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Meta-analysis

Sedentary behavior, physical inactivity, abdominal obesity and obesity in adults and older adults: A systematic review and meta-analysis

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S U M M A R Y

Background: Sedentary behavior and physical inactivity may increase the risk of obesity. This systematic review and meta-analysis aimed to investigate: i) the prevalence/incidence of sedentary behavior and physical inactivity, ii) the association of sedentary behavior and physical inactivity with obesity, and iii) the objective and subjective measures, diagnostic criteria, and cut-off points to estimate sedentary behavior and physical inactivity in adults and older adults with obesity.

Methods: We conducted a systematic review and meta-analysis in PubMed, Scielo, Lilacs, and Cochrane Library databases. A meta-analysis of a random-effects model was performed to estimate the combined prevalence of sedentary behavior and physical inactivity and their association with obesity.

Results: Twenty-three studies involving 638,000 adults and older adults were included in the systematic review. A meta-analysis was conducted with 111,851 individuals with obesity. The combined prevalence of sedentary behavior was 31% (95% CI, 23–41%), and physical inactivity was 43% (95% CI, 31–55%). Significant associations between obesity and sedentary behavior (OR 1.45, 95% CI, 1.21–1.75) and physical inactivity (OR 1.52, 95% CI, 1.23–1.87) were found. Nine studies have used objective measures to assess physical activity levels, such as accelerometers and pedometers, whereas fourteen applied subjective methods and self-reported questionnaires.

Conclusions: As expected, we found elevated rates of sedentary behavior and physical inactivity in individuals with obesity and a positive risk association. The wide range of objective and subjective measures, methods and cut-offs resulted in great variations of physical inactivity and sedentary behavior estimates.

Trial registration: PROSPERO (CRD42016037747).

1. Introduction

Obesity is a chronic disease that affects people of all ages and socioeconomic groups, independent of the income level of the country [1–3]. Globally, obesity is a public health concern that affects around 30% of adults, and it is projected to rise to 33% by 2030 [4,5]. For severe obesity, the estimates are even more concerning, with an expected increase of 130% worldwide [4]. These projections highlight the global pandemic nature of obesity and its significance

Abbreviations: PI, Physical Inactivity; SB, Sedentary Behavior; BMD - Body Mass Index, PRISMA; Preferred Reporting Items for Systematic Reviews and Meta-analyses, WC; Waist Circumference, MVPA; Moderate to Vigorous Physical Activity, METs; Metabolic Equivalent, NOS; Newcastle, Ottawa Scale; CI, Confidence Interval; IPAQ, International Physical Activity Questionnaire; GPAQ, Global Physical Activity Questionnaire.

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to public health [1,2,6–8]. The high prevalence of obesity is associated with physical inactivity (PI) and sedentary behavior (SB) [9,10]. Obesity, SB, and PI are associated with an increased risk of several chronic diseases, including heart disease, chronic obstructive pulmonary disease, diabetes, hypertension, osteoporosis, depression, and several types of cancers [8,11–17].

The effects of PI and SB on body mass index (BMI) have been analyzed previously [15,18–21]. However, the relationship between the occurrence (incidence or prevalence) of sedentary lifestyle and PI in adults and older adults with obesity, the strength of this association, and which methods and respective cut-off points to measure it remains unclear. Although several studies have been carried out to investigate the prevalence and association between physical activity level and obesity among children [17,22–24], studies with adults and older adults were not found. A systematic review and meta-analysis performed with adults indicated small, inconsistent, and non-significant associations between sedentary behavior and body weight [22]. However, systematic reviews investigating this type of association in adults and older adults with BMI greater than 30 kg/m^2 were not identified.

A systematic review of the literature and meta-analysis could help to understand the occurrence, assessment methods, and association of SB and PI with obesity in adults and older adults. Furthermore, such a review may support health promotion policies to improve physical activity levels in individuals with obesity, enhance the knowledge of the impact of SB and PI, and, ultimately, what aspects future studies should focus on. It is also important to investigate the objective and subjective measures used to classify PI and SB, as each measure has its inherent strengths and weaknesses [14,18,25].

Therefore, the objectives of this systematic review and meta-analysis were to evaluate in adults and older adults with obesity: (1) the prevalence and/or incidence of SB and PI, (2) their association with obesity, and (3) the various assessment methods applied i.e. objective or subjective, diagnostic criteria and cut-off points used.

2. Methods

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement guidelines [26] and was registered in PROSPERO (protocol number: CRD42016037747) [27].

2.1. Search strategy

An independent search was performed, without language restrictions, in PubMed, Scielo, Lilacs, and Cochrane Library databases in June 2021 by two researchers (CRM and MN). The PubMed search terms were "(Obesity [MeSH Terms] OR Obesity, morbid [MeSH Terms) AND (physical activity questionnaires OR exercise test OR motion sensors OR heart rate monitors OR doubly labeled water (DLW) OR accelerometers OR pedometers) AND (Motor Activity [MeSH Terms] OR Physical Activity OR Physical inactivity OR Leisure-Time Physical Activity) OR (Sedentary behavior [MeSH Terms] OR Sedentary OR Sedentary behavior) AND (older OR adults) AND (prevalence OR incidence)". The activated filters were as follows: a publication date from 2000/01/01 to 2021/06/27 and conducted in humans. For the other databases, we have adjusted the search in accordance with their specific characteristics.

2.2. Eligibility criteria

The inclusion criteria for selection of articles were as follows: (1) being conducted in adults and older adults; (2) obesity, defined as a BMI $\geq$30 kg/m^2 or abdominal obesity determined by waist circumference (WC) greater than 102 cm in men and 88 cm in women [28]; (3) cross-sectional studies, surveys, and cohort studies, or prevalence and incidence results of PI, and PI included in clinical trials of baseline data and (4) SB and PI assessment by objective measures (pedometer, accelerometer, heart rate monitors, direct or indirect calorimetry, doubly labeled water method, stress test) or subjective, self-report instruments (such as culturally validated questionnaires).

We excluded studies that included pregnant or nursing women, hospitalized patients, disabled people, amputees, patients with chronic obstructive pulmonary disease, osteoarthritis, and cancer, and those with incomplete data, review articles, and other outcomes with BMI <30 kg/m^2.

