activities of Daily Living (LCADL) scale,[28,39] Katz Index of Independence in Activities of Daily Living (Katz),[29,53] Glittre-ADL test,[45] Western Ontario and McMaster Universities osteoarthritis index (WOMAC) functional limitation sub-scale,[27] Health Assessment Questionnaire Disability Index (HAQ-DI),[49] Barthel Index,[40] Composite Physical Function (CPF) scale,[52] Knee injury and Osteoarthritis Outcome Score (KOOS) questionnaire function in daily life sub-scale,[44] Parkinson's Disease Questionnaire-39 (PDQ-39) activities of daily living dimension,[38] Nottingham Extended Activities of Daily Living (NEADI),[56] and custom questionnaires[30,31,35,36,43,48,50,51,55] (Table 4). In 13 articles, the association between measures of PA/SB and IADL was studied with the use of the following tools: Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG),[32] Rosow-Breslau scale,[37] CPF scale,[47,52] Late-Life Disability Index (LLDI),[54] Late-Life Function and Disability Index (LLFDI),[40–42,46] and custom questionnaires[31,33,34,43] (Table 5).

Associations of Physical Activity and Sedentary Behavior with Activities of Daily Living and Instrumental Activities of Daily Living

All associations are visualized by effect direction heat maps (Figure 2), standardized regression coefficients (βs) for each association are presented by albatross plo ts

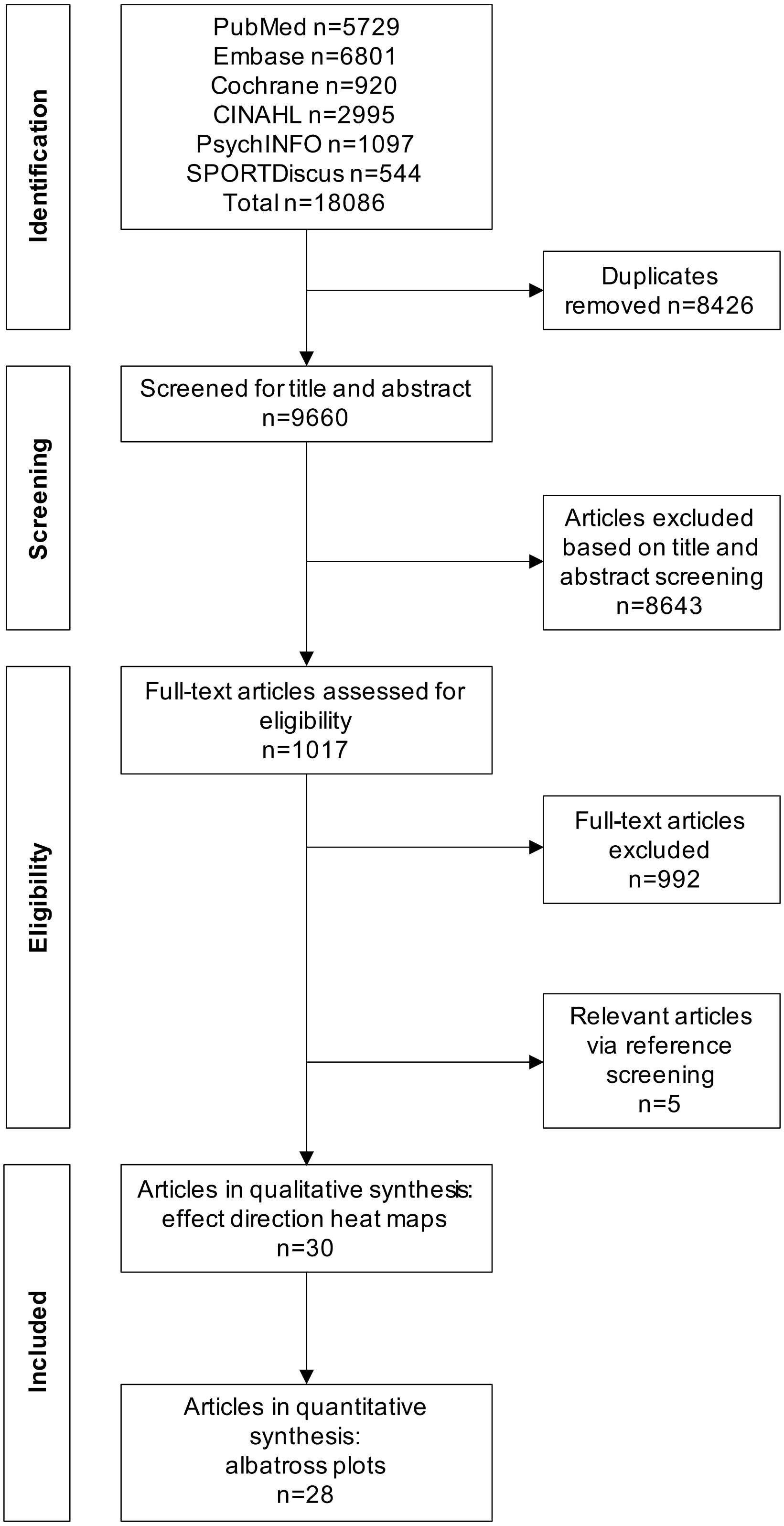

Figure 1 Flowchart of article selection process.

Table 1 Characteristics of Included Studies

Author, Year (Ref.)	Country	Cohort	Study Design	Population*	Sample Size (n)	Age, in Years	Female, n (%)
Balogun, 2020[26]	AU	TASOAC	Longitudinal, FU: 5.0 ± n/r years	—	1064	63 ± 7.4	543 (51)
Barriga, 2014[27]	PT	n/a	Cross-sectional	COPD (moderate to severe)	55	67.2 ± 9.6	0
Bielemann, 2020[28]	BR, US, GB, NO	"COMO VAI?"	Cross-sectional	—	973 (T1: 325; T2: 324; T3: 324)	60–69y: n=496; 70–79y: n=337; ≥80y: n=138	T1: 198 (61.1); T2: 207 (64.1); T3: 199 (61.4)
Blodgett, 2015[29]	CA	NHANES	Cross-sectional	—	3146	63.3 ± 10.1	1689 (53.7)
Cawthon, 2013[30]	US, CA	MrOS	Longitudinal, FU: 2.0 ± n/r years	—	Baseline: 2900 (inability yes: 743; no: 2157)	Baseline, inability yes: 80.6 ± 5.6; no: 78.5 ± 4.8	0
					FU: 1983	FU: 73.1 ± 4.8	
Chen, 2016[31]	JP	Sasaguri Genkimon	Cross-sectional	—	1634 (inability yes: 137; no: 1497)	73.3 ± 6.0 (inability yes: 75.1 ± 7.3; no: 73.1 ± 5.1)	1007 (61.6) (inability yes: 33 (24.1); no: 974 (65.1)
Chipperfield, 2008[32]	CA	Aging in Manitoba	Cross-sectional	—	198 (M: 73; F: 125)	All: 85 ± 4.39	125 (63.1)
Dunlop, 2014[33]	US	OAI	Longitudinal, FU: 2.0 ± n/r years	Knee OA (risk)	Inability onset: 1680; progression: 1814	Inability onset: 64.9 ± 9.0; progression: N/R	Inability onset: 915 (54.5); progression: n/r
Dunlop, 2015[34]	US	NHANES	Cross-sectional	—	2286	n/r	1127 (49.3)
Dunlop, 2019[35]	US	OAI	Longitudinal, FU: 4.0 ± n/r years	Knee OA (risk)	1460 (inability yes: 238; no: 1222)	n/r	All: 876 (56)
Dunn, 2016[36]	US	n/a	Cross-sectional	Cirrhosis	53	Range: 60 to 69	n/r
Ellingson, 2019[37]	US	n/a	Cross-sectional	Parkinson's disease	45**	67.8 ± 7.9	23 (44)

Furlanetto, 2016[38]	US	n/a	Cross-sectional	COPD	104 (active group: 36; inactive group: 68)	Active group: 65 ± 9; inactive group: 66 ± 8	All: 38 (37)
Gothe, 2020[39]	US	n/a	Cross-sectional	Stroke survivors	30	61.8 ± 11.2	22 (73.3)
Hall, 2010[40]	US	n/a	Cross-sectional	—	128 (active group: 35; inactive group: 93)	Active group: 68.1 ± 5.2; inactive group: 70.5 ± 6.1	100
Hornyak, 2013[41]	US	n/a	Cross-sectional	—	78	77.4 ± 5.7	58 (75.3)
Huisingh-Scheetz, 2016[42]	US	NSHAP	Cross-sectional	—	623	72.0 (95% CI: 71.4, 72.6)	328 (52.6)
Jeong, 2019[43]	KR	n/a	Cross-sectional	Knee OA	52	60.3 ± 5.6	47 (90.4)
Karloh, 2016[44]	BR	n/a	Cross-sectional	COPD (moderate to very severe)	38	65 ± 7	16 (42.1)
Kerr, 2012[45]	US	n/a	Cross-sectional	Continuing care retirement communities	117 (active group: 49; inactive group: 68)	Active group: 80.6 ± 6.1; inactive group: 85.1 ± 6.7	Active group: 31 (64.0); inactive group: 50 (73.0)
Marques, 2014[46]	PT	n/a	Cross-sectional	—	371 (risk of inability high: 95; low: 276)	74.7 ± 6.9 (risk of inability high: 78.7 ± 7.2; low: 73.3 ± 6.3)	240 (64.7) (risk of inability high: 77 (81.1); low: 163 (59.1))
Menai, 2017[47]	FR, NL, GB	Whitehall II	Cross-sectional	—	3749 (successful agers yes: 789; no: 2960)	69.4 ± 5.7 (successful agers yes: 68.2 ± 5.4; no: 69.7 ± 5.7)	953 (25.4) (successful agers yes: 212 (36.9); no: 741 (25.0))
Ortlieb, 2014[48]	DE	KORA-Age	Cross-sectional	—	168 (inability yes: 70; no: 98)	Median (95% CI): 73 (65, 86) (inability yes: 76 (67, 87); no: 71 (65, 84))	90 (53.6) (inability yes: 48 (68.6); no: 42 (42.9)
Pes, 2017[49]	IT	n/a	Cross-sectional	—	44 (M: 27; F: 17)	M: 92.3 ± 2.9; F: 92 ± 2.7	17 (38.6)
Portegijs, 2019[50]	FI	AGNES	Cross-sectional	—	496***	75y: n=250, 80y: n=158; 85y: n=87	296 (59.8)

(*Continued*)

Table 1 (Continued).

Author, Year (Ref.)	Country	Cohort	Study Design	Population*	Sample Size (n)	Age, in Years	Female, n (%)
Sardinha, 2015[51]	PT	n/a	Cross-sectional	—	371 (risk of inability high: 95; low: 276)	74.7 ± 6.9 (risk of inability high: 78.7 ± 7.2; low: 73.3 ± 6.3)	240 (64.7) (risk of inability high: 77 (81.1); low: 163 (59.1))
Shah, 2012[52]	US	Rush Memory & Aging Project	Longitudinal, FU: 3.4 ± 1.3 years	Continuing care retirement communities	Baseline: 870	Baseline: 81.9 ± 7.3	Baseline: 249 (73.2)
					FU: 584	FU: 81.8 ± 6.9	FU: 437 (4.8)
Song, 2017[53]	US	OAI	Longitudinal, FU: 2.0 ± n/r years	Knee OA (risk)	545 (remained inactive: 393 versus more active (insufficiently active: 137; met guidelines: 15))	≥65y, remained inactive: n=280 versus more active (insufficiently active: n=60; met guidelines: n=6)	Remained inactive: 260 (66.2) versus more active (insufficiently active: 77 (56.2); met guidelines: 10 (66.7)
Steeves, 2019[54]	US	NHANES	Cross-sectional	—	1524 (inability yes: 475; no: 1049)	Inability yes: 73.4 (SE: 0.5); no: 68.7 (SE: 0.3)	Inability yes: 259 (61.5); no: 475 (51.8)
Walker, 2008[55]	GB	n/a	Cross-sectional	COPD	23	66 ± 9	11 (47.8)

Notes: Age is presented as mean ± standard deviation/95% confidence interval or as described otherwise. — refers to community-dwelling older adults from the general population. Subgroups with corresponding information (sample size (n), age (in years), and n (%) female) are presented in italics. *Population selection based on specific criteria such as disease state or demographics. **Study included 52 participants but complete accelerometer data was only available for n=45. ***Accelerometer data was collected for ≥1 day(s) for 496 participants; in statistical analysis, n=485 for total physical activity and n=441 for moderate to vigorous physical activity was used. — refers to community-dwelling older adults from the general population. Subgroups with corresponding information (sample size (n); age (in years); and n (%) female) are presented in italics.

