**Introduction**

Osteoarthritis is a heterogenous disease with individual pathological changes39, which commonly affects the knee and hip joints, with a combined 303.1 million prevalent cases worldwide70. Established risk factors for developing osteoarthritis are; increasing age, more common after the age of 40, more common in the female sex, obesity, previous joint injury, and genetic factors2. A combination of these risk factors further increases the chance of developing osteoarthritis2. Internationally, osteoarthritis is a known cause for disability due to severe pain and stiffness, leading to a reduced quality of life and reductions in psychological wellbeing32,66,77,98.

Management of osteoarthritis includes physical activity (PA), defined as any bodily movement produced by skeletal muscles that results in energy expenditure, and exercise, a subtype of PA where movement is planned, structured and repetitive16. PA and exercise are utilised to reduce pain and stiffness, while also promoting muscular strength3,36. Those diagnosed with osteoarthritis have the same recommended World Health Organisation (WHO) PA guidelines as the general adult population; including two strength-based sessions and 150-300 minutes of moderate-intensity PA (3-6 metabolic equivalent of tasks [METs]) or 75-150 minutes of vigorous-intensity PA (> 6 METs) a week, or a combination of moderate-to-vigorous PA14. However, patients with osteoarthritis lead more inactive lifestyles, due to fear of worsening symptoms through PA6,13,97,99. Recent studies have reported that 55–91% of adults with osteoarthritis do not meet current WHO PA guidelines35,52. Low PA levels are a known risk factor for health conditions, such as increased mortality risk and development of non-communicable diseases such as obesity, type II diabetes and cardiovascular disease73,91. This further emphasises the importance of PA in populations diagnosed with lower limb osteoarthritis.

In addition to PA, sedentary behaviour (SB), defined as any waking behaviour spent at an energy expenditure ≤1.5 METs whilst sitting, reclining or lying86, has emerged as an independent risk factor that negatively affects cardiovascular health and all-cause mortality28,68. SB has been recognised for the first time in the 2020 WHO PA and SB guidelines, suggesting individuals limit the amount of time spent in SB. There is, however, currently insufficient evidence to prescribe quantitative recommendations for time spent in SB25. Interestingly, there is also evidence to suggest that in addition to total SB, how SB is accumulated, for example bouts and breaks from SB, may be important factors to consider for cardiovascular health41. However, this area needs further research to understand how different patterns of SB may impact individual’s health76. Importantly, those with osteoarthritis have been reported to spend up to 18 hours per day sedentary6,61. This highlights the importance of assessing both PA and SB levels within this population, as well as the patterning of these behaviours, as each pose their own modifiable health risks27.

Within the last 15 years, there has been emerging interest into the PA and SB levels of those with osteoarthritis27,51,75. This is, in part, due to technological advancements through wearable devices (e.g., accelerometers) that has enabled more comprehensive and precise measures of PA and SB compared to self-reporting27, which can overestimate PA and underestimate SB27,55. However, previous reviews have primarily focused on levels of PA with little acknowledgement of SB within this population89,94. A systematic review and meta-analysis indicated a high percentage of patients with lower limb osteoarthritis do not meet recommended PA guidelines, but did not synthesise SB levels89. Furthermore, a recent scoping review documented the importance of PA for the health of adults with osteoarthritis, however; whilst SB for the health of the general population was acknowledged, there was limited focus on the impact of SB in an osteoarthritic population94. Collectively, from these reviews the time spent in different intensities of PA and in SB remain unknown. This is of significance as recently, substituting time spent in prolonged SB with light-intensity PA has been shown to provide health benefits24. For a population who are known to not meet PA guidelines, this could be a strategy to help improve health outcomes and quality of life, however it is first important to understand what the PA and SB profiles are of this population.

Known risk factors for osteoarthritis such as age, sex and obesity have been shown to impact PA and SB levels in the general population1,20,69, however, there is a lack of understanding whether these factors also impact PA and SB in those with osteoarthritis. Synthesising the impact of these risk factors on PA and SB levels would create a more detailed understanding of these behaviours in this population and could help to inform future research and interventional strategies.