2.3. Definitions

PI was defined as an insufficient amount of moderate to vigorous physical activity (MVPA) (i.e. failure to meet specific guidelines for physical activity) [29].

SB refers to any behavior characterized by a low energy expenditure or energy expenditure of $\leq$1.5 metabolic equivalents (METs) while sitting or lying down [29,30].

2.4. Study selection and data extraction

All duplicate articles were removed. Titles and abstracts were reviewed independently by two reviewers (CRM and LPSR), and only potentially eligible articles were read in full. Data were extracted and filed, and disagreements were resolved by third and fourth reviewers (EAS and MN). The references section of the included articles was checked to identify other relevant studies not identified by the electronic search databases.

For data extraction, we prepared a table with the following parameters: identification (authors and year of publication and data collection country), study design (target population and age group, type of study, and sample size), methodological aspects or diagnostic criteria (obesity diagnosis, physical activity evaluation, and diagnostic criteria or cut-off points for SB/PI). When relevant data were not available in the manuscript, a researcher (CRM) contacted the authors directly to fill in gaps.

To evaluate the quality of the included cohort studies, the Newcastle–Ottawa Scale (NOS) was applied. The NOS uses the star system to judge the following: study group selection, comparability of groups, and the exposure or outcome assessment (from zero stars for "high risk of bias" to a maximum of nine stars for "low risk of bias") [31]. To assess the quality of cross-sectional studies, the adapted NOS scale was used [32].

2.5. Meta-analysis

A Meta-analysis was performed using the R Statistical Software (version 4.1.0), through the package meta. This analysis was conducted in twenty-three studies to estimate the overall prevalence of obesity. As one of our main objectives was to evaluate the prevalence of sedentary lifestyle and physical inactivity in adults and older adults with obesity, we performed a meta-analysis of a random-effects model, grouping studies that used objective and subjective measures of physical activity. In addition, random-effects model meta-analyses were performed to estimate the odds ratios (ORs) for the association between sedentary behavior and physical inactivity in adults and older adults. We transformed relative risks (RRs) or hazard ratios (HRs) into ORs using the formula: $OR = ((1 - p)*RR)/(1 - RR*p)$, where RR is the relative risk, OR is the odds ratio, and p is the control event rate [33]. For studies that reported data stratified by sex, we pooled the results through a fixed-effects model. Our results were graphically displayed in Forest plots, with 95% confidence intervals (CIs). Heterogeneity was assessed using the I^2 statistic. Egger's test was performed to determine the probability of publication bias. We conducted a subgroup analysis according to study design (cross-sectional or longitudinal). Meta-regression analysis was performed to evaluate potential sources of between-study variability, including analysis according to subjective or objective measure of physical activity.

3. Results

3.1. Study selection

Our initial search found 6295 potentially relevant manuscripts. After removing duplicates, 5989 articles were selected for the reading of titles and abstracts, and 165 were selected to be read in full (Fig. 1). The authors of seven studies were contacted by e-mail to recover some missing data on the prevalence of SB and PI [34–40]. Five authors did not respond and were excluded [35,36,38,40,41]. The reasons for exclusions are shown in the Supplementary Table 1. Finally, 23 studies were selected for qualitative analysis (Fig. 2).

3.2. Study characteristics

Of the 23 included studies, five were cohort studies [37,42–45] and 18 were cross-sectional studies [46–63] (Tables 1 and 2). The 23 included studies involved 638,000 adults and older adults, being 111,851 with obesity.

Most studies were performed in developed countries. The studies were carried out in the following countries: the United States [37,45,53,54,57,60,61], Sweden [63], Australia [47,58,64], Europe and the USA [48], the United Kingdom [42,44], Germany [43,62], Brazil [51,56,59], Spain [49,52], Ireland [46], and Uganda [54]. The participants' age ranged between 18 and 92 years. Only three studies evaluated only older adults [43,49,58] and three studies evaluated only women [56,58,60]. Only in one study the sample was composed mainly of individuals with obesity [60].

The methodological quality assessment resulted in 19 studies with an NOS $\geq$ 7, two studies with NOS = 6 [43,57], and two studies with NOS = 5 [44,49] (Supplementary Tables 2 and 3).

3.3. Methods of evaluation of SB and PI

In the 23 studies, the criterion used for defining obesity was BMI $\geq$30.0 kg/m^2. Waist circumference was used to determine obesity, with cut-offs of $\geq$102 cm for men and $\geq$88 cm for women [50].

Fourteen studies used subjective measures to assess PI, and nine studies used an accelerometer or pedometer as an objective measure. The subjective (Table 2) and objective (Table 1) measures used in the various studies are detailed below.