Abbreviations: AU, Australia; PT, Portugal; BR, Brazil; US, United States of America; GB, United Kingdom of Great Britain and Northern Ireland; NO, Norway; CA, Canada; JP, Japan; KR, South Korea; FR, France; NL, The Netherlands; DE, Germany; IT, Italy; FI, Finland; TASOAC, Tasmanian Older Adult Cohort; NHANES, National Health and Nutrition Examination Survey; MrOS, Osteoporotic Fractures in Men Study; OAI, Osteoarthritis Initiative; NSHAP, National Social Health and Aging Project; KORA-Age, Cooperative Health Research in the Region of Augsburg-Age study; AGNES, active aging-resilience and external support as modifiers of the disablement outcome study; n/a, not applicable; FU, follow-up period. n/r, not reported. COPD, chronic obstructive pulmonary disease; OA, osteoarthritis. T, tertile; M, males; F, females.

Table 2 Scoring of Study Quality Based on Modified Versions of the Newcastle–Ottawa Scale for Cross-Sectional and Longitudinal Studies

Author, Year (Ref.)	Selection			Comparability			Outcome			Score	Study Quality
	Q_1	Q_{2a}	Q_{2b}	Q_{3a}	Q_{3b}	Q_4	Q_5	Q_6	Q_7		
Balogun, 2020[26]	★	★	—	★	★	★	★	★	★	8/9	High
Barriga, 2014[27]	★	★	—	—	—	★	★			4/7	High
Bielemann, 2020[28]	★	★	—	—	—	—	★			3/7	Low
Blodgett, 2015[29]	★	★	—	★	★	★	★			6/7	High
Cawthon, 2013[30]	★	★	—	—	★	★	★	★	—	6/9	High
Chen, 2016[31]	★	★	★	★	—	★	★			6/7	High
Chipperfield, 2008[32]	★	★	—	—	★	★	★			5/7	High
Dunlop, 2014[33]	★	★	—	★	★	★	★	★	★	8/9	High
Dunlop, 2015[34]	★	★	—	★	★	★	★			6/7	High
Dunlop, 2019[35]	★	★	—	★	★	★	★	★	★	8/9	High
Dunn, 2016[36]	—	★	—	—	—	★	★			3/7	Low
Ellingson, 2019[37]	★	—	★	—	—	★	★			4/7	High
Furlanetto, 2016[38]	★	★	—	—	—	—	★			3/7	Low
Gothe, 2020[39]	★	★	—	—	★	★	★			5/7	High
Hall, 2010[40]	★	★	—	—	—	★	★			4/7	High
Hornyak, 2013[41]	★	★	—	★	—	★	★			5/7	High
Huisingh-Scheetz, 2016[42]	★	★	—	★	★	★	★			6/7	High
Jeong, 2019[43]	★	★	—	—	—	★	★			4/7	High
Karloh, 2016[44]	★	—	—	—	—	★	★			3/7	Low
Kerr, 2012[45]	★	★	—	★	—	★	★			5/7	High
Marques, 2014[46]	★	★	★	★	—	★	★			6/7	High
Menai, 2017[47]	★	★	—	★	★	★	★			6/7	High
Ortlieb, 2014[48]	★	★	★	★	—	★	★			6/7	High
Pes, 2017[49]	★	★	—	—	—	★	★			4/7	High
Portegijs, 2019[50]	★	★	—	★	—	★	★			5/7	High
Sardinha, 2015[51]	★	★	★	★	★	★	★			7/7	High
Shah, 2012[52]	★	★	★	★	★	★	★	★	★	9/9	High
Song, 2017[53]	★	★	—	★	★	★	★	★	★	8/9	High
Steeves, 2019[54]	★	★	★	★	★	—	★			6/7	High
Walker, 2008[55]	★	★	—	—	—	★	★			4/7	High

Notes: ★Indicates that a star (point) was awarded. —Denotes that no star (point) was awarded. A blank cell implies that the criterion was not applicable. Median cut-off values to discriminate high and low study quality were defined as ≥ and < 4 out of 7 and ≥ and < 5 out of 9 points for cross-sectional and longitudinal studies, respectively.
Abbreviation: Q, Question.

Table 3 Measurement Methods and Scores of Physical Activity and Sedentary Behavior

Author, Year (Ref.)	Assessment Tool and Device Wear					Assessment of Valid Days		Physical Activity (PA) and Sedentary Behavior (SB)		
	A or P	Device Name	Worn on	# of Monitor Days	Mean Wear Duration (hrs/Day)	Valid Day Defined as (hrs/Day)	Required # of Valid Days for Analysis	Reported Measure(s)	Definition	Score
Balogun, 2020[26]	P	Baseline: Omron HJ 003 and 102; FU: Yamax SW200	Waist or belt above lower limb	7	n/r	n/r	n/r	(Δ) Steps (#/)/1000/day)	Device detected	< vs ≥ median WOMAC score: 9084 ± 3379 vs 8223 ± 3288
Barriga, 2014[27]	P	Geonaute Dista T300	Waist-band	3 (days during the week)	n/r	n/r	n/r	Steps (#/day)	Device detected	4972.4 ± 2242.3
Bielemann, 2020[28]	A	GENEActiv	Wrist	7	n/r	24	2	Accelerations (mg)	Device detected	T1: 13.2 ± 3.3; T2: 21.3 ± 1.9; T3: 30.5 ± 5.6
Blodgett, 2015[29]	A	ActiGraph AM-7164s	Hip	7	n/r	10	4	MVPA (hrs/day)	≥2021 cpm	15.3 ± n/r (min/day)
								SB (hrs/day)	0–100 cpm	8.59 ± n/r
Cawthon, 2013[30]	A	SenseWear Pro Armband	Triceps	7	n/r	≥90% of a 24-hour period	5	EE (kcal/day)	Device detected	Baseline, inability yes: 2220.6 ± 452.9; no: 2383.4 ± 421.2
										FU: 2395.6 ± 420.6
								MVPA (min/day)	≥3 MET	Baseline, inability yes: 58.6 ± 53.2; no: 90.8 ± 60.7
										FU: 92.8 ± 61.1
								SB (min/day)	≤1.5 MET	Baseline, inability yes: 875.4 ± 118.7; no: 831.9 ± 105.8
										FU: 829.4 ± 105.1

Chen, 2016[31]	A	Active style Pro HJ350IT	Waist	7	14.0 ± 1.8	10	4	MVPA (min/day)	≥3 MET	Inability yes: 33.2 ± 27.3; no: 46.1 ± 34.8
								BST (#/day)	≥1 min intensity above 1.5 MET after a SB bout	59.0 ± 13.2
								SB (min/day)	≤1.5 MET	463.0 ± 125.4
Chipperfield, 2008[32]	A	ActiGraph 7164	Wrist	1	31.1% removed device for 1.4 ± 2.7	n/r	1	Activity counts (#/day)	Device detected	M: 756 ± n/r; F: 769 ± n/r
Dunlop, 2014[33]	A	ActiGraph GT1M	Hip	7	n/r	10	4	MVPA (min/day) quartiles (Q1=least active)	≥2020 cpm with quartile cut-offs or 4.3, 12.2, and 28.2 minutes	Q1 (reference): 13.1 ± 17.6; Q2: 18.0 ± 19.2; Q3: 20.3 ± 18.6; and Q4: 24.3 ± 20.9
								LPA (min/day) quartiles (Q1=least active)	100–2019 cpm with quartile cut-offs of 229, 277, and 331 minutes	Q1 (reference): 192.3 ± 29.2; Q2: 154.9 ± 14.2; Q3: 302.1 ± 15.7; and Q4: 385.9 ± 50.0
Dunlop, 2015[34]	A	ActiGraph 7164	Hip	7	n/r	10	4	SB (hrs/day)	<100 cpm	8.9 ± 1.9
Dunlop, 2019[35]	A	CSA model 7164	Waistline	7	n/r	10	4	MVPA meet vs do not meet PA guidelines	≥2020 cpm; ≥ vs < 55 min/week of MVPA	Median [IQR], inability yes: 52 [18, 138]; no: 93 [33, 206]
Dunn, 2016[36]	A	SenseWear Pro Armband	Triceps	7	n/r	10	4	Steps (#/day)	Device detected	3164 ± 2824
								EE (kcal/day)	Device detected	2328 ± 476
								MVPA (% time)	≥3 MET	4.9 ± 6.9
								SB (% time)	<1.5 MET	75.9 ± 18.9
Ellingson, 2019[37]	A	ActiGraph GT3X+ and ActivPAL3	Hip and thigh	7	14.3 ± 1.6	10	4 (including one weekend day)	Steps (#/day)	Device detected	5900.5 ± 3131.7
								MVPA (min/day)	n/r	Median [IQR]: 38.7 [21.8, 75.6]
								SB (hrs/day)	n/r	8.7 ± 2.1

(*Continued*)

Table 3 (Continued).

Author, Year (Ref.)	Assessment Tool and Device Wear					Assessment of Valid Days		Physical Activity (PA) and Sedentary Behavior (SB)		
	A or P	**Device Name**	**Worn on**	**# of Monitor Days**	**Mean Wear Duration (hrs/Day)**	**Valid Day Defined as (hrs/ Day)**	**Required # of Valid Days for Analysis**	**Reported Measure(s)**	**Definition**	**Score**
Furlanetto, 2016[38]	A	SenseWear Armband	n/r	2 (days during the week)	12	n/r	n/r	MVPA active vs inactive	30 min/day of PA based on age, ≥65y: ≥ vs < 3.2 MET or <65y: ≥ vs < 4 MET	Active: n=36; inactive: n=68
Gothe, 2020[39]	A	ActiGraph wGT3x-BT	Hip	7	6.0 ± 2.1 days	10	n/r	MVPA (min/day)	≥2020 cpm	7.0 ± 11.7
								LPA (min/day)	101–2019 cpm	203.3 ± 91.4
								SB (min/day)	≤100 cpm	603.5 ± 108.9
Hall, 2010[40]	A	ActiGraph 7165	n/r	7	n/r	n/r	n/r	Steps active vs inactive	Device detected; ≥ vs < 10,000 steps per day	Active: n=35; inactive: n=93
Hornyak, 2013[41]	A	ActiGraph	Waist	7	n/r	n/r	n/r	Activity counts (#/day)	Device detected	148.5 ± 77.9
Huisingh-Scheetz, 2016[42]	A	Actiwatch Spectrum	Wrist	3	Total: 42.1 (95% CI: 41.2, 43.0) hours	10	n/r	Activity counts (#/15-sec epoch)	Device detected	54.0 (95% CI: 51.9, 56.2)
								SB (% time) (immobile)	Proportion of "0" activity counts	27.1 (95% CI: 26.1, 28.2)
Jeong, 2019[43]	A	Fitbit Charge model 2	Wrist	7	n/r	10	4	Steps (#/day)	Device detected	9907.6 ± 3641.8

Karloh, 2016[44]	A	DynaPort MiniMod	n/r	2 (days during the week)	n/r	12	n/r	Steps (#/day)	Device detected	6557 (95% CI: 5496, 7619)
								EE (kcal/day)	Device detected	1392 (95% CI: 1283, 1501)
								Movement intensity (m/s^2)	Device detected	1.78 (95% CI: 1.70, 1.87)
								TPA (min/day) (standing)	n/r	155 (95% CI: 140, 171)
								SB (min/day) (sitting)	n/r	381 (95% CI: 351, 412)
Kerr, 2012[45]	A	ActiGraph 3X+	n/r	7	n/r	10	4	MVPA active vs inactive	≥1040 cpm; ≥ vs < 30 min of PA	Active: 54.4 ± 24.1; inactive: 14.2 ± 7.8
Marques, 2013[46]	A	ActiGraph GT1M	Hip	4	n/r	10	3 (including one weekend day)	TPA (min/day)	Device detected	Risk of inability high: 176.2 ± 109.8; low: 247.9 ± 93.2
								VPA (min/day)	≥5999 cpm	Risk of inability high: 0.3 ± 1.8; low: 0.3 ± 2.6
								MVPA (min/day)	≥2020 cpm	24.7 ± 25.6
								MPA (min/day)	2020–5998 cpm	Risk of inability high: 13.3 ± 23.2; low: 28.1 ± 24.7
								LPA (min/day)	100–2019 cpm	204.9 ± 89.8
								SB (min/day)	<100 cpm	592.9 ± 115.6
Menai, 2017[47]	A	ActiGraph GT1M	Hip	4	n/r	10	3 (including one weekend day)	MVPA (min/day)	ENMO ≥100 mg; sum of short and long PA bouts	Successful agers yes: 34.9 ± 25.7; no: 24.5 ± 21.6

(*Continued*)

Table 3 (Continued).