This systematic review, therefore, aims to synthesise in adults with lower limb osteoarthritis what percentage of this population meet WHO PA guidelines, as well as the amount of time spent in different intensities of PA and the amount of time spent in SB. The secondary aim is to explore metrics of PA and SB including step count and bouts and breaks of PA and SB to provide a narrative understanding of the patterning of both behaviours. Lastly, this review aims to explore the impact of risk factors for osteoarthritis, including age, sex, and obesity, on PA and SB, to help inform future healthcare practice.

**METHODS**

The systematic review adhered to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines67. The systematic review was registered prospectively with PROSPERO in April 2021 (CRD42021247889), the international prospective register for systematic reviews.

**Search strategy and selection criteria**

Relevant peer-reviewed studies relating to PA and SB in an osteoarthritis population were identified from conducting a computer-based search. Four topic relevant electronic databases were searched up to July 2023, which included PubMed, Cochrane Library, ScienceDirect and CINAHL. The initial database search was extended by hand searching relevant review studies in the subject area as well as the reference lists of included studies. Medical subject headings (MeSH) and key words were utilised in the development of search terms (Appendix A). Searches were restricted to published studies written in English. Manual searches of the reference lists for eligible studies were reviewed and included as appropriate. Search results were imported into EndNote version X9 (Clarivate, Boston, MA, USA) for study management. Initial screening of title and abstracts were conducted independently by one author (ZD). Full texts were screened by two authors (ZD and SC). The authors then conferred, and any disagreements were presented to a third author (AB) for arbitration.

Studies were included providing they met each of the following: (1) clinical and/or radiographic diagnosis of lower limb osteoarthritis; (2) reported quantitative time spent in PA or SB (including step count and bouts and breaks from SB, as the accumulation of SB is important to cardiovascular health47) using device-based or self-report measures; (3) had available baseline data for prospective studies and randomised control trials; and (4) had a human population aged 18 years and over. Potential studies were excluded if they: (1) included an ‘at risk’ osteoarthritis population without clinical diagnosis; (2) included participants with rheumatoid or inflammatory arthritis; (3) PA or SB data included participants with joint replacements (pre-joint-replacement data were included); (4) were a protocol paper or review study; (5) were a conference abstract or unpublished study; or (6) unable to obtain full text.

**Quantitative Data Extraction**

Data was extracted by one author (ZD) into an Excel spreadsheet (Microsoft Excel 2016, Microsoft Corporation, Redmond, WA, USA) and cross checked for accuracy by two authors (SC and AB). Data collection included author names, date of publication, sample size, and participant characteristics (age, female percentage, and body mass index [BMI]). The study design, osteoarthritic joint, method of osteoarthritis diagnosis, and the type of questionnaire or device used to obtain PA and SB variables were also collected. Extracted PA variables included: daily step count, movement time, total time in PA, light-intensity PA, moderate PA, moderate-to-vigorous PA, vigorous PA, time walking, and walking bouts. SB variables included: mean time spent sedentary, sedentary bout length, number of breaks from SB, duration of breaks from SB, total sitting time, and sitting bouts. For experimental trials providing pre- and post-intervention data, only baseline data were extracted for synthesis purposes.

Where possible, PA and SB variable(s) were converted and presented as minutes per week (mins/week) for PA to allow for comparisons to current WHO recommended aerobic PA guidelines14, steps per day (steps/day), and hours per day (hrs/day) for SB. To allow for a representation of overall levels of PA and SB within this cohort, averages of the reported mean and standard deviation (SD) from the included studies were calculated. Furthermore, the smallest and largest reported mean value for each variable were extracted to provide insight into the range of values reported within the population. Values were calculated separately for device-based and self-reported data collection methods for the variables: total PA, each intensity of PA, step count, total SB, and sitting time. In the instance data were only presented in figures, the study authors were contacted for the relevant data. However, studies were excluded if no data was attainable. Studies that reported on relationships or referred to PA or SB and age, sex or BMI were documented, and relevant data extracted. For studies reporting medians and interquartile range (IQR) or means and 95% confidence intervals (CI), the study authors were contacted for the raw data. On failure of obtaining raw data, means and 95% CI were converted to means ± SD using the equation below18 where t-distribution was calculated in excel as ‘=tinv(1-0.95,sample size-1)’, representing degrees of freedom equal to the group size, minus one18. Medians and IQR were excluded from the study on failure of obtaining raw data22.