(A) Objective measures

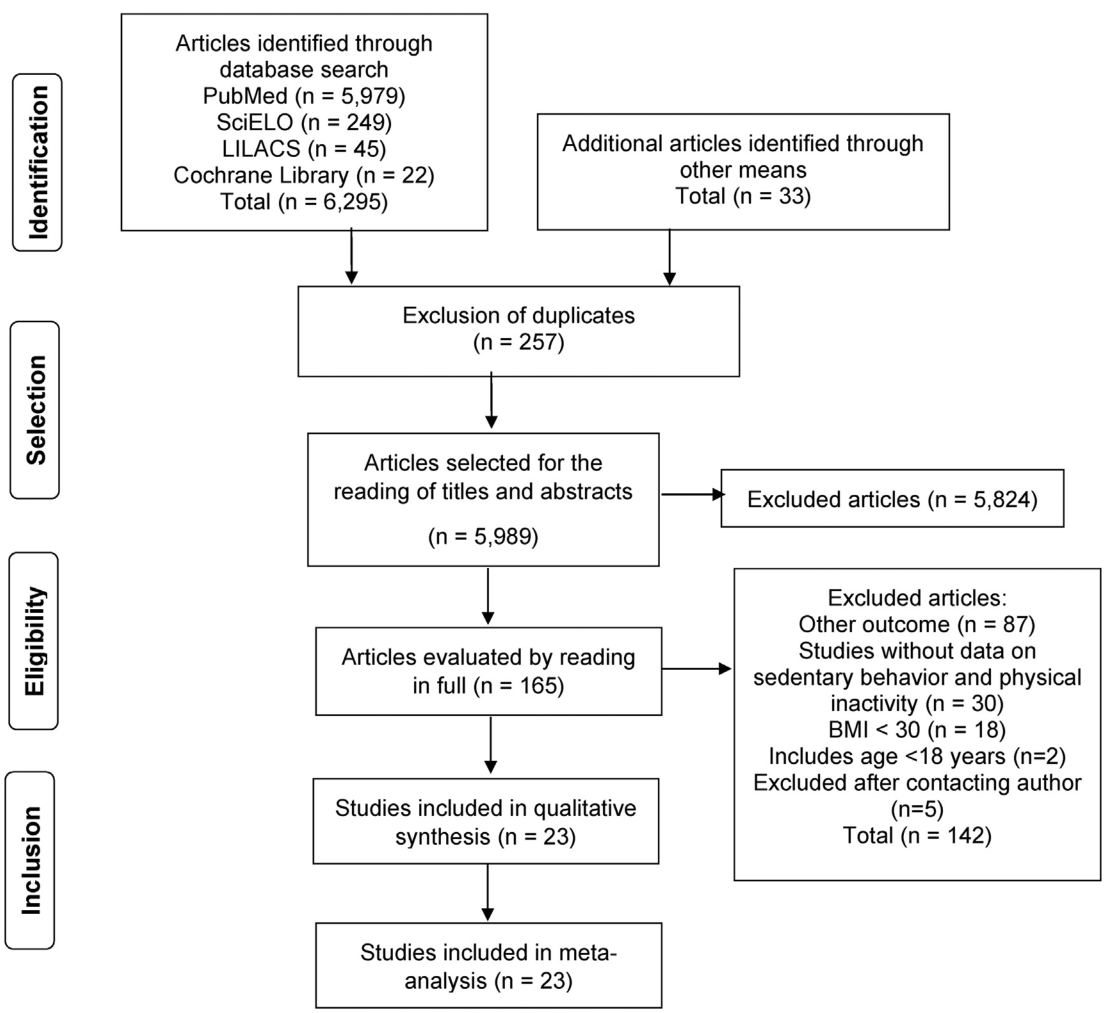

Fig. 1. Study selection flowchart.

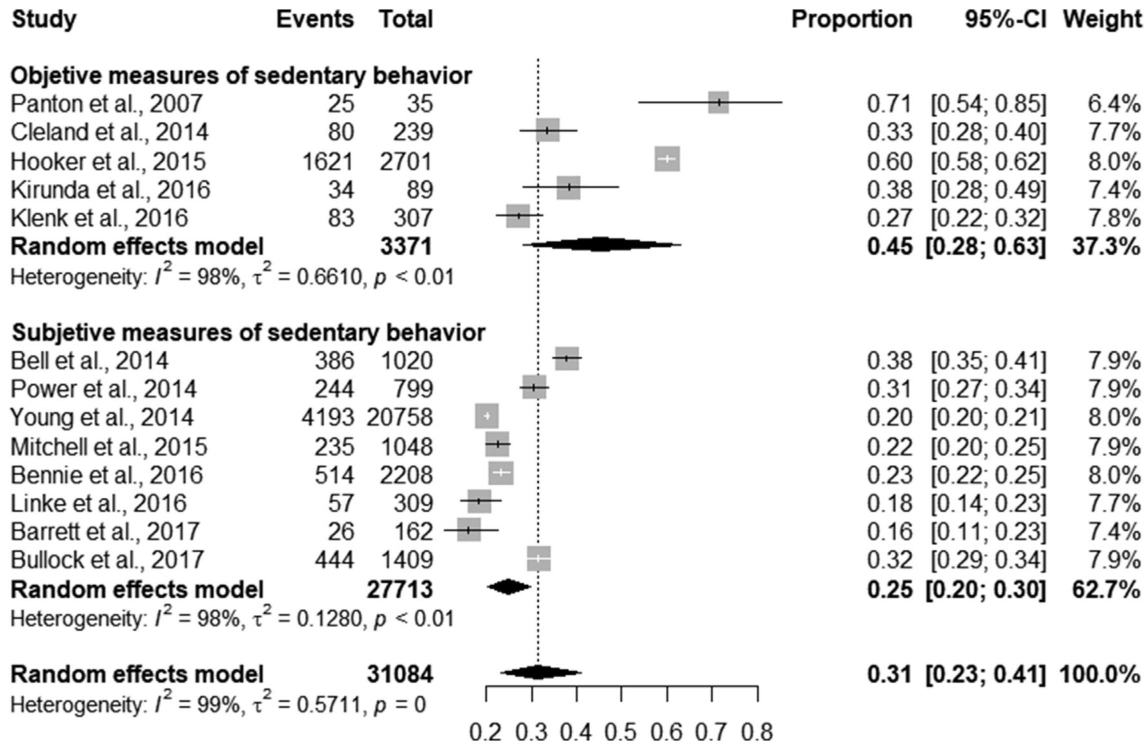

Fig. 2. Forest plot of the combined prevalence of sedentary behavior in individuals with obesity according to data from objective and subjective measures of physical activity.

Of the nine studies [37,43,49,50,53,54,60,61,63] that used objective measures, two studies from the United States used triaxial accelerometers [53,63], one from Portugal used a biaxial accelerometer [49], one study from the United States used an omnidirectional accelerometer [37], and two studies (one from the United States and one from Germany) used a uniaxial accelerometer [43,61]. In addition, three studies utilized pedometers (one study each conducted in the United States [60], Australia [50], and Uganda [54].

Studies that utilized accelerometers did not use standardized cut-off points, and the methods differed between sitting time and counts per minute (cpm) (Table 1). For studies using pedometers, the cut-off point used for sedentary lifestyle was <5000 steps/day [54,60], and the cut-off point for PI was not standardized (i.e., <8555 steps/day for women and <8611 for men [50], and <7500 steps/day for both sexes) [54].