Author, Year (Ref.)	Assessment Tool and Device Wear					Assessment of Valid Days		Physical Activity (PA) and Sedentary Behavior (SB)		
	A or P	**Device Name**	**Worn on**	**# of Monitor Days**	**Mean Wear Duration (hrs/Day)**	**Valid Day Defined as (hrs/Day)**	**Required # of Valid Days for Analysis**	**Reported Measure(s)**	**Definition**	**Score**
Ortlieb, 2016[48]	A	ActiGraph GT3X	Hip	10	740 ± 114 min/day	10	4	Activity counts (#/day)	Device detected	Median (95% CI), inability yes: 174 (57, 439); no: 269 (119, 542)
								MVPA (% time)	≥1952 cpm	Median (95% CI): 0.22 (0.00, 0.08)
								LPA (% time)	101–1951 cpm	Median (95% CI): 0.32 (0.18, 0.48)
								SB (% time)	≤100 cpm	Median (95% CI): 0.65 (0.48, 0.82)
Pes, 2017[49]	A	SenseWear Armband	Triceps	3	n/r	n/r	n/r	Steps (#/day)	Device detected	M: 12,110 ± 5141; F: 12,799 ± 6420
								EE (kcal/day)	Device detected	M: 2284 ± 543; F: 1810 ± 302
Portegijs, 2019[50]	A	UKK RM42 and eMotion Faros 180	Trunk and thigh	Range: 7 to 10	n/r	n/r	1	TPA (min/day) (standing)	Device detected	333.8 ± 103.0
								MVPA (min/day)	MAD ≥0.091*g*	28.5 ± 23.5

Sardinha, 2015[51]	A	ActiGraph GT1M	Hip	4 (including weekend)	823.4 ± 92.1 min/day	10	3 (including one weekend day)	MVPA (min/day)	≥2020 cpm	15.6 ± 22.5
								LPA (min/day)	100–2019 cpm	Risk of inability high: 206.9 ± 121.7; low: 285.5 ± 106.6
								SB break rate (#/hour in SB)	BST divided by total time in SB	9.0 ± 3.6
								BST (#/day)	≥1 min intensity above 100 cpm	Risk of inability high: 65.9 ± 23.6; low: 78.0 ± 17.6
								SB (min/day)	<100 cpm	Risk of inability high: 581.7 ± 132.5; low: 525.5 ± 125.5
Shah, 2012[52]	A	Actical	Wrist	10	9.3 ± 1.1	24	n/r	Activity counts (#/day x10^5)	Device detected	Baseline: 2.9 ± 1.6
										FU: 3.1 ± 1.5
Song, 2017[53]	A	ActiGraph GT1M	Hip	7	n/r	10	4	MVPA remained inactive vs more active (insufficiently active and met PA guidelines)	Absence of PA bouts vs (one session/week below guideline intensity and ≥150 min/week)	Remained inactive: n=n/r vs (insufficiently active: +7.8 min; met PA guidelines: +31.7 min
Steeves, 2019[54]	A	ActiGraph AM-7164	Hip	7	Inability yes: 13.9 (SE: 0.1); no: 14.1 (SE: 0.1)	10	4	Steps (#/day)	Device detected	Inability yes: 4108 (SE: 202); no: 4468 (SE: 219)
								Activity counts (#/day)	Device detected	Inability yes: 178.8 (SE: 6.2); no: 242.5 (SE: 6.5)
								MVPA (% time)	≥2020 cpm	Inability yes: 0.9 (SE: 0.1); no: 1.6 (SE: 0.1)
								LPA (% time)	100–2019 cpm	Inability yes: 26.2 (SE: 0.5); no: 28.7 (SE: 0.3)
								BST (#/day)	Transition from SB to non-SB (≥100 cpm)	Inability yes: 83.4 (SE: 1.0); no: 86.6 (SE: 0.7)
								SB (% time)	< 100 cpm	Inability yes: 67.5 (SE: 0.7); no: 62.0 (SE: 0.6)

(Continued)

Table 3 (Continued).

Author, Year (Ref.)	Assessment Tool and Device Wear					Assessment of Valid Days		Physical Activity (PA) and Sedentary Behavior (SB)		
	A or P	Device Name	Worn on	# of Monitor Days	Mean Wear Duration (hrs/Day)	Valid Day Defined as (hrs/Day)	Required # of Valid Days for Analysis	Reported Measure(s)	Definition	Score
Walker, 2008[55]	A	Actiwatch	Waist and thigh	3	15.7 ± 0.2	n/r	n/r	Activity counts (#/day x10^3)	Device detected	156 ± 68.2
								TPA (% time) (mobile)	% of 30-sec epochs with an activity score ≥1	50.0 ± 2.7

Notes: Device wear time is presented as mean ± standard deviation or standard error (SE) hours per day. Valid days are defined as mean hours per day. Subgroups with corresponding information (physical activity/sedentary behavior score) are presented in italics.

Abbreviations: P, pedometer; A, accelerometer; n/r, not reported; MVPA, moderate to vigorous physical activity; EE, energy expenditure; BST, breaks in sedentary time; LPA, light physical activity; TPA, total physical activity; VPA, vigorous physical activity; MPA, moderate physical activity; Δ, change; #, number; min/day, minutes per day; m/s^2, meters per second squared; mg, milligal; kcal/day, kilocalories per day; #/day, number per day; % time, percentage of time; cpm, counts per minute; MET, metabolic equivalent units; min, minutes; vs, versus; min/week, minutes per week; ENMO, Euclidean Norm Minus One; MAD, mean amplitude deviation; T, tertile; M, males; F, females; Q, quartile; IQR, interquartile range; n, sample size; 95% CI, confidence interval; FU, follow-up;

(Figure 3), and the sensitivity analyses (population selection, study design, adjustment, device type, and device wearing location) are demonstrated in Figure 4.

Associations of PA and SB with ADL

Longitudinal associations between PA/SB measures and ADL were studied in four articles;[27,31,36,53] all associations were significant and effect directions showed that higher PA and lower SB were consistently associated with better ADL: lower MVPA and EE, and higher SB at baseline, were associated with an increased likelihood to become dependent in ADL after two years in community-dwelling older males,[31] higher baseline activity counts was associated with a lower hazard of ADL dependence after 3.4 years in a general community-dwelling older adult population,[53] engaging in approximately one-hour MVPA was associated with a lower risk of becoming dependent in ADL after four years in an osteoarthritis population,[36] and a bidirectional association was identified between number of steps and ADL (a higher average number of steps was associated with better ADL from baseline and, additionally, worsened ADL from baseline was associated with a lower average number of steps) over five years in an osteoarthritis population.[27] These findings were supported by cross-sectional associations, which demonstrated that higher PA and lower SB were associated with better ADL; furthermore, three articles[28,51,55] studied ADL as independent and PA/SB as dependent variable, showing that limited ability to complete ADL was associated with lower PA and higher SB (Table 6; Figure 2A). The median [interquartile range] standardized regression coefficient (β) for all articles reporting associations between PA/SB measures and ADL was 0.145 [0.072, 0.280] (Figure 3A).

Associations of PA and SB with IADL

Three articles studied longitudinal associations between PA/SB measures and IADL,[31,34,54] which were all significant and had a positive effect direction: community-dwelling older male adults with lower MVPA and EE, and higher SB at baseline were more likely to become dependent in IADL after two years[31] and in two articles including older adults from the Osteoarthritis Initiative (OAI), after two years follow-up, higher MVPA and LPA at baseline[34] and increasing MVPA from baseline[54] were associated with a lower hazard for the development and progression of IADL dependence[34] and improved IADL,[54] respectively. Cross-sectional associations were in line with these results, showing that PA/SB measures were

Table 4 Assessment, Scores, and Breakdown of Activities in Tool Used for the Assessment of Activities of Daily Living

Author, Year (Ref.)	Assessment Tool {Range of Possible Scores}	Activities									Definition	Score, in Mean ± sd or n (%)
		Bathing	Grooming	Dressing	Toileting	Continence	Transferring	Feeding	Walking	Other		
Balogun, 2020[26]	WOMAC, functional limitation sub-scale {0 to 153}	★		★	★		★		★	★ (12)	Continuous; each activity scored from 0 (no difficulty) to 9 (worse ADL), with higher score indicating worse ADL	n/r
Barriga, 2014[27]	LCADL scale {0 to 75}	★	★	★					★	★ (11)	Continuous; each activity scored from 0 to 5, with higher score indicating worse ADL	17.7 ± 5.1
Bielemann, 2020[28]	Katz Index {0 to 6}	★		★	★	★	★	★			Continuous; each activity scored as 0 (dependent) or 1 (independent), with higher score indicating better ADL	Independent, T1: 41 (13.6); T2: 67 (21.2); T3: 87 (27.7)
Blodgett, 2015[29]	Custom questionnaire {0 to 4}			★			★		★	★ (1)	Dichotomous; inability defined as no difficulty in activity	535 (17.0)
Cawthon, 2013[30]	Custom questionnaire {0 to 4}	★					★		★	★ (1)	Dichotomous; inability defined as no difficulty in activity	314 (16.0)
Dunlop, 2015[34]	Custom questionnaire {0 to 4}			★			★	★	★		Dichotomous; inability defined as much difficulty or did not perform an activity	103 (4.5)
Dunlop, 2019[35]	Custom questionnaire {0 to 6}	★		★	★		★		★	★ (1)	Dichotomous; inability-free status defined as reporting no difficulty in ≥1 activity	1222 (83.7)

(*Continued*)

Table 4 (Continued).

Author, Year (Ref.)	Assessment Tool {Range of Possible Scores}	Activities									Definition	Score, in Mean ± sd or n (%)
		Bathing	Grooming	Dressing	Toileting	Continence	Transferring	Feeding	Walking	Other		
Ellingson, 2019[37]	PDQ-39, activities of daily living dimension {0 to 100%}	★		★						★ (4)	Continuous; each activity scored from 0 to 5 (x 100%), with higher score indicating better ADL	Median [IQR]: 50 [37.5, 58.3]
Furlanetto, 2016[38]	LCADL scale {0 to 75}	★	★	★					★	★ (11)	Continuous; each activity scored from 0 to 5, with higher score indicating worse ADL	Median [IQR], active: 18 [15, 26]; inactive: 23 [16, 29]
Gothe, 2020[39]	Barthel Index {0 to 20}	★		★	★	★	★	★	★	★ (3)	Continuous; each activity scored as 0 (dependent), 1 (need help), 3 (independent), with higher score indicating better ADL	18.03 ± 2.61
Huisingh-Scheetz, 2016[42]	Custom questionnaire {0 to 7}	★		★	★		★	★	★	★ (1)	Dichotomous; inability defined as difficulty in ≥1 activity	193 (31.1)
Jeong, 2019[43]	KOOS questionnaire, function in daily life sub-scale {0 to 100}			★	★		★		★	★ (13)	Continuous; each activity scored from 0 (no problems) to 4 (extreme problems) and transformed to a 0 (worse) to 100 (better) scale	57.4 ± 12.5
Karloh, 2016[44]	Glittre-ADL test, in minutes						★		★	★ (5)	Continuous; time necessary to complete 10-m long circuit, with longer time as worse ADL	4.69 (95% CI: 4.27, 5.11)

Menai, 2017[47]	Custom questionnaire {0 to 7}	★		★	★		★	★	★		Dichotomous; inability-free status defined as reporting no difficulty in ≥1 activity	Successful agers yes: 789 (100); no: 2551 (87.4)
Ortlieb, 2014[48]	HAQ-DI {0 to 60}	★	★	★			★	★	★	★ (14)	Dichotomous; each activity scored from 0 (no difficulty), 1 (some difficulty), to 3 (unable to perform), with inability defined as difficulty in ≥1 activity	70 (41.7)
Pes, 2017[49]	Custom questionnaire {0 to 6}	★	★	★	★	★	★	★			Continuous; higher score indicates better ADL	M: 4.9 ± 1.5; F: 4.8 ± 1.4
Portegijs, 2019[50]	Custom questionnaire {0 to 5}	★		★	★		★	★			Dichotomous; inability defined as difficulty in ≥1 activity	51 (9.6)
Sardinha, 2015[51]	CPF scale {0 to 24}	★		★					★	★ (9)	Dichotomous; each activity scored as 2 (can do), 1 (need help), or 0 (cannot do); age-adjusted scoring indicating low risk of inability as ≥14/16/18/20 points for 90+, 80–89-, 70–79-, and 65–69-year old's, respectively	Risk of inability high: 95 (25.6); low: 276 (74.4)
Shah, 2012[52]	Katz Index {0 to 6}	★		★	★		★	★	★	★	Baseline: dichotomous; inability-free status defined as reporting no difficulty in ≥1 activity	Baseline: 718 (82.5)
											FU: dichotomous; inability defined as difficulty in ≥1 activity	FU: 182 (31.2)

(*Continued*)

Table 4 (Continued).