(SD, standard deviation; N, sample size; CI confidence intervals)

**Data Synthesis**

Data syntheses took place after the quantitative data was extracted. A meta-analysis was not conducted due to large heterogeneity,therefore, a narrative review of the data was conducted. To avoid amplification of results, studies that contained participants from the same population cohort, i.e., studies from the Osteoarthritis Initiative, were checked for duplication of reported variables. For studies reporting the same variable, only the study with the largest sample size was included, to best reflect the study sample. Additionally, only studies reporting means ± SD were used within the descriptive data.

Data were synthesised to identify the number of studies reporting ≥150 mins/week of moderate PA, ≥150 mins/week of moderate-to-vigorous PA, or ≥75 mins/week of vigorous PA, to provide an understanding of how often WHO aerobic PA guidelines are met. The overall sample size from studies reporting a mean moderate or moderate-to-vigorous PA value that met or exceeded these guidelines was calculated. Thereafter, the percentage of those who met the guidelines based on the total sample size of all studies that reported moderate or moderate-to-vigorous PA was then determined. Separate averages of the reported mean ± SD from the studies that met and did not meet the PA guidelines were also calculated. Furthermore, studies that reported ≥420 mins/week of moderate-to-vigorous PA were also synthesised, as this level of activity appears to reduce the risk of all-cause mortality that is associated with SB29 . Where two moderate-to-vigorous PA cut-points where reported within the same study, the lower cut-point of moderate-to-vigorous PA was used to best reflect the activity of an elderly population74,93. Data were synthesised to identify the number of studies reporting a step count that met or exceeded the recommended 7,000 steps/day78.

Additionally, mean time spent in SB, SB bouts, and breaks from SB were synthesised to further understand the accumulation, as well as total SB of this population. Studies reporting ≥8 hrs/day of mean SB were identified due to the associated increased risk of cardiovascular disease mortality29. Physical inactivity variables were viewed with caution and only included within SB synthesis if the study’s classification of physical inactivity concurred with the definition of SB86 . Furthermore, data synthesis was conducted on PA and SB and factors associated with osteoarthritis disease risk and progression including age, sex, and BMI2.

**Quality Assessment and Risk of Bias**

Study quality assessment was performed by one author (ZD) using the National Heart, Lung and Blood Institute (NHLBI) study quality assessment tools63. RCT, observational cohort and cross-sectional study assessment tools were used for the appropriate studies. Each question for the quality assessment tools were answered as either ‘yes’, ‘no’, or ‘not applicable’. The tool helps guide users to identify methodological limitations allowing judgement on the severity of bias and the ‘internal validity of the study’63. A subjective rating of ‘poor’, ‘fair’, or ‘good’ were provided for individual studies depending on the outcome of each individual question according to the NHLBI guidelines63.

**RESULTS**

**Search Outcome**

Results for the search, screening, and included studies are illustrated in Figure 1. The initial search identified 1930 studies, 265 were removed as duplicates. Title and abstract screening were conducted on 1665 studies, with 1422 studies excluded. Full text screening included 243 studies, with a total of 204 excluded, an additional 9 studies were identified and included through manual searches. A total of 48 eligible studies were, therefore, included within the systematic review.

**Study Characteristics**

Characteristics for the included studies are shown in Table 1. There was a total of 12,870 participants with a mean age of 65 ± 8 years. From the studies that reported sex (n=47)3,5–8,10,11,13,17,21–23,26,30,31,33–35,37,40,42,43,45,49,50,52–54,57,58,61,65,74,75,81,87,93,95,96,99, 67% of participants were female. From the available studies (n=43)3,5–8,11,13,17,21–23,26,30,31,33–35,37,40,43–45,49,50,52–54,57,58,61,65,74,75,81,85,87,88,93,95,96, mean BMI was 29.6 ± 5.2 kg/m2. Knee osteoarthritis (n=35)5–8,13,15,17,19,21,23,26,30,31,33–35,37,40,45,46,49,52–54,57,58,64,65,74,81,87,93,95,96,99, combined knee and hip osteoarthritis (n=10)3,10,11,22,43,44,50,61,75,88, and hip osteoarthritis (n=3)9,42,85 were identified osteoarthritis diagnoses.