(B) Subjective measures

Validated questionnaires were utilized in the following seven studies: the "Minnesota Leisure Time Physical Activity Questionnaire" in Europe [65]; the International Physical Activity Questionnaire (IPAQ) in Brazil [56,59], Europe and the U.S.A [48], and Ireland [46]; the GPAQ in Germany [62], and the Active Australia Survey in Australia [47]. Seven other studies used self-report structured questionnaires (Table 2). The cut-off points for evaluating PI and SB varied according to each instrument used. For example, the IPAQ Questionnaire considered PI as performing less than 150 min of moderate to vigorous physical activity per week [56,59]. This same questionnaire was also used to define sedentary lifestyle as >8 h of sitting time per day [46,48]. For the Global Physical Activity Questionnaire (GPAQ), PI was defined as <600 MET-minutes/week MVPA [62].

We also identified variation in the cut-off points used for PI among the self-report questionnaires used by different studies. For example, to evaluate PI, two studies used similar cut-offs of <2 h/week [51] and <2.5 h/week [57]. However, a cut-off points of ≤2–3 times/month was also used [44]. Sedentary lifestyle was assessed in four studies. Two used the following cut-off points: ≥5 h of SB per day outside of work [45], one ≥4 h per day watch TV or spend time online [55] and ≥3 h per day for leisure-time [43], while one study [58] used four questions to evaluate sedentary lifestyle.

3.4. Meta-analysis

For the meta-analysis we included 13 studies which analysed SB [43–48,50,53–55,58,60,66] and 15 which analysed PI [37,44,45,47,49,51,52,54,56,57,59,61–63,66].

3.5. Prevalence/incidence of SB and PI

The prevalence of SB ranged from 16.4% to 71.4%, and PI ranged from 2.9% to 81.9%, both being positively associated with obesity (Tables 1 and 2). We found substantial variability in the prevalence of both PI and SB.

The combined prevalence of SB in individuals with obesity was 31% [95% CI, 23–41%]. In studies that used objective measures of physical activity, the prevalence was 45% [95%CI, 28–63%]. On the other hand, in studies that used subjective measures of physical activity assessment, the prevalence of SB was 25% [95% CI, 20–30%] [43–48,50,53–55,58,60,66] (Fig. 2). Meta-regression analysis showed that the method of physical activity measurement was not a mediator for our results ($p = 0.253$).

The combined prevalence of physical inactivity in individuals with obesity was 43% [95% CI, 31–55%]. In studies that used objective measures of physical activity the prevalence of PI was 37% [95% CI, 10–76%] and in studies that used subjective measures the prevalence was 46% [95% CI, 33–60%] [37,44,45,47,49,51,52,54,56,57,59,61–63,66] (Fig. 3). Meta-regression analysis showed that

Table 1
Characteristics of included studies with objective measurement data on physical activity and sedentary behavior.

Identification	Study design			Methodological aspects or diagnostic criteria			Results			
Author/Year/Country	Sample size	Age	Type of study	Definition of obesity	Assessment of physical inactivity (PI) and/or sedentary behavior (SB)	Categorization of PI and SB (cut-off points)	Occurrence of obesity	Occurrence of PI and SB in individuals with obesity	Measure of effect/ association between obesity and PI/SB	NOS
Dohrn et al., 2020 [63] Sweden	656 older adults (64% women)	81–87 or ≥90 years	Cross-sectional, population-based	BMI ≥30 kg/m2	Accelerometer	PI ≤ 150 min	13%	PI: 29%	NA	9
Cabanas-Sánchez et al., 2019 [49] Spain	432	65–92 years	Cross-sectional	BMI ≥30 kg/m2	Accelerometer	SB lie, recline, and passive sit – not meeting PA recommendations	31,94%	SB: 81.90%	NA	5
Moon et al., 2017 [37] U.S.A.	9645	18–74 years	Cohort	BMI ≥30 kg/m2	Accelerometer	SB < 100 counts/min	41,2%	PI: 2.89%	OR (95% CI)SB: 1.10 (1.07–1.13)	9
Kirunda et al., 2016 [54] Uganda	1208	18–92 years	Cross-sectional	BMI ≥30 kg/m2	Pedometer	SB < 5000 stepsPI <7500 steps	7.4%	SB: 38.2%PI: 66.3%	OR (95% CI)SB: 3.6 (2.2–5.7)PI: 2.5 (1.5–4.2)	8
Klenk et al., 2016 [43,53] Germany	1271	≥65 years	Cohort	BMI ≥30 kg/m2	Accelerometer	SBQuartiles of sedentarism (sitting/ lying) duration [min]	24.2%	1° Qt: 14.8%2° Qt: 19.5% 3° Qt: 25.8%4° Qt: 36.8%	NA	9
Hooker et al., 2015 [53] U.S.A.	7967	>45 years	Cross-sectional	BMI ≥30 kg/m2	Accelerometer	SB ≤ 49 cpm	33.9%	SB: 60%	NA	8
Peterson et al., 2014 [61] U.S.A.	5268	>20 years	Cross-sectional	BMI ≥30 kg/m2	Accelerometer	PILow MVPA (minutes) defined by tercile	32.5%	PI: 38.9%	OR (95% CI)PI: Men 4.25 (2.24–8.10)PI: Women 8.08 (5.16–12.65)	7
Panton et al., 2007 [60] U.S.A.	35 women	30–65 years	Cross-sectional	BMI ≥30 kg/m2	Pedometer	SB (<5000 steps/day)	AO	SB: 71.42%	Pearson correlation (r = −0.45, p < 0,05)	7
Cleland et al., 2014 [50] Australia	1662	26–36 years	Cross-sectional	WC ≥ 102 cm (men), ≥88 cm (women)	Pedometer	SBHigh sitting time (>38 h/week for men;>35 for women) PILow step count (<8611 daily steps for men; <8555 for women)	14.4%	High sitting time, low step count:Men 33.75% Women 35.8%	OR (95% CI) MenSitting and steps 2.68 (1.36–5.32) WomenSitting and steps2.66 (1.58–4.49)	9

BMI, body mass index; WC, waist circumference; cpm, counts per minute; MVPA, moderate or vigorous physical activity; SB, sedentary behavior; PI, physical inactivity; NA, not available; OR, odds ratios; AO, all subjects with obesity; * mean ± SD.

Table 2
Characteristics of included studies with subjective measurement data on physical activity and sedentary behavior.