Author, Year (Ref.)	Assessment Tool {Range of Possible Scores}	Activities									Definition	Score, in Mean ± sd or n (%)
		Bathing	Grooming	Dressing	Toileting	Continence	Transferring	Feeding	Walking	Other		
Steeves, 2019[54]	Custom questionnaire {n/r}			★			★	★	★	★ (3)	Dichotomous; inability defined as difficulty in ≥1 activity	475 (31.2)
Walker, 2008[55]	NEADL {0 to 22}						★	★	★	★ (19)	Continuous; each activity scored as 0 (dependent) or 1 (independent), with higher score indicating better ADL	16.4 ± 0.5

Notes: Score is presented in mean ± standard deviation (sd), number and percentage (n (%)) of participants with inability or inability-free status, or as reported otherwise. Custom questionnaire refers to questionnaires that were developed in-house by research for the purposes of their studies, as opposed to a validated questionnaire. Subgroups with corresponding information (sample size (n), age (in years), and n (%) female) are presented in italics. ★ indicates that the activity was present in the assessment tool.

Abbreviations: ADL, Activities of daily living; WOMAC, Western Ontario and McMaster Universities osteoarthritis index; LCADL, London Chest Activities of Daily Living; PDQ-39, Parkinson's Disease questionnaire; KOOS, knee injury and osteoarthritis outcome score; HAQ-DI, Health Assessment Questionnaire Disability Index; CPF, Composite Physical Function; NEADL, Nottingham Extended Activities of Daily Living.

positively associated with IADL. Three studies investigated the cross-sectional association between measures of PA/SB and IADL with IADL as independent variable and PA/SB as dependent variable, showing that experiencing difficulty in IADL was associated with lower levels of PA (Table 6; Figure 2B). The median [interquartile range] standardized regression coefficient (β) for all articles reporting associations between PA/SB measures and IADL was 0.135 [0.093, 0.211] (Figure 3B).

Sensitivity Analyses

Sensitivity analyses demonstrated that population selection (general and disease populations) had an influence on the effect sizes of associations between PA/SB and, in particular, ADL with larger standardized regression coefficients found for disease populations (median [IQR]: β=0.314 [0.159, 0.460]) than general populations (median [IQR]: β=0.111 [0.067, 0.178]) (Figure 4A). Longitudinal associations presented smaller standardized regression coefficients (median [IQR] for ADL: β=0.078 [0.065, 0.120] and IADL: β=0.084 [0.069, 0.094]) when compared to cross-sectional associations (median [IQR] for ADL: β=0.157 [0.098, 0.301] and IADL: β=0.162 [0.113, 0.224]) (Figure 4B). For unadjusted associations larger standardized regression coefficients were found (median [IQR] for ADL: β=0.316 [0.304, 0.462] and IADL: β=0.170 [0.144, 0.176]) in comparison to adjusted associations, especially for the relationship between PA/SB and ADL (median [IQR] β=0.112 [0.072, 0.178]) (Figure 4C). In all studies, except for two that used a pedometer, accelerometers were used to monitor PA and SB (median β [IQR] for ADL: 0.145 [0.076, 0.266] and for IADL: 0.135 [0.093, 0.211]) (Figure 4D). For ADL, largest median standardized coefficient was observed when the device was located on the wrist (median [IQR] β=0.187 [0.082, 0.232], followed by a positioning on the hip (median [IQR] β=0.114 [0.064, 0.157]) and triceps (median [IQR] β=0.078 [0.059, 0.277]); whereas for IADL, device wearing location had no influence on the effect size (median β [IQR] for hip: 0.162 [0.090, 0.204] and for triceps: 0.158 [0.106, 0.213]) (Figure 4E).

Discussion

Higher PA and lower SB at baseline and increased PA from baseline were consistently associated with maintaining or improving the ability to complete ADL and IADL from baseline in community-dwelling older adults. These longitudinal associations were supported by the more

Table 5 Assessment, Scores, and Breakdown of Activities in Tool Used for the Assessment of Instrumental Activities of Daily Living

Author, Year (Ref.)	Assessment Tool {Range of Possible Scores}	Activities									Definition	Score, in Mean ± sd or n (%)
		Telephone use	Shopping	Food preparation	Housekeeping	Laundry	Public transportation	Medication Use	Handle finances	Other		
Cawthon, 2013[30]	Custom questionnaire {0 to 5}		★	★	★			★	★		Dichotomous; inability defined as difficulty in ≥1 activity	Baseline: 743 (25.6)
												FU: 263 (13.0)
Chen, 2016[31]	TMIG-IC {0 to 5}		★	★			★		★		Dichotomous; each activity scored as 1 (able to do) or 0 (not able to), with inability defined as total score below 5 points	137 (8.4)
Chipperfield, 2008[32]	Custom questionnaire {0 to 22}	★	★	★	★	★	★	★	★	★ (12)	Continuous; each activity scored as 0 (needs help) or 1 (yes, can do), with a higher score indicating better IADL	18.6 (3.0)
Dunlop, 2014[33]	Custom questionnaire {0 to 11}	★	★	★				★	★	★ (6)	Inability onset: dichotomous; inability defined as difficulty in ≥1 activity and progression: ordinal as none (no difficulty), mild (only difficulty in IADL), moderate (difficulty in 1 or 2 ADL), and severe (difficulty in ≥3 ADL)	Inability onset: 149 (8.9); progression: n/r
Dunn, 2016[36]	Rosow-Breslau scale {0 to 3}				★					★ (2)	Continuous; each activity scored as 1 (no help), 2 (needs help), or 3 (unable to do), with a higher score indicating worse IADL	2.3 ± 0.8
Gothe, 2020[39]	LLFDI function component {15 to 75}	n/r (15 activities)									Continuous; each activity scored from 0 (cannot do) to 5 (no difficulty), with higher score indicating better IADL	52.50 ± 13.91
Hall, 2010[40]	LLFDI function component {15 to 75}	n/r (15 activities)									Continuous; each activity scored from 0 (no difficulty) to 5 (cannot do), with higher score indicating worse IADL	Active: 22.54 ± 6.6; inactive: 26.65 ± 8.25

(*Continued*)

Table 5 (Continued).

Author, Year (Ref.)	Assessment Tool {Range of Possible Scores}	Activities									Definition	Score, in Mean ± sd or n (%)
		Telephone use	Shopping	Food preparation	Housekeeping	Laundry	Public transportation	Medication Use	Handle finances	Other		
Hornyak, 2013[41]	LLFDI function component {0 to 100}			★	★		★			★ (29)	Continuous; each activity scored from 0 to 5 (converted to a 0 to 100 scale), with higher score indicating better IADL	60.3 ± 9.7
Huisingh-Scheetz, 2016[42]	Custom questionnaire {0 to 7}		★	★	★			★	★	★ (2)	Dichotomous; inability defined as difficulty in ≥1 activity	279 (44.8)
Kerr, 2012[45]	LLFDI function component {9 to 45}	n/r (15 activities)									Continuous; each activity scored from 0 (cannot do) to 5 (no difficulty), with higher score indicating better IADL	Active: 39.1 ± 8.0; inactive: 30.3 ± 8.4
Marques, 2014[46]	CPF scale {0 to 24}		★		★					★ (9)	Dichotomous; each activity scored as 2 (can do), 1 (need help), or 0 (cannot do); age-adjusted scoring indicating low risk of inability as ≥14/16/18/20 points for 90+, 80–89-, 70–79-, and 65–69-year old's, respectively	Risk of inability high: 95 (25.6); low: 276 (74.4)
Sardinha, 2015[51]	CPF scale {0 to 24}		★		★					★ (9)	Dichotomous; each activity scored as 2 (can do), 1 (need help), or 0 (cannot do); age-adjusted scoring indicating low risk of inability as ≥14/16/18/20 points for 90+, 80–89-, 70–79-, and 65–69-year old's, respectively	Risk of inability high: 95 (25.6); low: 276 (74.4)

Song, 2017[53]	LLDI limitation component {0 to 100}	n/r (16 activities)	Continuous; each activity scored from 0 (cannot do) to 5 (no difficulty) and converted to a 0 to 100 scale, with higher score indicating better ADL	Remained inactive: 79.3 ± 15.3 vs more active (insufficiently active: 82.1 ± 14.5; met PA guidelines: 78.3 ± 12.8)

Notes: Score is presented in mean ± standard deviation (sd) or as number and percentage (n (%)) of participants with inability. Custom questionnaire refers to questionnaires that were developed in-house by research for the purposes of their studies, as opposed to a validated questionnaire. n/r: not reported. Subgroups with corresponding information (sample size (n), age (in years), and n (%) female) are presented in italics. ★ indicates that the activity was present in the assessment tool.

Abbreviations: IADL, Instrumental activities of daily living; TMIG-IC, Instrumental Self-Maintenance or the Tokyo Metropolitan Institute of Gerontology Index of Competence; LLFDI, Late-Life Function and Disability Index; LLDI, Late-Life Disability Index.

frequently reported cross-sectional studies. Effect sizes were similar for associations between PA/SB and ADL or IADL; cross-sectional results yielded larger effect sizes for both ADL and IADL, and larger effect sizes were additionally found for ADL in disease populations and unadjusted analyses.

Objective measures of higher PA and lower SB showed associations with better ADL and IADL, which was in line with previous literature that purports health benefits from PA of any intensity and limited sedentary time.[57] This is also in accordance with intervention studies that provide evidence of improved functional capacities in response to PA, such as coordination, muscle strength, and balance, which are essential for ADL and IADL.[58]

This systematic review identified similar standardized effect sizes for the association of PA/SB measures with ADL and IADL, which was unexpected considering differences in capacities required to complete ADL and IADL. ADL primarily depends on motor functions, such as upper limb control and postural stability, that are necessary to complete the most basic forms of self-care;[26] whereas, IADL additionally places a demand on cognition, particularly executive function during activities, such as grocery shopping.[59] Furthermore, IADL dependence precedes ADL with the latter hence indicating greater system-level impairment and severe loss of autonomy.[60] This is because ADL dependence is typically caused by musculoskeletal failure to where minimally demanding activities can no longer be performed.[61] However, inclusion of exclusively community-dwelling older adults may have masked differences between ADL and IADL as to remain non-institutionalized requires a certain minimum ADL ability.[62] While it is likely that the ability to complete ADL and IADL plays a role in determining to what extent someone can engage in PA, it is important to acknowledge that having the capacity to perform these activities does not ensure that the capacity is actually used to partake in PA.[63]

Population selection revealed dissimilarity in the effect sizes for disease versus general populations, showing that associations were dependent on the population studied, which can be explained by the pathophysiological backing regarding the effect of disease on the engagement in PA. Chronic diseases, such as COPD and osteoarthritis (commonly studied populations within this systematic review), may modify the effect that PA has on ADL because engaging in PA may be more critical for physical functioning in the presence of disease-induced impairments, such as