**Study Design**

Study designs consisted of RCT (n=14)3,5,8,9,11,30,33,37,45,50,52–54,88, longitudinal (n=10)10,13,26,34,35,49,58,85,95,96, cross-sectional (n=12)17,19,21,23,31,40,43,44,46,61,74,81, retrospective cohorts (n=4)15,42,57,99, prospective cohorts (n=4)6,7,64,65, descriptive (n=1)75, case control (n=2)87,93, and prospective follow ups (n=1)22 (Table 1) as stated by the authors in the original study.

**Data Collection Methods**

Tables 2 and 3 show the various self-reported and device-based methods used for data collection. Device-based only (n=36)5–7,9,11,13,15,17,19,21,22,26,30,31,33–35,37,42–45,48,52–54,57,58,61,65,74,81,85,95,96,99, self-reported only (n=7)10,23,40,46,64,75,88, and both self-reported and device-based (n=5)3,8,50,87,93 methods were identified. Studies that used device-based methods used either accelerometers (n=29)5–7,11,13,17,21,22,26,31,33,35,37,42,45,48,50,57,58,61,65,74,81,85,87,88,93,95,99, multi-sensory monitors (n=5)30,43,52–54, inclinometers (n=3)3,8,34, or pedometers (n=5)9,13,19,46,96. One study used an accelerometer and pedometer to record daily activity and step count, respectively13.

**Risk of Bias**

Studies were rated ‘good’ (n= 13), ‘fair’ (n=30) or ‘poor’ (n= 5) according the NHLBI study quality assessment tool (Table 1). Small sample size was acknowledged within several studies when assessing risk of bias. It is worth noting there were many observational studies included within this review (n=33), which poses challenges when assessing risk of bias within and across studies especially around factors such as publication and reporting biases59.

**Physical Activity**

At least one or more PA variable(s) were reported in 47 of the included studies. Device-based measures included total PA (n=13)5–8,11,22,33,37,40,42,45,50,75, light PA (n=9)15,17,26,35,42,48,85,93,95, moderate PA (n=6)17,31,42,48,57,85, moderate-to-vigorous PA (n=19)17,19,26,30,31,33,35,37,43,44,48,52–54,61,74,92,93,95,99, vigorous PA (n=6)17,26,31,42,48,85, and step count (n=24)3,8,9,13,15,17,19,21,34,35,42,43,46,52,53,57,58,61,65,81,87,88,93,96 (Table 2). Self-reported measures included total PA (n=4)40,50,75,87, moderate PA (n=2)10,75, vigorous PA (n=1)75 (Table 2). Means and standard deviations for device-based and self-reported PA levels calculated from all included studies are shown in Table 4.

WHO aerobic PA guidelines were met by 33% of the total sample size from the included studies that measured either moderate PA or moderate-to-vigorous PA10,19,30,31,37,43,52–54,57,61,74,85,93,99 with a calculated mean ± SD of 399.4 ± 353.0 mins/week of moderate-to-vigorous PA. The calculated mean ± SD of moderate-to-vigorous PA for studies that did not meet WHO aerobic guidelines was 85.3 ± 98.1 mins/week. Importantly, it is worth noting this data should be viewed with caution as this would suggest that all 33% of these participants met the PA guidelines. Additionally, no studies reported meeting or exceeding 75 mins/week of vigorous PA and eight studies reported 420 mins/week or more (equivalent to 60 mins/day) of moderate-to-vigorous PA30,43,52–54,57,74,99. Means and standard deviations for steps per day calculated from all included studies are shown in Table 4. Only 11% of the total sample size from the included studies that reported step count met or exceeded 7,000 steps/day.

**Sedentary Behaviour**

One or more SB variable was documented in 26 of the studies (Table 3). Device-based measures included daily average SB (n=16)3,5–7,11,19,35,43,44,50,52–54,61,85,99, physical inactivity (n=3)5–7, sitting time (n=3)3,34,81, and bouts and breaks in SB (n=6)3,35,81,85,87,93. Self-report measures included daily average SB (n=4)3,10,23,93 and sitting time (n=1)75 (Table 3). Methods for defining a sedentary bout varied between studies (Table 3) and were classified as: >30 minutes (n=4)3,44,85,93, >20 minutes (n=4)30,52–54, 0-10 seconds, 10-60 seconds, 20-30 minutes and >30 minutes81. An average of more than 8 hrs/day of SB were reported in 58% of the total sample size from the included studies that measured SB3,5–7,11,23,30,34,35,43,45,50,52–54,81,85,93,95,99. Means and standard deviations for SB variables calculated from all included studies are shown in Table 4.