Identification	Study design			Methodological aspects or diagnostic criteria			Results			
Author/Year/ Country	Sample size	Age	Type of study	Definition of obesity	Assessment of physical inactivity (PI) and/or sedentary behavior (SB)	Categorization of PI and SB (cut-off points)	Occurrence of obesity	Occurrence of PI and SB in individuals with obesity	Measure of effect/ association between obesity and PI/SB	NOS
Monteiro et al., 2019 [59] Brazil	2163	20 years or over	Cross-sectional	BMI $\geq$30 kg/m^2	International Physical Activity Questionnaire (IPAQ)	PI (less than 150 min of moderate-intensity physical activity per week or less than 75 min of vigorous-intensity physical activity per week accumulated across work, home, transport or discretionary domains)	4,8%	PI: 45.5%	NA	9
Bullock et al., 2017 [48] Europe and the U.S.A.	5338	18 years or over	Cross-sectional	BMI $\geq$30 kg/m^2	International Physical ActivityQuestionnaire (IPAQ)	SB - Sitting time $\geq$8 h/d	26,4%	SB: 31.5%	OR (95% CI)SB: 1.62 (1.24–2.12)	9
Barrett et al., 2017 [46] Ireland	885	18–69 years	Cross-sectional	BMI $\geq$30 kg/m^2	International Physical Activity Questionnaire (IPAQ)Self-reported	SBSitting time in minutes, >8 h	18.3%	SB: 16.4%	NA	8
Linke et al., 2016 [55]U.S.A.	1050	18 years or older	Cohort	BMI $\geq$30 kg/m^2	Authors' own instrumentInterview	Leisure time sedentary behavior (SB) Screen time was assessed with the question: 'during your free time, about how many hours per day do you watch TV or spend time online?'$\geq$4 h/day	29.4%	SB: 18.3%	NA	9
Bennie et al., 2016 [47] Australia	9435	18–85 years	Cross-sectional	BMI $\geq$30 kg/m^2	Active Australia SurveySelf-reported	PI- MVPA (<150 min/week)SB (ii) high sedentary time ($\geq$480 min/day)	23.4%	PI: 55%SB: 23.3%	OR (95% CI)SB: 1.44 (1.04–1.98)	7
Goday et al., 2016 [52] Spain	451,432	$\geq$18 years	Cross-sectional	BMI $\geq$30 kg/m^2	Authors' own instrument Self-reported	PI < 2 h/week exercise	15.5%	PI: 73,4%	NA	7
Mitchell et al., 2015 [58] Australia	5320	$\geq$65 years	Cross-sectional (Baseline)	BMI $\geq$30 kg/m^2	Authors' own instrumentInterview	SBFour questions: a. Did strength activities on 2 or more occasions in the last week.b. Usually sat more than 8 h per day on weekdays.c. Walked more than 2 h in the last weekd. Has some problems doing usual activities	19.7%	a. 7.0%b. 10.5%c. 41.7%d. 30.4%	NA	8
Totaro Garcia LM et al., 2014 [51] Brazil	45,508	$\geq$18 years	Cross-sectional	BMI $\geq$30 kg/m^2	Authors' own instrumentInterview	PINegative response to the question: "Do you regularly perform some kind of physical activity in your leisure time, such as physical exercise?"	7.9%	Men 47,5% Women66,2%	OR (95% CI)MenPI 1.27 (1.16–1.39) WomenPI 1.33 (1.11–1.58)	8
Bell et al., 2014 [66] England	3670	Average age of 56 years	Cohort	BMI $\geq$30 kg/m^2	Minnesota LeisureTime Physical Activity QuestionnaireSelf-reported	PIModerate-to-vigorous physical activity$\geq$3 MET when $\leq$ 0–1.50 h/ weekSB (leisure time sitting) high, >25 h/week	27.8%	PI: 41.6%SB: 37.8%	OR (95% CI)PI: 1.43SB: 0.99	6
Marcellino et al., 2014 [56] Brazil	790	$\geq$20 years	Cross-sectional	BMI $\geq$30 kg/m^2	International Physical Activity Questionnaire, short form (IPAQ-8)Self-reported	PI $\leq$ 150 min	17.3%	PI: 59.1%	OR (95% CI)PI: 1.30 (1.08–1.52)	7
Power et al., 2014 [44] England	8155	>35 years	Cohort	BMI $\geq$30 kg/m^2.	Authors' own instrument Self-reported	PI $\leq$ 2–3 times/month,SB (leisure-time)$\geq$3 h/day	9.8%	PI: 41.8%SB: 30.5%	NA	5
Young et al., 2014 [45] U.S.A.	77,746	44–69 years	Cohort	BMI $\geq$30 kg/m^2	Authors' own instrumentSelf-reported	PI $\leq$ 470 MET-minutesSB$\geq$5 h a day do you spend watching television, sitting at a computer, or reading hours	26.78%	PI: 41.2%SB: 20.2%	RR (95% CI)PI1.57 (1.36–1.83)SB 1.26 (1.09–1.47)	7
Wallmann-Sperlich et al., 2014 [62] Germany	2248	18–65 years	Cross-sectional	BMI >30 kg/m^2	Global Physical Activity Questionnaire (GPAQ)Self-reported	PI < 600 MET-minutes/week, MVPA	13.4%	PI: 24.6%	NA	7
Mathur et al., 2014 [57] U.S.A.	17,584	$\geq$18 years	Cross-sectional	BMI $\geq$30 kg/m^2	Authors' own instrumentInterview	PI"In the past 7 days, how many hours did you spend doing strenuous exercise?"<2.5 h/week	21.9%	PI: 29.8%	NA	6

BMI, body mass index; MVPA, moderate or vigorous physical activity; IPAQ, International Physical Activity Questionnaire; NA = not available; OR, odds ratio; RR, risk ratio.