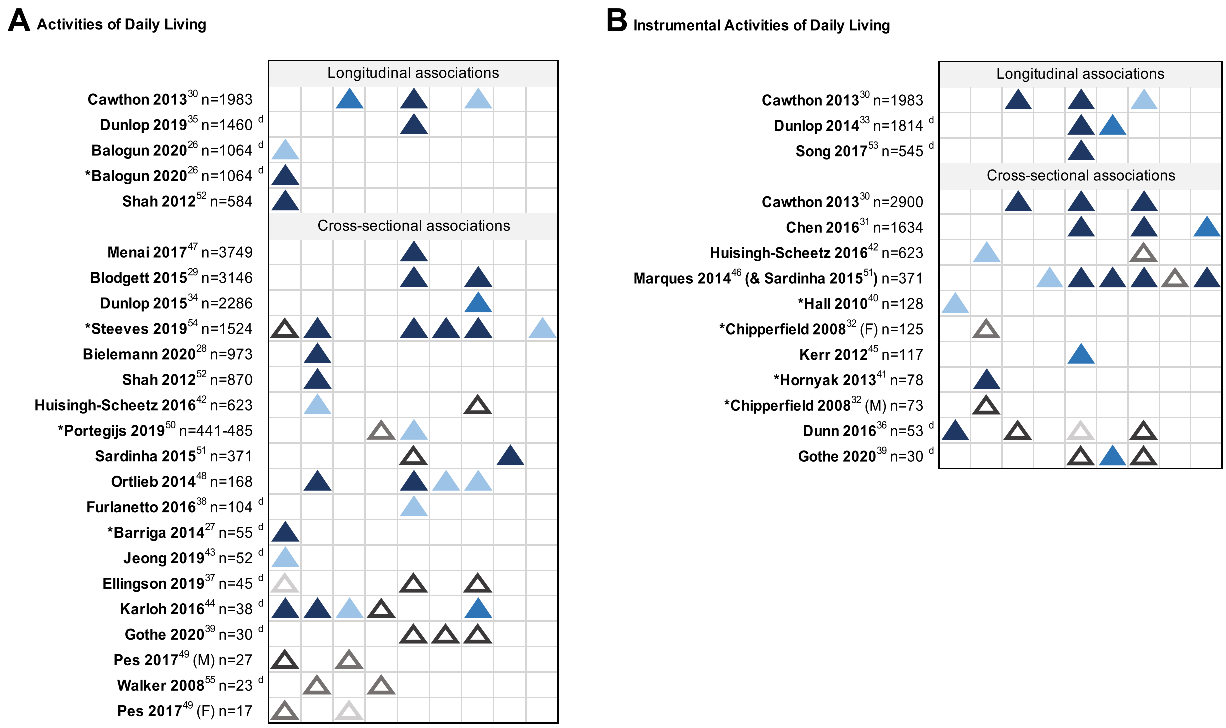

Figure 2 Effect direction heat map visualizing associations of objectively measured physical activity and sedentary behavior with (**A**) activities of daily living and (**B**) instrumental activities of daily living based on p-values, ordered by sample size, and stratified by study design (cross-sectional and longitudinal). ± indicate positive/negative effect direction (higher PA and lower SB are associated with better (+) or worse (-) activities of daily living (ADL) or instrumental activities of daily living (IADL). PA/SB measures: Counts=activity counts, EE=energy expenditure, TPA=total physical activity, MVPA=moderate to vigorous physical activity, LPA=light physical activity, SB=sedentary behavior, break rate=number of breaks per sedentary hour, BST=breaks in sedentary time. ▲/▼ (dark blue): $p<0.001$, ▲/▼ (blue): $0.001\leq p<0.01$, ▲/▼ (light blue): $0.01\leq p<0.05$, Δ/∇ (light grey): $0.05\leq p<0.1$, Δ/∇ (grey): $0.1\leq p<0.25$, Δ/∇ (dark grey): $p\geq 0.25$. *activities of daily living or instrumental activities of daily living as independent variables and PA/SB as dependent variable. [d]Disease population.
Abbreviations: M, Males; F, Females.

breathlessness and stiffness, and inversely, SB may be more detrimental in the presence of disease. Stratification by study design showed that there were smaller effect sizes for longitudinal studies when compared to cross-sectional studies, which may suggest that while baseline PA and SB are determinants of baseline and future ability to perform ADL and IADL, changes in ADL and IADL in short periods of time may be more affected by other factors involved in health status. Larger effect sizes found for unadjusted associations in comparison to adjusted associations strengthen the importance of our adjustment hierarchy, which was applied to prevent inflation by confounders, such as age and sex, that may mask the actual relationship of PA/SB with ADL and IADL.

PA and SB are, as highlighted in this systematic review, associated with the ability to independently accomplish ADL and IADL. Enhancing PA and reducing the time spent sedentarily are therefore promising strategies to maintain functional independence. With increasing age, however, multimorbidity and cognitive impairment are more prominent and threaten healthy aging.[64] It may therefore be that the inability to perform ADL and IADL influences PA engagement and involves higher levels of SB, resulting in an overall more inactive lifestyle. Conversely, an active lifestyle could protect older adults from a loss of functional independence, which is implicated by our longitudinal findings. To disentangle this reverse causation, future randomized controlled trials are advised to inform public health strategies about an attainable active lifestyle for older adults based on their functional capability.

Population aging is accompanied by an increase in disease burden among older adults, which threatens functioning in daily life and, therefore, underpins the clinical relevance of our findings that objectively measured PA and SB are modifiable lifestyle factors of the ability to carry out ADL and IADL. This can be used to determine the dose–response relationship of PA and SB with ADL and IADL to guide public health and clinical interventions for preventing and delaying loss of independence.

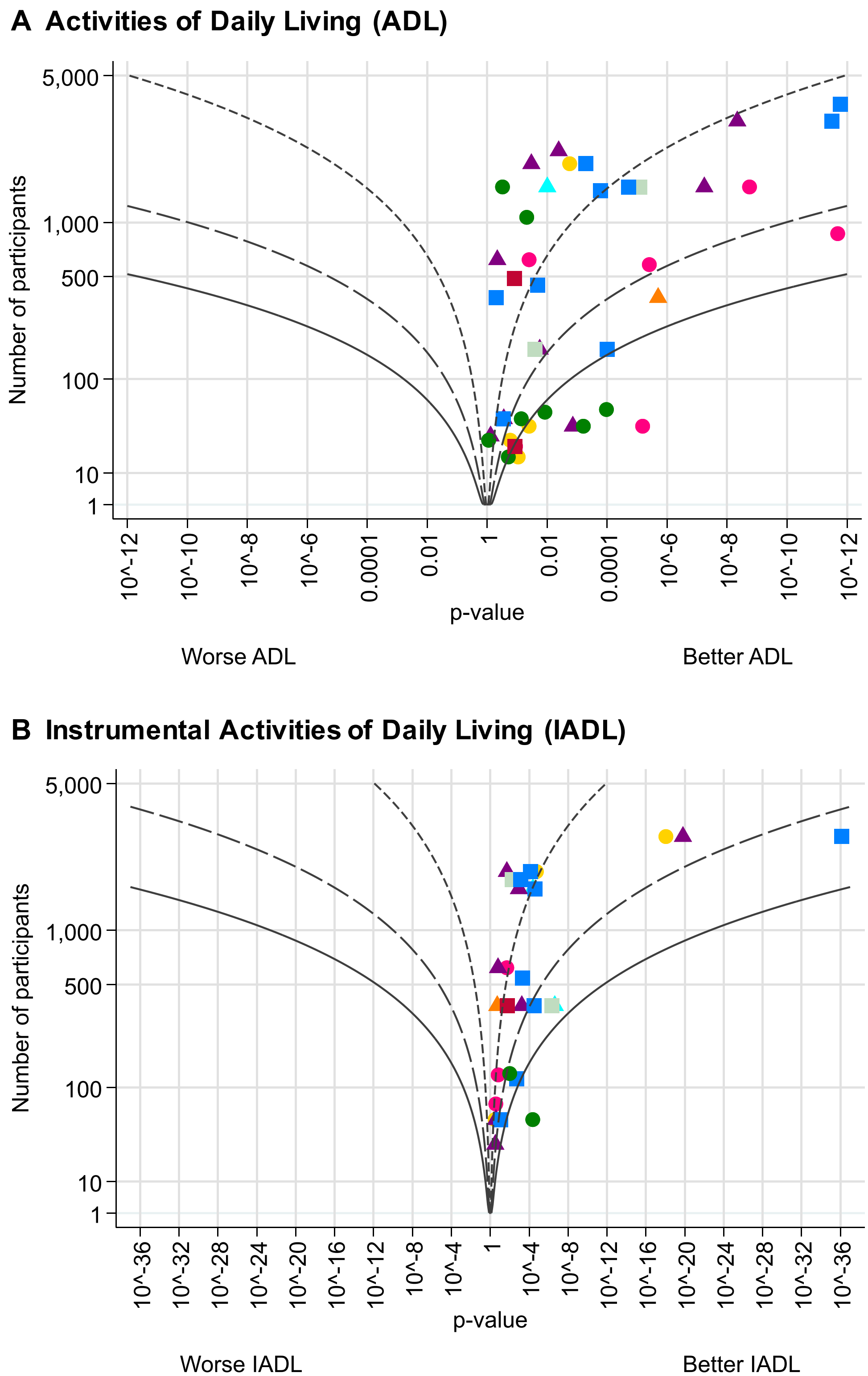

Figure 3 Albatross plots depicting the magnitude of associations, provided as standardized regression coefficients (βs), of higher physical activity (PA) and lower sedentary behavior (SB) with (**A**) activities of daily living and (**B**) instrumental activities of daily living. ● (green) steps, ● (pink) activity counts, ● (yellow) energy expenditure, ■ (red) total physical activity, ■ (blue) moderate to vigorous physical activity, ■ (light green) light physical activity, ▲ (purple) inverse sedentary behavior, ▲ (orange) break rate (number of breaks per sedentary hour), ▲ (cyan) breaks in sedentary time. β = ±0.10, β = ±0.20, β = ±0.30.

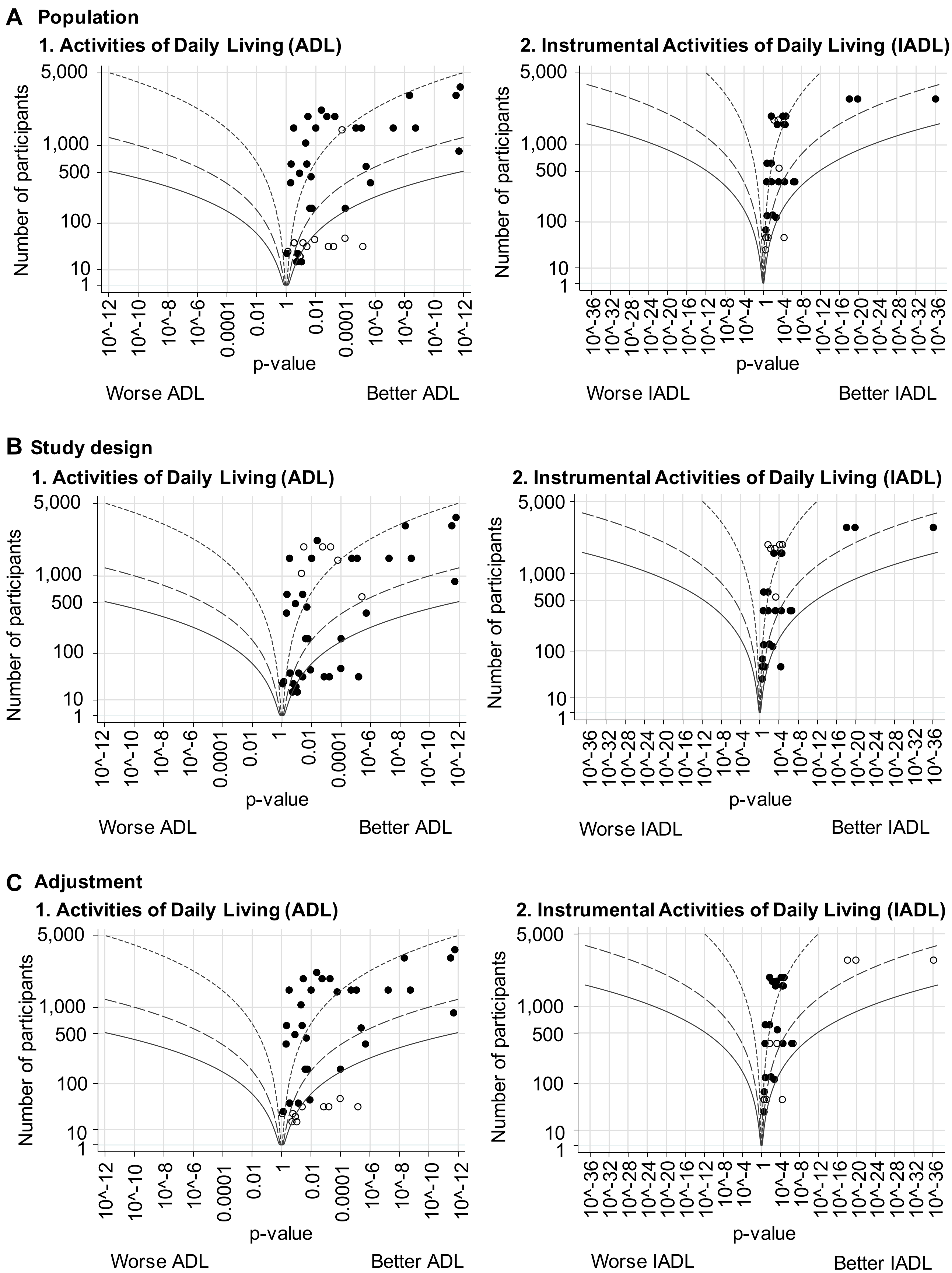

Figure 4 Continued.