**Osteoarthritis Risk Factors and Physical Activity and Sedentary Behaviour**

*Age*

There were 14 studies10,17,22,26,42–44,57,61,74,75 that explored age and habitual PA levels. The majority (n=10) documented a negative relationship with age and PA, meaning that with advancing age, individuals with osteoarthritis were less active17,22,26,42,43,57,61,74,75. One study21 reported age had no impact on PA. Two studies reported that there was no age-specific effect on SB43,61. Due to the available data, it was not possible to provide a quantitative break down of PA and SB by age.

*Sex*

Thirteen studies10,17,21,26,31,40,43,44,65,74,75,81,99 explored PA and SB levels between men and women. Men and women demonstrated different PA and SB patterns in 10 of the 13 studies10,17,26,31,40,44,65,74,75,99. Due to the available data, it was not possible to provide a quantitative breakdown of PA and SB by sex, however, studies highlighted men are more likely to meet recommended PA guidelines compared to women26,31,40,75. Additionally, men typically engage in higher intensities of PA compared to women26,75. However, women typically engage in greater amounts of light PA compared to men10,26,44,81. There was an overall agreement that men spent more time in SB compared to women from the five studies that reported sex differences and SB measures10,26,65,81,99.

*Body Mass Index*

Exploration into BMI and the influence on habitual activity were reported in 13 studies10,17,21,22,26,31,42–44,74,75,81,87. Higher BMI, or obesity, was associated with lower PA levels10,22,26,43,75,81. However, caution is needed with interpreting these results, as on occasion, other confounding factors, such as age or sex have been shown to influence findings31,74. In addition to this, BMI was also shown to have no influence on PA measures in four studies17,21,74. From the 13 studies exploring BMI, four reported SB10,43,81,87. Within three10,43,87 of these studies, higher BMI, being overweight, or obese was associated with greater time in SBs. As with age and sex, due to data availability, it was not possible to provide a quantitative breakdown of PA and SB by levels of BMI.

**DISCUSSION**

The aims of this systematic review were to firstly, synthesise in adults with lower limb osteoarthritis what percentage of this population meet WHO PA guidelines, as well as the amount of time spent in different intensities of PA and the amount of time spent in SB. Additional aims were to explore metrics of PA and SB including step count and bouts and breaks of PA and SB, and to explore known osteoarthritis risk factors; age, sex, and BMI, and their influence on PA and SB. This is the first systematic review to evaluate both daily PA and SB for those diagnosed with lower limb osteoarthritis and principally highlights noteworthy observations. (1) From studies reporting PA, 33% of this population met the WHO PA guidelines. (2) From the studies that measured SB, 58% of this population spent eight or more hours a day in SB. (3) Confounding factors that are associated with osteoarthritis disease risk and progression may influence PA and SB levels. (4) The review identified various methodologies used for the assessment of PA and SB, and this inconsistency poses challenges when attempting to compare and understand the current literature surrounding PA and SB in those diagnosed with lower limb osteoarthritis.

**Physical Activity and Sedentary Behaviour**

Only 33% of the population diagnosed with knee and/or hip osteoarthritis from the included studies that reported appropriate PA variables, met WHO aerobic PA guidelines. This corroborates with the ranges from a previous systematic review, that reported 13% to 58% of those with knee or hip osteoarthritis, respectively, met PA guidelines89. However, a large proportion (67%) of this population would be classed as physically inactive from the available data in this review. The calculated averages across the appropriate studies show that those who meet the WHO aerobic PA guidelines complete 399.4 ± 353.0 and 291.3 ± 312.1 mins/week of moderate-to-vigorous PA and moderate PA, respectively, compared to those who do not meet the same guidelines, who complete 74.1 ± 46.2 and 85.3 ± 98.1 mins/week, respectively. This is of significance as physical inactivity is associated with an increased risk of premature mortality and developing noncommunicable diseases, such as heart disease and diabetes73. Although it is well known that a healthy adult population also struggle to meet PA guidelines38, those diagnosed with osteoarthritis are already predisposed to developing diseases such as hypertension and diabetes62,90, therefore, there could be greater health implications for this population not meeting recommended PA guidelines.