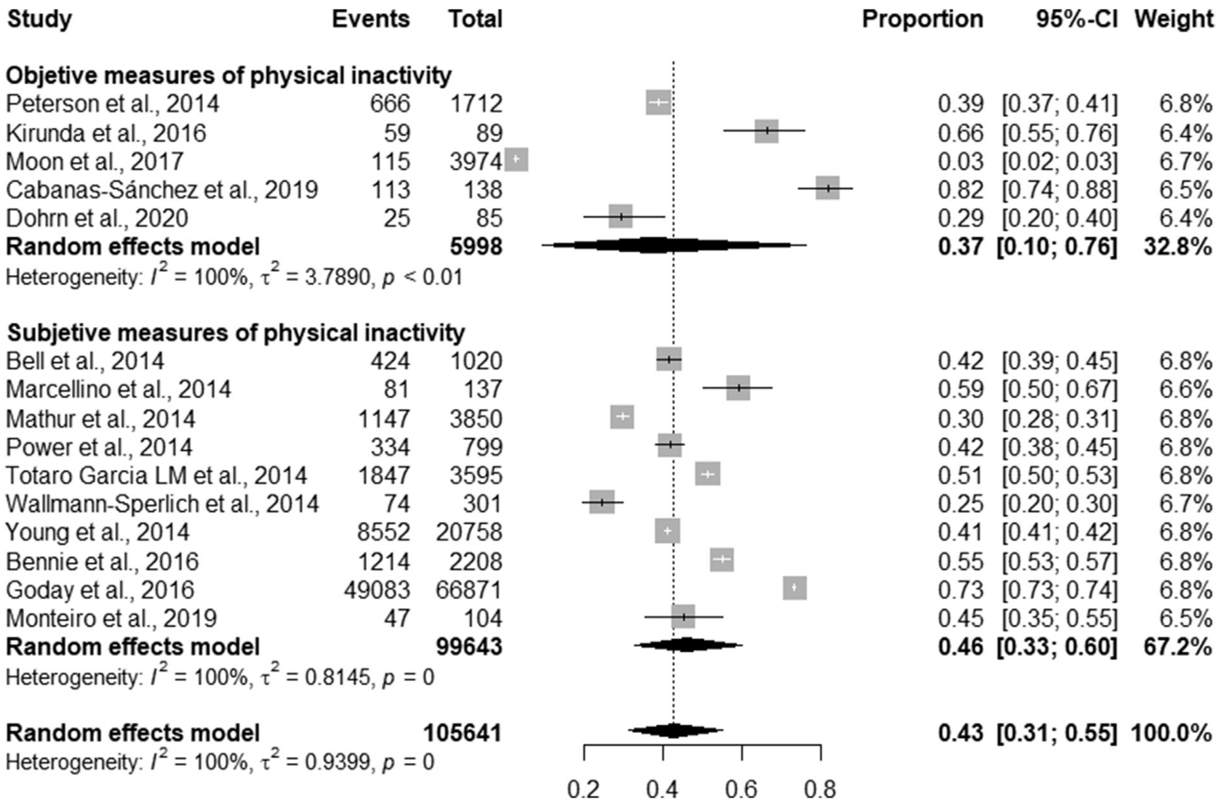

Fig. 3. Forest plot of the combined prevalence of physical inactivity in individuals with obesity according to data from objective and subjective measures of physical activity.

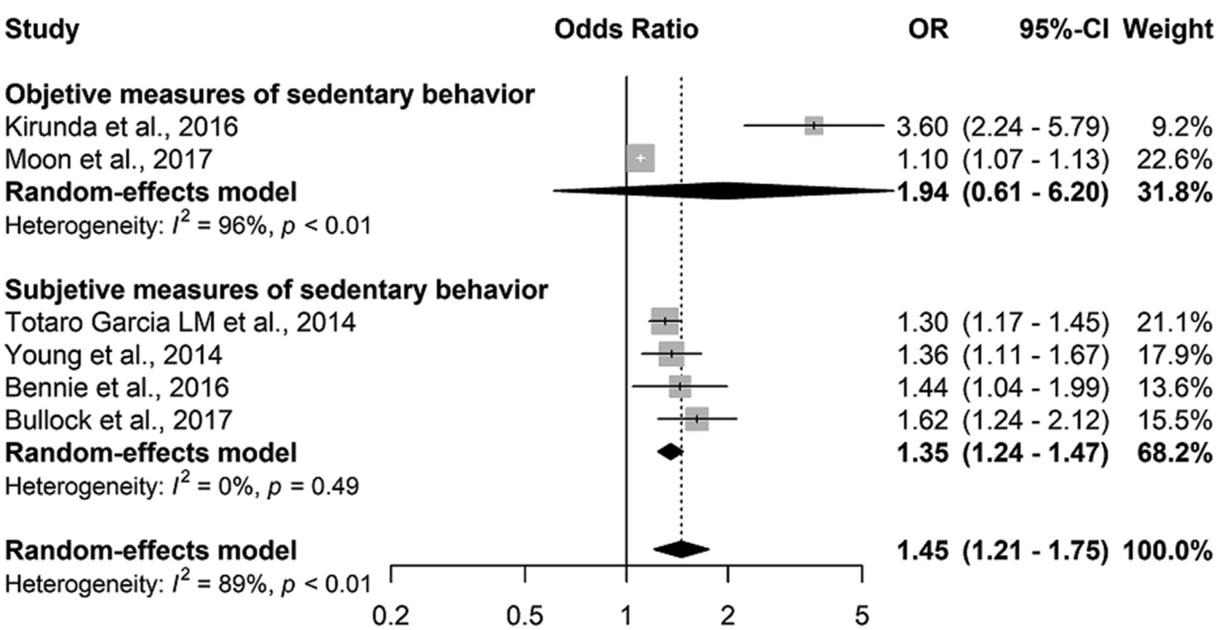

Fig. 4. Forest plot of the association of sedentary behavior in individuals with obesity according to data from objective and subjective measures of physical activity.

the method of physical activity measurement was not a mediator for our results ($p = 0.194$).