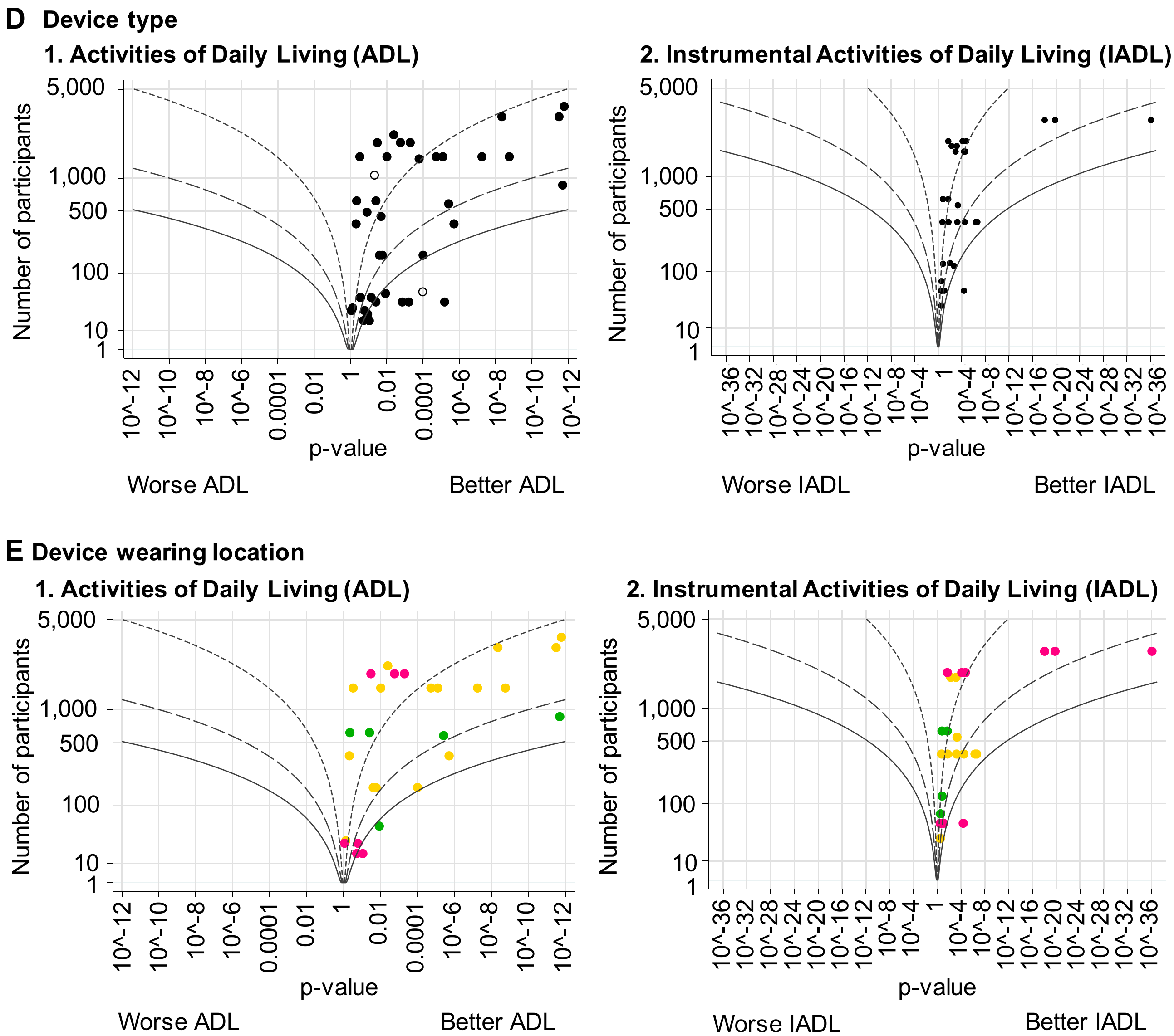

Figure 4 Albatross plots depicting the magnitude of associations, provided as standardized regression coefficients (βs), of higher physical activity (PA) and lower sedentary behavior (SB) with activities of daily living (ADL) and instrumental activities of daily living (IADL), stratified by (**A**) population (general versus disease), (**B**) study design (cross-sectional versus longitudinal), (**C**) adjustment (adjusted versus unadjusted associations), (**D**) device location (accelerometer versus pedometer), and (**E**) device wearing location. (**A**) population selection: ● general, ○ disease, (**B**) study design: ● cross-sectional, ○ longitudinal, (**C**) adjustment: ● adjusted, ○ unadjusted, (**D**) device type ● accelerometer, ○ pedometer, (**E**) device wearing location: ● (green) wrist, ● (pink) triceps, ● (yellow) hip. β = ±0.10, β = ±0.20, β = ±0.30.

Considering the importance of an active lifestyle for maintaining independence, as shown in this systematic review, PA may act as a target for future intervention studies. Future studies should aim to improve standardization in the assessment of PA and SB (eg, device-wearing location, cut-off points, and assessment of ADL and IADL) to unravel the dose–response relationships of PA and SB with ADL and IADL and, ultimately, establish thresholds to prevent deterioration in the ability to complete ADL and IADL.

The inclusion of solely articles that objectively measured PA and SB is a strength of this systematic review as it eliminates bias that is involved in self-reported assessment and thus provides the most accurate insight into PA and SB and the subsequent association with ADL and IADL. As older adults regularly spend most of their time in low-intensity activities, a broad range of PA measures, including LPA, is an additional strength because this metric is often neglected due to the difficulty of measuring LPA via self-report.[65] Furthermore, diverse community-dwelling older adults were included, without exclusion of specific disease groups, which allows for generalizability of our findings. Another strength is that the literature search focused on articles that were explicitly described

Table 6 Associations of Objectively Measured Physical Activity and Sedentary Behavior with Activities of Daily Living and Instrumental Activities of Daily Living in Community-Dwelling Older Adults, Stratified by Domain

Author, Year (Ref.)	PA/SB Measure(s)	ADL/IADL		Adjustment Model	Effect Size (95% Confidence Interval)	p-value Used in Data Syntheses*
		Assessment Tool	Definition/ Unit			
ADL						
Balogun, 2020[26]	Steps (1000/day)	WOMAC functional limitation sub-scale	Δ in WOMAC score {0 to 153}	Baseline age, sex, BMI, time to FU, # of chronic conditions	B=0.86 (−1.31, 0.40)	p(calc) =0.048
	Δ Steps (#/day)	WOMAC functional limitation sub-scale	Average WOMAC score {0 to 153}	Baseline age, sex, BMI, time to FU, # of chronic conditions	**B=−22.9 (−32.4, −13.4)	—
Barriga, 2015[27]	Steps (#/day)	LCADL scale	Score {0 to 75}	Unadjusted	**Spearman's Rho=−0.499	p(calc) <0.001
Bielemann, 2020[28]	Accelerations (mg)	Katz Index	Score {0 to 6}	Unadjusted	Kruskal–Wallis=n/r; p<0.001	p(n/r) <0.001
Blodgett, 2015[29]	MVPA (hrs/day)	Custom questionnaire	Inability yes vs no	Age, sex, wear time, race	OR=0.06 (0.03, 0.14)	p(calc) <0.001
	SB (hrs/day)	Custom questionnaire	Inability yes vs no	Age, sex, wear time, race	OR=1.43 (1.32, 1.56)	p(calc) <0.001
Cawthon, 2013[30]	EE (kcal/day)	Custom questionnaire	Inability onset yes vs no	Age, clinical center, season for activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-rated health, # of chronic conditions, cognition	OR=1.35 (0.12, 1.63)	p(calc) =0.002
	MVPA (min/day)	Custom questionnaire	Inability onset yes vs no	Age, clinical center, season for activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-rated health, # of chronic conditions, cognition	OR=1.36 (1.14, 1.61)	p(calc) <0.001
	SB (min/day)	Custom questionnaire	Inability onset yes vs no	Age, clinical center, season for activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-rated health, # of chronic conditions, cognition	OR=1.17 (1.01, 1.35)	p(calc) =0.034

Dunlop, 2015[34]	SB (hrs/day)	Custom questionnaire	Inability yes vs no	Age, sex, race/ethnicity, education, income, health insurance, wear time, cohort membership of the NHANES	OR=1.56 (0.15, 2.11)	p(calc) =0.004
Dunlop, 2019[35]	MVPA meet vs do not meet guidelines	Custom questionnaire	Inability above vs below optimal PA threshold	Age, sex, BMI, presence of knee OA	RR=0.60 (0.46, 0.78)	p(calc) <0.001
Ellingson, 2019[37]	Steps (#/day)	PDQ-39 activities of daily living scale	Score {0 to 100%}	Unadjusted	Spearman's Rho=−0.27	p(calc) =0.073
	MVPA (min/day)	PDQ-39 activities of daily living scale	Score {0 to 100%}	Unadjusted	Spearman's Rho=−0.16	p(calc) =0.294
	SB (hrs/day)	PDQ-39 activities of daily living scale	Score {0 to 100%}	Unadjusted	Spearman's Rho=0.165	p(calc) =0.279
Furlanetto, 2016[38]	MVPA active vs inactive	LCADL scale	Score {0 to 75}	Unadjusted	ANOVA=n/r; p<0.05	0.01≤p(n/r) <0.05
Gothe, 2020[39]	MVPA (min/day)	Barthel Index	Score {0 to 20}	Age, time since stroke	β=0.19 (n/r); p>0.05	p(n/r)≥0.25
	LPA (min/day)	Barthel Index	Score {0 to 20}	Age, time since stroke	β=0.28 (n/r); p>0.05	p(n/r)≥0.25
	SB (min/day)	Barthel Index	Score {0 to 20}	Age, time since stroke	Partial R=−0.061	p(calc) =0.768
Huisingh-Scheetz, 2016[42]	Activity counts (#/15-sec epoch)	Custom questionnaire	Inability yes vs no	Age, sex, education, race, ethnicity, household assets, BMI categories, timed gait, cognition, employment status, wear time	OR=0.87 (n/r)	p=0.04
	SB (% time)	Custom questionnaire	Inability yes vs no	Age, sex, education, race, ethnicity, household assets, BMI categories, timed gait, cognition, employment status, wear time	OR=1.1 (n/r)	p=0.46

(Continued)

Table 6 (Continued).

Author, Year (Ref.)	PA/SB Measure(s)	ADL/IADL		Adjustment Model	Effect Size (95% Confidence Interval)	p-value Used in Data Syntheses*
		Assessment Tool	Definition/ Unit			
Jeong, 2019[43]	Steps (#/day)	KOOS function in daily life sub-scale	Score {0 to 100}	Adjustment=n/r	β=0.38 (n/r); R^2=0.12; p<0.01	p(calc) =0.012
Karloh, 2016[44]	Steps (#/day)	Glittre-ADL test	Minutes	Unadjusted	Spearman's Rho=−0.53	p(calc) <0.001
	EE (kcal/day)	Glittre-ADL test	Minutes	Unadjusted	Spearman's Rho=−0.33	p=0.04
	Movement intensity (m/s^2)	Glittre-ADL test	Minutes	Unadjusted	Spearman's Rho=−0.66	p(calc) <0.001
	TPA (min/day)	Glittre-ADL test	Minutes	Unadjusted	Spearman's Rho=n/r; p≥0.05	p(n/r)≥0.25
	SB (min/day)	Glittre-ADL test	Minutes	Unadjusted	Spearman's Rho=0.50	p(calc) =0.001
Menai, 2017[47]	MVPA (min/day)	Custom questionnaire	Inability no vs yes	Age, sex, ethnicity, education, smoking status, consumption of alcohol, consumption of fruit and vegetables, season, wear time	OR=1.35 (1.25, 1.47)	p(calc) <0.001
Ortlieb, 2014[48]	Activity counts (#/day) high vs low	HAQ-DI	Inability yes vs no	Unadjusted	Wilcoxon's test=n/r; p≤0.05	p(calc) <0.001
	MVPA (% time) high vs low	HAQ-DI	Inability yes vs no	Age, sex	OR=0.99 (0.99, 1.00)	p(calc) <0.001
	LPA (% time) high vs low	HAQ-DI	Inability yes vs no	Age, sex	OR=0.86 (0.76, 0.99)	p(calc) =0.025
	SB (% time) high vs low	HAQ-DI	Inability yes vs no	Age, sex	OR=1.74 (1.10, 2.75)	p(calc) =0.018

Pes, 2017[49]	Steps (#/day)	Custom questionnaire	Score {0 to 6}	Unadjusted	M: Spearman's Rho=0.027; F: Spearman's Rho=0.329	p(calc) =0.894; p (calc)=0.197
	EE (kcal/day)	Custom questionnaire	Score {0 to 6}	Unadjusted	M: Spearman's Rho=0.272; F: Spearman's Rho=0.421	p(calc) =0.170; p (calc)=0.092
Portegijs, 2019[50]	TPA (min/day)	Custom questionnaire	Inability yes	Age, sex	**Partial R=−0.07	p(calc) =0.124
	MVPA (min/day)	Custom questionnaire	Inability yes	Age, sex	**Partial R=−0.11	p(calc) =0.021
Sardinha, 2015[51]	MVPA meet vs do not meet guidelines	CPF scale	Inability yes vs no	Age, sex, BMI	OR=1.52 (0.53, 5.52)	p(calc) =0.493
	SB break rate (#/sedentary hour)	CPF scale	Inability yes vs no	Age, sex, BMI	OR=6.12 (2.93, 12.78)	p(calc) <0.001
Shah, 2012[52]	Activity counts (#/day x10^5)	Katz Index	Baseline: inability yes vs no	Age, sex, education	HR=0.55 (0.47, 0.65)	p(calc) <0.001
			FU: Inability onset yes vs no	Age, sex, education	HR=0.75 (0.66, 0.84)	p(calc) <0.001

(*Continued*)

Table 6 (Continued).