Furthermore, emerging research suggests that prolonged SB may pose its own, independent health risks and that individuals who spend greater than 8 hrs/day in SB need to exceed 60 min/day of moderate PA to mitigate the mortality risk from being sedentary28. The data reported in this review (Table 4) indicates adults with lower limb osteoarthritis accrue high volumes of SB which may, therefore, have health implications for this population. Furthermore, sitting for prolonged periods may promote the development of sitting-induced ‘exercise resistance’, whereby typical physiologically beneficial responses to acute exercise are attenuated27. Consequently, health benefits from the prescription of PA for adults with lower limb osteoarthritis may be lessened if individuals also engage in high amounts of SB. Whilst osteoarthritis-specific research is sparse and needs further investigation regarding the patterning of SB, given the current evidence from this review, it seems prudent to encourage recommended guidelines to minimise and break up prolonged SB. Overall, further research is needed to understand the impact both PA and SB have on aspects of health, such as non-communicable diseases, for adults with lower limb osteoarthritis. Furthermore, potential SB-focussed interventions to reduce prolonged SB in this population should be explored.

**Step Count**

Current recommendations to reach 7,000 to 10,000 steps/day is associated with decreased risk of all-cause mortality and cardiovascular disease78. Only 11% of the sample (524 out of 4770 participants) from the included studies that collected step count data met or exceeded 7,000 steps/day, with no studies reporting 10,000 steps/day or more. This is a lower percentage compared to previously reported ranges in those with knee or hip osteoarthritis (48% and 60% of the population walking 7,000 steps a day or more, respectively)89. This review provides a more recent representation of daily step count for those with lower limb osteoarthritis (6060 ± 2880 steps/day for those with knee and/or hip osteoarthritis compared to previous reported values of 7753 (95% CI 7582, 7924) and 8174 (95% CI 7670, 8678) steps/day for those with knee or hip osteoarthritis, respectively)89. Although the focus of this review was not on functional limitation of osteoarthritic patients, it is noteworthy to suggest that a personal increase of 1,000 steps/day may reduce the risk of functional limitation by 16-18%96 in those diagnosed with osteoarthritis and reduce mortality risk within healthy populations by 15%47.

The range of mean daily step counts (Table 4) could potentially be due to the variability in grades of osteoarthritis present between studies. This is supported by White et al.,96 who demonstrated that non-symptomatic knee osteoarthritis patients walk 347 steps more than symptomatic knee osteoarthritis patients. It is well known that radiographic evidence of graded osteoarthritis does not correlate to pain or functional ability82, suggesting that symptomatic osteoarthritis may be more of a limiting factor for daily step count than the grade of osteoarthritis82. However, it was beyond the scope of this review to investigate the impact of the grade or severity of the disease on PA or SB.

**Demographic Characteristics**

The included studies identified that higher intensity PA decreases with advancing age17,22,26,42,43,57,61,74,75. The findings of this review are in keeping with previously reported literature that PA declines with age in healthy non-osteoarthritic older adults60. This is of significance as both aging and physical inactivity are linked with increased inflammation, anabolic and insulin resistance, and skeletal muscle atrophy12. Although greater health benefits are seen in those who participate in higher intensities of PA29, engaging with and maintaining light PA may provide health56 and functional95 benefits within those diagnosed with osteoarthritis. Therefore, for a population that evidently struggles to maintain high intensity activities, promoting light PA may be a more feasible approach to take56.

The current review highlights differences in PA and SB between sexes. Men with osteoarthritis are reported to engage in more moderate PA compared to women, and are more likely to meet recommended PA guidelines26,75,81,83. However, the current review identified that women spend a greater amount of time in light PA and less time in SB compared to males10,26,44,81. In comparison to previously published reviews, albeit in a non-osteoarthritic elderly population, our findings corroborate those which found men to be more physically active compared to women1,84. However, women had greater total PA, spent greater time in light PA, and less time in daily SB than males1.

Furthermore, those with higher BMI or obesity have lower PA levels compared to those of lower or normal BMI10,22,26,43,75,81, meaning higher BMI in an osteoarthritic population may reduce the ability to perform PA. Additionally, BMI is a modifiable factor and has a progressive relationship with developing knee osteoarthritis79 and symptom severity72. It is, therefore, important to consider BMI when developing successful interventions, as reducing BMI may influence osteoarthritic-related symptoms as well as the ability to participate in PA.