3.6. Association between obesity and PI/SB

Less than half of all studies included in this systematic review had analyzed the association between obesity and SB and/or PI. Only six studies had analysed the association between obesity and SB [37,45,47,48,51,54]. The meta-analysis found a significant association between obesity and SB [OR = 1.45, 95% CI, 1.21–1.75] in adults and older adults. For the studies that had used objective instruments, this association was not significant [OR = 1.94, 95% CI, 0.61–6.20]. However, the association was significant for those studies using subjective measures [OR = 1.35, 95% CI, 1.24–1.47]

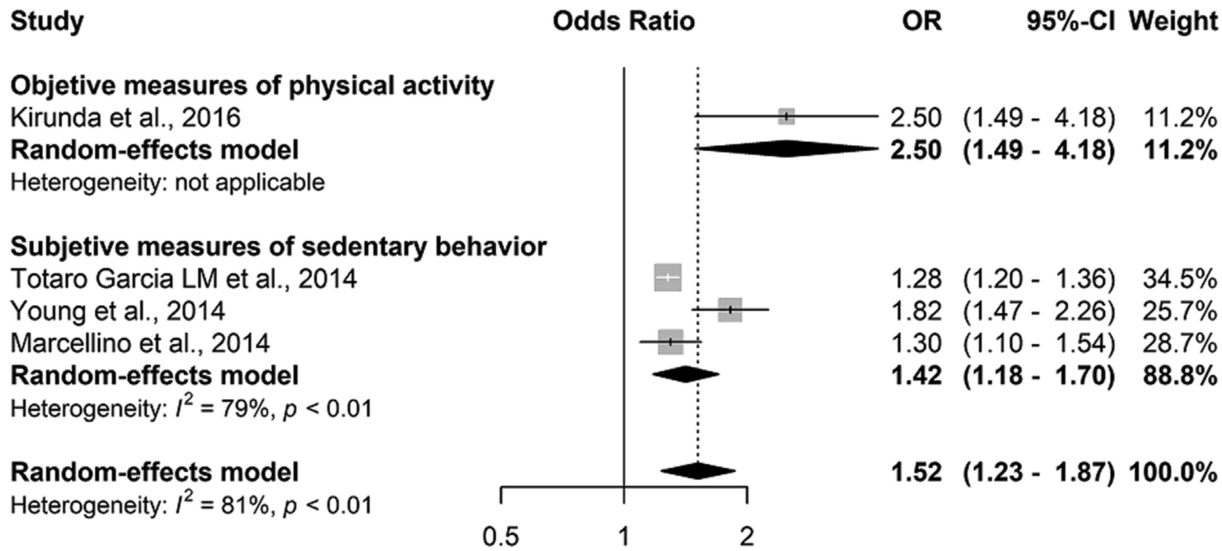

Fig. 5. Forest plot of the association between physical inactivity in individuals with obesity according to data from objective and subjective measures of physical activity.

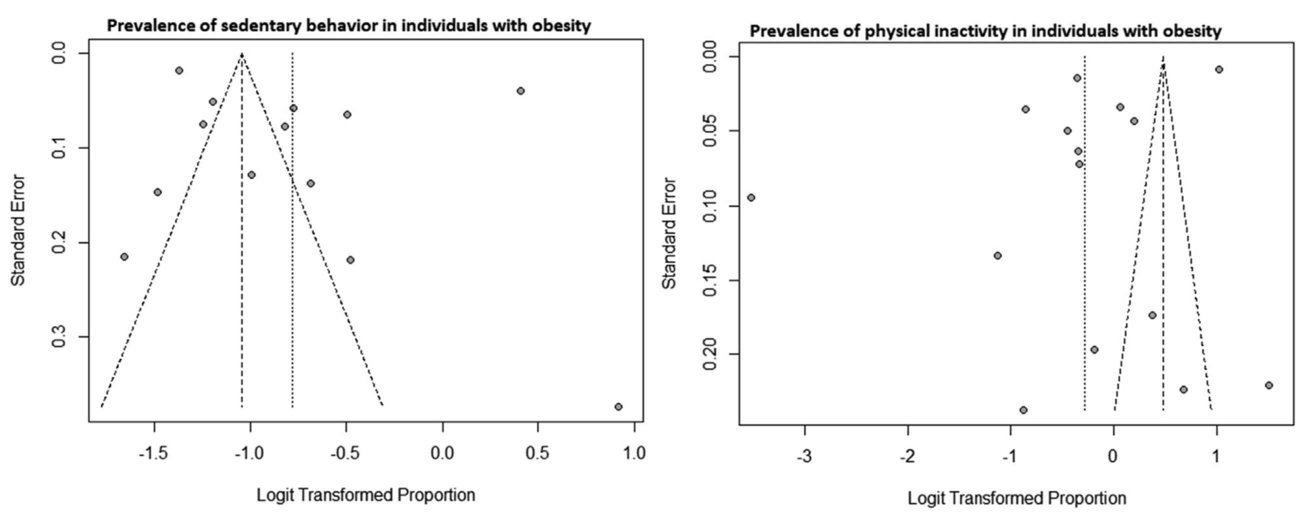

Fig. 6. Funnel plot of the association between sedentary behavior and physical inactivity in individuals with obesity.

(Fig. 4). The heterogeneity index (I^2) for this meta-analysis was 89% ($p < 0,01$) with 0% of heterogeneity between subjective measures.

Considering physical inactivity, only four studies analyzed its association with obesity [45,51,54,56], and only one had used objective measures [54]. The meta-analysis for this association was significant [OR = 1.52, 95% CI, 1.23–1.87] (Fig. 5). The heterogeneity index (I^2) for this meta-analysis was 81% ($p = 0,02$).

Supplementary Fig. 1 shows the prevalence of sedentary behavior and physical inactivity in individuals with obesity according to the study design. No significant differences were observed in the prevalence of sedentary behavior and physical inactivity, regardless of the design of the studies.

3.7. Publication bias and heterogeneity

Egger's tests showed no significant publication bias for the prevalence of SB in individuals with obesity ($p = 0.30$) and for the prevalence of PI in individuals with obesity ($p = 0.07$) (Fig. 6). The heterogeneity assessed by the I^2 values is represented in each of the corresponding Forest plots (Figs. 2–5).

4. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis of observational studies to investigate the prevalence of sedentary lifestyle (35%) and physical inactivity (43%) in adult and older adults with obesity. We found high estimates and a large variability for SB (16%–71%) and PI (3%–82%) in individuals with obesity. Less than half of the studies included in this systematic review had analysed an association between obesity and PI and/or SB [37,45,47,48,51,54,56]. Our meta-analysis indicated a positive association of obesity with SB and PI. However, the evidence using objective measures is very small, with only three studies that analyzed this association. Therefore, it is important that future studies include this investigation's physical activity level variables and test their association and risk with obesity. The studies included in this systematic review had large samples and low risk of bias, as verified by the NOS scale, which revealed the high quality of the presented information made by extensive literature search with well-defined inclusion criteria and critical reading of the articles in full.