Author, Year (Ref.)	**PA/SB Measure(s)**	**ADL/IADL**		**Adjustment Model**	**Effect Size (95% Confidence Interval)**	**p-value Used in Data Syntheses***
		Assessment Tool	**Definition/ Unit**			
Steeves, 2019[54]	Steps (#/day)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p=n/r	p(calc) =0.308
	Activity counts (#/min)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p<0.001	p(calc) <0.001
	MVPA (% time)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p<0.001	p(calc) <0.001
	LPA (% time)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p<0.001	p(calc) <0.001
	BST (#/day)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p=n/r	p(calc) <0.010
	SB (% time)	Custom questionnaire	Inability yes vs no	Age, sex, BMI, wear time	**ANOVA=n/r; p<0.001	p(calc) <0.001
Walker, 2008[55]	Activity counts (#/day x10^3)	NEADL scale	Score {0 to 22}	Unadjusted	Pearson's R=0.28 (−0.07, 0.57)	p=0.113
	TPA (% time)	NEADL scale	Score {0 to 22}	Unadjusted	Pearson's R=0.28 (−0.07, 0.57)	p=0.119
IADL						

Cawthon, 2013[30]	EE (kcal/day)	Custom questionnaire	Inability yes vs no	Baseline: unadjusted	ANOVA=n/r; p<0.001	p(calc) <0.001
				FU: age, clinical center, season activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-reported health, # of chronic conditions, cognition	OR=1.61 (1.30, 2.00)	p(calc) <0.001
	MVPA (min/day)	Custom questionnaire	Inability yes vs no	Baseline: unadjusted	ANOVA=n/r; p<0.001	p(calc) <0.001
				FU: age, clinical center, season activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-reported health, # of chronic conditions, cognition	OR=1.47 (1.22, 1.78)	p(calc) <0.001
	LPA (min/day)	Custom questionnaire	Inability yes vs no	Baseline: unadjusted	ANOVA=n/r; p<0.001	p(calc) <0.001
				FU: age, clinical center, season activity measurement, % body fat, race, depressive symptoms, weight, marital status, self-reported health, # of chronic conditions, cognition	OR=1.20 (1.03, 1.40)	p(calc) =0.020
Chen, 2016[31]	MVPA (min/day)	TMIG-IC	Inability yes vs no	Unadjusted	T-test=n/r; p<0.0001	p(calc) <0.001
	BST (#/day)	TMIG-IC	Inability yes vs no	Age, sex	OR=1.53 (1.25, 1.87)	p(calc) =0.001
	SB (min/day)	TMIG-IC	Inability yes vs no	Age, sex	OR=0.74 (0.62, 0.89)	p(calc) <0.001
Chipperfield, 2008[32]	Activity counts (#/min)	Custom questionnaire	Score {0 to 22}	Age, annual income, living arrangements, health	**M: β=0.14 B=13.76 (SE=12.40); **F: β=0.14 B=15.59 (SE=10.92)	p(calc) =0.270; p (calc)=0.154

(*Continued*)

Table 6 (Continued).

Author, Year (Ref.)	PA/SB Measure(s)	ADL/IADL		Adjustment Model	Effect Size (95% Confidence Interval)	p-value Used in Data Syntheses*
		Assessment Tool	Definition/ Unit			
Dunlop, 2014[33]	MVPA (min/day) quartiles	Custom questionnaire	Inability yes vs no	Age, sex, race/ethnicity, education, income, comorbidity, depression score, BMI category, current smoking, knee OA severity, knee pain/symptoms/injury, other lower extremity joint pain, gait speed	Inability onset: Q4 vs Q1, OR=0.34 (0.18, 0.62); progression: Q4 vs Q1, OR=0.36 (0.20, 0.65)	—; p(calc) for trend<0.001
	LPA (min/day) quartiles	Custom questionnaire	Inability yes vs no	Age, sex, race/ethnicity, education, income, comorbidity, depression score, BMI category, current smoking, knee OA severity, knee pain/symptoms/injury, other lower extremity joint pain, gait speed	Inability onset: Q4 vs Q1, OR=0.58 (0.36, 0.92); progression: Q4 vs Q1, OR=0.53 (0.34, 0.83)	—; p(calc) for trend=0.005
Dunn, 2016[36]	Steps (#/day)	Rosow Breslau	Score {0 to 3}	Unadjusted	Spearman's Rho=0.531	p(calc) <0.001
	EE (kcal/day)	Rosow Breslau	Score {0 to 3}	Unadjusted	Spearman's Rho=0.138	p=0.32
	MVPA (% time)	Rosow Breslau	Score {0 to 3}	Unadjusted	Spearman's Rho=0.239	p=0.09
	SB (% time)	Rosow Breslau	Score {0 to 3}	Unadjusted	Spearman's Rho=−0.159	p=0.26
Gothe, 2020[39]	MVPA (min/day)	LLFDI function component	Score {15 to 75}	Age, time since stroke	β=0.05 (n/r); p>0.05	p(n/r)≥0.25
	LPA (min/day)	LLFDI function component	Score {15 to 75}	Age, time since stroke	β=0.52 (n/r); p>0.05	p(n/r)≥0.25
	SB (min/day)	LLFDI function component	Score {15 to 75}	Age, time since stroke	Partial R=−0.211	p=0.301
Hall, 2010[40]	Steps active vs inactive	LLFDI function component	Score {15 to 75}	Age	**ANOVA F=6.96	p=0.01

Hornyak, 2013[41]	Activity counts (#/day)	LLFDI function component	Score {0 to 100}	Age, sex	**β=0.45 (n/r); p<0.001	p(n/r) <0.001
Huisingh-Scheetz, 2016[42]	Activity counts (#/15-sec epoch)	Custom questionnaire	Inability yes vs no	Age, sex, education, race, ethnicity, household assets, BMI categories, timed gait, cognition, employment status, wear time	OR=0.88 (n/r)	p=0.02
	SB (% time)	Custom questionnaire	Inability yes vs no	Age, sex, education, race, ethnicity, household assets, BMI categories, timed gait, cognition, employment status, wear time	OR=1.16 (n/r)	p=0.16
Kerr, 2012[45]	MVPA active vs inactive	LLFDI function component	Score {9 to 45}	Age, sex	ANOVA F=10.4	p=0.002
Marques, 2014[46]	TPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	p(calc) <0.001
	VPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	—
	MVPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	OR=1.432 (1.211, 1.694)	p(calc) <0.001
	MPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	—
	LPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	OR=1.013 (1.008, 1.018)	p(calc) <0.001
	SB (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	Spearman's Rho=−0.178	p(calc) <0.001

(*Continued*)

Table 6 (Continued).

Author, Year (Ref.)	PA/SB Measure(s)	ADL/IADL		Adjustment Model	Effect Size (95% Confidence Interval)	p-value Used in Data Syntheses*
		Assessment Tool	Definition/ Unit			
Sardinha, 2015[51]	MVPA meet vs do not meet guidelines	CPF scale	Inability yes vs no	Age, sex, BMI	OR=0.83 (0.42, 1.61)	"Marques, 2014"
	LPA (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	"Marques, 2014"
	SB break rate (#/day) with ≤7 breaks as reference	CPF scale	Inability yes vs no	Age, sex, BMI	OR=1.46 (0.83, 2.58)	p(calc) =0.192
	BST (#/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	p(calc) <0.001
	SB (min/day)	CPF scale	Risk of inability high vs low	Unadjusted	T-test=n/r; p<0.05	"Marques, 2014"
Song, 2017[53]	MVPA remained inactive vs more active (insufficiently active; met PA guidelines)	LLDI limitation component	Δ from baseline {0 to 100}	Age, sex, live alone, race, education, income, BMI, comorbidity, high depressive symptoms, smoking, Kellgren and Lawrence grade, pain score (WOMAC), knee symptoms/pain/injury, other lower extremity pain, LLDI disability score at baseline	More active (met PA guidelines: B=10.2 (4.5, 15.8); insufficiently active: B=2.6 (0.3, 4.8) vs remained inactive; p-trend<0.001	p(calc) for trend <0.001

Notes: Continuous scores of activities of daily living and instrumental activities of daily living are presented as {range}. p(calc): calculated p-value. —Denotes that associations were not included in data syntheses as these associations were already represented. "Author, year" in "p-values used in data syntheses" table refers to the article of which data were combined based on hierarchy of adjustment described in the method section. *p-values used in data syntheses (effect direction heat maps and/or albatross plots) are presented as reported p-value in the article, calculated p-value, p(calc), or conservatively estimated, p(n/r). **Effect sizes should be interpreted with activities of daily living or instrumental activities of daily living as independent variable and measures of physical activity or sedentary behavior as dependent variable.

Abbreviations: PA, physical activity; SB, sedentary behavior; ADL, activities of daily living; IADL, instrumental activities of daily living; MVPA, moderate to vigorous physical activity; EE, energy expenditure; BST, breaks in sedentary time; LPA, light physical activity; TPA, total physical activity; VPA, vigorous physical activity; MPA, moderate physical activity; Δ, change; #, number; min/day, minutes per day; m/s^2, meters per second squared; mg, milligal; kcal/day, kilocalories per day; #/day, number per day; % time, percentage of time; WOMAC, Western Ontario and McMaster Universities osteoarthritis index; LCADL, London Chest Activities of Daily Living; PDQ-39, Parkinson's Disease questionnaire; KOOS, knee injury and osteoarthritis outcome score; HAQ-DI, Health Assessment Questionnaire Disability Index; CPF, Composite Physical Function; NEADL, Nottingham Extended Activities of Daily Living; TMIG-IC, Instrumental Self-Maintenance or the Tokyo Metropolitan Institute of Gerontology Index of Competence; LLFDI, Late-Life Function and Disability Index; LLDI, Late-Life Disability Index.

as measuring ADL and/or IADL, in contrast to the liberal use of keywords related to these daily-life activities throughout the literature. Despite the important advantages of measuring PA and SB objectively, accelerometers and pedometers are limited in their ability to capture loading or resistance during PA, which represents a limitation to fully characterizing PA. Our strategy in making a hierarchy of adjusted covariates to address confounding by age and sex may have suppressed the true relationship between PA and SB with ADL or IADL due to over-adjustment. While we aim to include associations only adjusted for age and sex, in some studies the closest available model includes adjustments for a range of variables beyond age and sex that may have interfered in the causal pathway, which would therefore represent over-adjustment and lower effect sizes. In all studies, except for one study that included performance-based measures of ADL,[45] the ability to perform ADL and IADL was assessed by self-report of the participants themselves. Such a subjective approach in assessing ADL and IADL may lead to biases, including individual differences in self-perceived difficulty or ability to perform ADL or IADL and therefore presents a limitation. However, the ability to accurately self-assess ADL and IADL is likely easier than PA or SB given that the activities assessed are familiar and finite. Methodological challenges were also encountered in PA/SB measures due to large variability in units, definitions, and statistical analyses used to examine the association of interest. This limitation has precluded us from performing a meta-analysis and led to alternative methods to synthesize our results.

Conclusion

Higher PA and lower SB are significantly associated with better ADL and IADL in community-dwelling older adults. Future research should, based on older adults' ability to function in daily life, aim to establish the optimal dose of PA to prevent development and progression of dependence in ADL and IADL, as well as investigating if higher PA and lower SB can recover loss of independence in one or more activities to, ultimately, design attainable lifestyle guidelines for older adults.

Acknowledgments

We sincerely thank René Otten (RO), the Vrije Universiteit librarian, for assisting the literature search of the systematic review and Luke D'Andrea (LD), Eva van der Rijt (EvdR), Alec Tolley, and Waner Zhou (WZ) for their fruitful discussion.

Funding

This work was supported by European Union's Horizon 2020 research (No. 675003); and innovation programme (No. 689238).

Disclosure

The authors report no conflicts of interest in this work.

References

1. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*. 1985;100(2):126–131.
2. Vogel T, Brechat PH, Lepretre PM, Kaltenbach G, Berthel M, Lonsdorfer J. Health benefits of physical activity in older patients: a review. *Int J Clin Pract*. 2009;63(2):303–320.
3. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012; 380(9838):247–257.
4. Gomes M, Figueiredo D, Teixeira L, et al. Physical inactivity among older adults across Europe based on the SHARE database. *Age Ageing*. 2017;46(1):71–77.
5. Milanovic Z, Pantelic S, Trajkovic N, Sporis G, Kostic R, James N. Age-related decrease in physical activity and functional fitness among elderly men and women. *Clin Interv Aging*. 2013;8:549–556.
6. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75.
7. van der Ploeg HP, Hillsdon M. Is sedentary behaviour just physical inactivity by another name? *Int J Behav Nutr Phys Act*. 2017;14 (1):142.
8. Bowden Davies KA, Pickles S, Sprung VS, et al. Reduced physical activity in young and older adults: metabolic and musculoskeletal implications. *Ther Adv Endocrinol Metab*. 2019;10:2042018819888824.
9. Santos DA, Silva AM, Baptista F, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Exp Gerontol*. 2012;47(12):908–912.
10. Wheeler MJ, Dempsey PC, Grace MS, et al. Sedentary behavior as a risk factor for cognitive decline? A focus on the influence of glycemic control in brain health. *Alzheimers Dement*. 2017;3(3):291–300.
11. Millan-Calenti JC, Tubio J, Pita-Fernandez S, et al. Prevalence of functional disability in activities of daily living (ADL), instrumental activities of daily living (IADL) and associated factors, as predictors of morbidity and mortality. *Arch Gerontol Geriatr*. 2010;50(3):306–310.
12. Paterson DH, Warburton DE. Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *Int J Behav Nutr Phys Act*. 2010;7:38.
13. Tak E, Kuiper R, Chorus A, Hopman-Rock M. Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. *Ageing Res Rev*. 2013;12(1):329–338.
14. Scher LML, Guarda F, Barros MG, Chen Z, Anton S. Sedentary time and disability in older adults: a systematic review and meta-analysis. *J Aging Sci*. 2019;7:1–9.
15. Ryan DJ, Wullems JA, Stebbings GK, Morse CI, Stewart CE, Onambele-Pearson GL. Reliability and validity of the international physical activity questionnaire compared to calibrated accelerometer cut-off points in the quantification of sedentary behaviour and physical activity in older adults. *PLoS One*. 2018;13(4):e0195712.

16. Tudor-Locke CE, Myers AM. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Med*. 2001;31(2):91–100.
17. Silfee VJ, Haughton CF, Jake-Schoffman DE, et al. Objective measurement of physical activity outcomes in lifestyle interventions among adults: a systematic review. *Prev Med Rep*. 2018;11:74–80.
18. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med*. 2009;151(4):264–269, W264.
19. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5(1):210.
20. Wells G, Shea B, O'Connell D, et al. The Newcastle–Ottawa Scale (NOS) for assessing the quality of non-randomized studies in meta-analysis. *Ottawa Hosp Res Inst*. 2000.
21. Thomson HJ, Thomas S. The effect direction plot: visual display of non-standardised effects across multiple outcome domains. *Res Synth Methods*. 2013;4(1):95–101.
22. Harrison S, Jones HE, Martin RM, Lewis SJ, Higgins JPT. The albatross plot: a novel graphical tool for presenting results of diversely reported studies in a systematic review. *Res Synth Methods*. 2017;8(3):281–289.
23. Campbell M, McKenzie JE, Sowden A, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. *BMJ*. 2020;368:l6890.
24. Altman DG, Bland JM. How to obtain the P value from a confidence interval. *BMJ*. 2011;343:d2304.
25. Ramsey KA, Rojer AGM, D'Andrea L, et al. The association of objectively measured physical activity and sedentary behavior with skeletal muscle strength and muscle power in older adults: a systematic review and meta-analysis. *Ageing Res Rev*. 2021;101266.
26. Kingston A, Collerton J, Davies K, Bond J, Robinson L, Jagger C. Losing the ability in activities of daily living in the oldest old: a hierarchic disability scale from the Newcastle 85+ study. *PLoS One*. 2012;7(2):e31665.
27. Balogun S, Scott D, Cicuttini F, Jones G, Aitken D. Longitudinal study of the relationship between physical activity and knee pain and functional limitation in community-dwelling older adults. *Arch Gerontol Geriatr*. 2020;90:104101.
28. Barriga S, Rodrigues F, Barbara C. Factors that influence physical activity in the daily life of male patients with chronic obstructive pulmonary disease. *Rev Port Pneumol*. 2014;20(3):131–137.
29. Bielemann RM, LaCroix AZ, Bertoldi AD, et al. Objectively measured physical activity reduces the risk of mortality among Brazilian older adults. *J Am Geriatr Soc*. 2020;68(1):137–146.
30. Blodgett J, Theou O, Kirkland S, Andreou P, Rockwood K. The association between sedentary behaviour, moderate-vigorous physical activity and frailty in NHANES cohorts. *Maturitas*. 2015;80(2):187–191.
31. Cawthon PM, Blackwell TL, Cauley JA, et al. Objective assessment of activity, energy expenditure, and functional limitations in older men: the Osteoporotic Fractures in Men study. *J Gerontol a Biol Sci Med Sci*. 2013;68(12):1518–1524.
32. Chen T, Narazaki K, Haeuchi Y, Chen S, Honda T, Kumagai S. Associations of sedentary time and breaks in sedentary time with disability in instrumental activities of daily living in community-Dwelling older adults. *J Phys Act Health*. 2016;13(3):303–309.
33. Chipperfield JG, Newall NE, Chuchmach LP, Swift AU, Haynes TL. Differential determinants of men's and women's everyday physical activity in later life. *J Gerontol B Psychol Sci Soc Sci*. 2008;63(4):S211–S218.
34. Dunlop DD, Song J, Semanik PA, et al. Relation of physical activity time to incident disability in community dwelling adults with or at risk of knee arthritis: prospective cohort study. *BMJ*. 2014;348:g2472.
35. Dunlop DD, Song J, Arnston EK, et al. Sedentary time in US older adults associated with disability in activities of daily living independent of physical activity. *J Phys Act Health*. 2015;12(1):93–101.
36. Dunlop DD, Song J, Hootman JM, et al. One hour a week: moving to prevent disability in adults with lower extremity joint symptoms. *Am J Prev Med*. 2019;56(5):664–672.
37. Dunn MA, Josbeno DA, Schmotzer AR, et al. The gap between clinically assessed physical performance and objective physical activity in liver transplant candidates. *Liver Transpl*. 2016;22(10):1324–1332.
38. Ellingson LD, Zaman A, Stegemoller EL. Sedentary behavior and quality of life in individuals with Parkinson's disease. *Neurorehabil Neural Repair*. 2019;33(8):595–601.
39. Furlanetto KC, Pinto IF, Sant'Anna T, Hernandes NA, Pitta F. Profile of patients with chronic obstructive pulmonary disease classified as physically active and inactive according to different thresholds of physical activity in daily life. *Braz J Phys Ther*. 2016;20(6):517–524.
40. Gothe NP, Bourbeau K. Associations between physical activity intensities and physical function in stroke survivors. *Am J Phys Med Rehabil*. 2020;99(8):733–738.
41. Hall KS, McAuley E. Individual, social environmental and physical environmental barriers to achieving 10 000 steps per day among older women. *Health Educ Res*. 2010;25(3):478–488.
42. Hornyak V, Brach JS, Wert DM, Hile E, Studenski S, VanSwearingen JM. What is the relation between fear of falling and physical activity in older adults? *Arch Phys Med Rehabil*. 2013;94(12):2529–2534.
43. Huisingh-Scheetz MJ, Kocherginsky M, Magett E, Rush P, Dale W, Waite L. Relating wrist accelerometry measures to disability in older adults. *Arch Gerontol Geriatr*. 2016;62:68–74.
44. Jeong JN, Kim SH, Park KN. Relationship between objectively measured lifestyle factors and health factors in patients with knee osteoarthritis: the STROBE Study. *Medicine*. 2019;98(26):e16060.
45. Karloh M, Araujo CL, Gulart AA, Reis CM, Steidle LJ, Mayer AF. The Glittre-ADL test reflects functional performance measured by physical activities of daily living in patients with chronic obstructive pulmonary disease. *Braz J Phys Ther*. 2016;20(3):223–230.
46. Kerr J, Marshall S, Godbole S, et al. The relationship between outdoor activity and health in older adults using GPS. *Int J Environ Res Public Health*. 2012;9(12):4615–4625.
47. Marques EA, Baptista F, Santos DA, Silva AM, Mota J, Sardinha LB. Risk for losing physical independence in older adults: the role of sedentary time, light, and moderate to vigorous physical activity. *Maturitas*. 2014;79(1):91–95.
48. Menai M, van Hees VT, Elbaz A, Kivimaki M, Singh-Manoux A, Sabia S. Accelerometer assessed moderate-to-vigorous physical activity and successful ageing: results from the Whitehall II study. *Sci Rep*. 2017;8:45772.
49. Ortlieb S, Gorzelniak L, Nowak D, et al. Associations between multiple accelerometry-assessed physical activity parameters and selected health outcomes in elderly people–results from the KORA-age study. *PLoS One*. 2014;9(11):e111206.
50. Pes GM, Dore MP, Errigo A, Poulain M. Analysis of physical activity among free-living nonagenarians from a Sardinian longevous population. *J Aging Phys Act*. 2018;26(2):254–258.
51. Portegijs E, Karavirta L, Saajanaho M, Rantalainen T, Rantanen T. Assessing physical performance and physical activity in large population-based aging studies: home-based assessments or visits to the research center? *BMC Public Health*. 2019;19(1):1570.
52. Sardinha LB, Ekelund U, Dos Santos L, Cyrino ES, Silva AM, Santos DA. Breaking-up sedentary time is associated with impairment in activities of daily living. *Exp Gerontol*. 2015;72:57–62.
53. Shah RC, Buchman AS, Leurgans S, Boyle PA, Bennett DA. Association of total daily physical activity with disability in community-dwelling older persons: a prospective cohort study. *BMC Geriatr*. 2012;12:63.
54. Song J, Gilbert AL, Chang RW, et al. Do inactive older adults who increase physical activity experience less disability: evidence from the osteoarthritis initiative. *J Clin Rheumatol*. 2017;23(1):26–32.

55. Steeves JA, Shiroma EJ, Conger SA, Van Domelen D, Harris TB. Physical activity patterns and multimorbidity burden of older adults with different levels of functional status: NHANES 2003-2006. *Disabil Health J*. 2019;12(3):495–502.
56. Walker PP, Burnett A, Flavahan PW, Calverley PM. Lower limb activity and its determinants in COPD. *Thorax*. 2008;63(8):683–689.
57. Lee PG, Jackson EA, Richardson CR. Exercise prescriptions in older adults. *Am Fam Physician*. 2017;95(7):425–432.
58. Zhang Y, Zhang Y, Du S, Wang Q, Xia H, Sun R. Exercise interventions for improving physical function, daily living activities and quality of life in community-dwelling frail older adults: a systematic review and meta-analysis of randomized controlled trials. *Geriatr Nurs*. 2020;41(3):261–273.
59. Boyle PA, Cohen RA, Paul R, Moser D, Gordon N. Cognitive and motor impairments predict functional declines in patients with vascular dementia. *Int J Geriatr Psychiatry.* 2002;17(2):164–169.
60. Sanchez-Garcia S, Garcia-Pena C, Ramirez-Garcia E, Moreno-Tamayo K, Cantu-Quintanilla GR. Decreased autonomy in community-Dwelling older adults. *Clin Interv Aging*. 2019;14:2041–2053.
61. Stamm TA, Pieber K, Crevenna R, Dorner TE. Impairment in the activities of daily living in older adults with and without osteoporosis, osteoarthritis and chronic back pain: a secondary analysis of population-based health survey data. *BMC Musculoskelet Disord*. 2016;17:139.
62. Luppa M, Luck T, Weyerer S, Konig HH, Brahler E, Riedel-Heller SG. Prediction of institutionalization in the elderly. A systematic review. *Age Ageing*. 2010;39(1):31–38.
63. van Lummel RC, Walgaard S, Pijnappels M, et al. Physical performance and physical activity in older adults: associated but separate domains of physical function in old age. *PLoS One*. 2015;10(12): e0144048.
64. Garcia-Esquinas E, Ortola R, Martinez-Gomez D, et al. Causal effects of physical activity and sedentary behaviour on health deficits accumulation in older adults. *Int J Epidemiol*. 2020;30:852–865.
65. Washburn RA. Assessment of physical activity in older adults. *Res Q Exerc Sport*. 2000;71(Suppl 2):79–87.