Although there is the impression that this research topic has been well documented in previous publications, we have identified only 23 studies with data on the prevalence of SB and PI in individuals with obesity. The prevalence of PI and SB in the individuals with obesity analyzed reached high levels, close to 82% for PI and 71% for SB, highlighting this finding as a relevant public health concern. The treatment of adults with obesity and older adults to reduce their cardiovascular disease risk and other health complications should aim at stimulating these individuals to be at least minimally active i.e. not to be sedentary. From a public health perspective, this approach is relevant to improving the treatment of individuals with obesity to prevent the worst health outcomes. Promoting physical activity can reduce the risk of comorbidity, and it is well-known that medication [67] does not promote effective and long-term treatment.

We expected to find more evidence on this topic to better understand the magnitude of SB and PI risk in individuals with obesity and to perform a metanalysis with more data, comparing the risk with subjective and objective measures. However, even with only four studies for PI and six for SB we found a significant positive association of obesity with SB and PI [37,45,47,48,50,51,54,56,60,61,66]. Meta-analyses on the association of obesity with SB/PI in adults and using observational studies are quite rare. There are some studies in children and adolescents [68–70], pregnant women [71], sitting time and cardiovascular risk and mortality [72], and SB and all-cause mortality [73]. There is also a systematic review and meta-analysis of the association between SB and diabetes [74]. However, we did not find previous studies with adults and older adults with obesity to compare our results. Only two similar meta-analyses had analyzed the association of SB with other health outcomes, including obesity. One of them did not find a non-linear association with overweight/obesity [75] and the other one also found no association of SB and body weight [22]. In contrast, our results showed that both SB and PI increased the risk of obesity in adults and older adults. Furthermore, in our prevalence analyses, the results showed a significant number of individuals with obesity who were sedentary and/or physically inactive.

Subjective measures of PI and sedentary lifestyle have been widely employed in both developed and developing countries, mainly because they are easy to apply and cheap. Subjective methodologies include validated questionnaires such as the GPAQ and IPAQ, conducted via interview or self-report, and instruments developed by the research authors themselves. Other subjective measures included direct observation records and activity journals [14,25]. These types of measures have the following advantages: (1) allowing for the analysis of large populations, (2) evaluation of a variety of dimensions of physical activity, (3) adaptation to a particular target population, and (4) facilitating the comparison of results across different locations. However, they have the following disadvantages: (1) under-or overestimation, (2) recall bias, and (3) limitations related to the level of education (illiteracy) and interpretation inherent to self-report [25].

Among the various objective methods of evaluating physical activity and sedentary lifestyle, accelerometer and pedometer were the main methods used, primarily in developed countries, which have more resources available for the acquisition of more sophisticated equipment (Table 1). Only one study conducted in a developing country (Uganda) used a pedometer [54]. However, the pedometer is a less sophisticated tool than the accelerometer and is less expensive [14,25]. The evaluation of physical activity and sedentary lifestyle by objective measures facilitates the collection of precise data, such as the intensity, frequency, and duration of physical activity, without relying on participants' memory and level of commitment [14,66]. However, this approach requires a great deal of patience, as the collection of reliable data depends upon the proper use of portable equipment for several days, thus the research participants' commitment.

Two other considerations are worth mentioning, as follows: a) the possibility of collecting data on different outcomes from the same instrument, such as the IPAC, which is, for example, used to both collect data on physical activity time [56], and to observe sitting time [46], and b) the use of different cut-off points for objective and subjective measures in the analysis of both sedentary lifestyle and PI (for example, in the use of questionnaires and accelerometers). One exception is the standardization of the cut-off point for sedentary lifestyle in pedometers (<5000 steps/day) [53,58]. The lack of a gold standard for the analysis of sedentary lifestyle and PI leads to a lack of consensus between research groups, culminating in the use of different analysis instruments and respective cut-off points, leading to even more discrete/heterogeneous results. Ultimately, this lack of standardization makes comparing the results of different studies highly challenging.

This study has some limitations, such as excluding some studies due to the lack of data on the prevalence of PI and sedentary behavior in people with obesity (Supplementary Table 1) and reduced number of studies that had analyzed the association of obesity SB/PI. If all the included articles had published complete results and analyzed the measurement of effect, we would be able to provide a stronger estimate of the influence of SB and PI in individuals with obesity. In addition to the high level of heterogeneity of the studies due to different assessment instruments, cut-off points and age of participants, the lack of association data made it impossible to analyze the data by meta-analysis.

Future research on physical inactivity and SB in people with obesity should provide data on both prevalence and measure of effect or association (relative risk). We also suggest expanding studies in specific populations, such as older adults and people with severe obesity (BMI >35 kg/m^2). A consensus or standardization of methods of assessing SB and PI in individuals with obesity is needed. Ideally, most studies should include objective measures to estimate physical activity since they better estimate physical activity level. Public health policies must include strategies to promote physical activity in individuals with obesity. Guidelines to treat obesity should include physical activity as a pillar of treatment of people with obesity. This approach would prevent not only obesity but also prevent adverse health outcomes associated with obesity.

In conclusion, there was a high prevalence of PI and SB, assessed by a wide range of methods and cut-off points, in individuals with obesity. Individuals with obesity should receive special heath attention and/or non-pharmacological treatment from public or private health systems. They should also receive motivation and support from their health professional team to change their sedentary lifestyle and start a minimal level of physical activity to prevent the worst health outcomes of obesity. Few studies had analyzed the association of PI and SB with obesity in adults and older adults, and in our meta-analysis, this association was positive with an estimated risk of 1.5. We described the cut-offs used in several assessing methods of SB and PI. Several methods are still a major limitation reducing the quality of evidence on this research topic. It is crucial to standardize the assessment of SB and PI in adults and older adults with obesity.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All relevant data are within the manuscript and in the Supporting Information files.

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Authors' contributions

EAS, CRM, GVES, LPSR, CO, and MN participated in planning, conceptualizing, and writing the draft and final manuscript. FMD participated in the data analysis. All authors contributed to data interpretation and reviewed, edited, and approved the final manuscript.

Declaration of competing interest

The authors have declared that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2022.06.001.

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