It is worth noting that multiple studies have explored confounding factors, such as age, sex, and BMI, collectively. For example, Robbins et al.,74 noted age, sex and BMI accounted for 23% of explained variance in moderate-to-vigorous PA, with age being the only significant variable to explain this variance. Additionally, Farr et al.,31 reported a significant inverse relationship between BMI and moderate-to-vigorous PA in women. This highlights there may be multifactorial influences on PA, and not solely determined by one characteristic. It is, therefore, important to initially understand the barriers and facilitators for reducing SB and improving PA for different ages, between sexes, and for different levels of BMI.

**Potential Implications for Health**

This review demonstrates those with lower limb osteoarthritis have low PA and high SB levels, which is important with consideration to the development of non-communicable diseases within this population knowing the impact both PA and SB patterns can have on diseases risk73. Despite this, from the included studies, there was little focus on non-communicable diseases. This is surprising considering 62% of those with osteoarthritis have one or more comorbidity, with hypertension presenting as the most common condition62. The majority of the included RCTs explored the impact PA has on pain and/or physical function8,11,33,37,45,50,52–54. Additionally, the included observational studies focused on physical function6,7,13,21,22,31,34,35,40,42,61,65,85,87,93 or predictors of these behaviours10,17,26,61,74,75,81,99. Although these studies provide valuable outcomes, there is little understanding of the impact these behaviours have on disease risk in those with lower limb osteoarthritis.

Within this review, only two studies assessed the impact of PA and SB on disease outcomes. Deguchi et al.,23 observed women with knee osteoarthritis had a higher incidence of heart disease compared to women without knee osteoarthritis, however, there were no significant between-group differences in total or passive SB (including tasks such as watching television, lying without sleeping, socialising and other activities such as watching YouTube and smartphone use)23. Furthermore, Deguchi et al.,23 investigated factors associated with passive SB and observed heart disease was not a significant predictor. However, the analysis was performed on those with and without knee osteoarthritis, and may, therefore, not accurately reflect those with knee osteoarthritis. Aunger et al.,3 conducted an intervention to reduce SB in older adults undergoing knee or hip arthroplasty that included cardiometabolic biomarkers, however, no differences were observed after the intervention, which were attributed to multiple factors, such as diet and medication, that can influence cardiometabolic biomarkers3. Further research assessing the impact of PA and SB has on disease risk is, therefore, warranted in a population diagnosed with lower limb osteoarthritis.

*Limitations of Present Review*

Possible limitations need to be considered, firstly, it is possible that the systematic review did not capture all available, relevant literature. However, multiple online databases were searched to collate all available research at the time, with manual searches of the included studies also conducted. Additionally, some papers may have been missed due to the requirement to be published in English, however this avoided misinterpretation of non-English speaking studies.

Some data are not presented as originally reported in the published study, but instead calculated to mins/week or hrs/day to allow comparisons to known guidelines. It is worth noting that volunteers for exercise-based studies are considered to be more physically fit and healthier compared to non-volunteers4. As pre-intervention data for exercise-based studies were included in this review the generalisability of the systematic review to a general osteoarthritis population should be viewed with caution due to this potential participation bias4.

Furthermore, it is worth acknowledging that a large proportion of the included studies were observational in nature (n=28). Observational studies tend to carry greater risk of within and cross-study biases59. There is often larger heterogeneity compared to RCTs due to more lenient study inclusion criteria59. However, results from observational studies may have stronger application to the general population as study protocols are less restrictive compared to RCTs and may better reflect ‘real-life’ conditions. The averages that have been calculated in this review need to be viewed with caution as there is large heterogeneity within the data and, as reported in the results, the ranges of reported values for all data sets. By providing overall averages there is the possibility of masking this variability and leading to false assumptions of the data.

Finally, studies that used a sample ‘at risk’ of developing osteoarthritis were excluded from the review, which limits the generalisability of the data to this sub-clinically diagnosed population. However, utilising a diagnosed osteoarthritis population allows for meaningful data that can be utilised and interpreted within the healthcare industry to a specific clinical lower limb condition.

*Methodological Limitations of Included Studies*

Methodological inconsistencies within the literature when defining accelerometer cut-points for moderate-to-vigorous PA made comparisons between studies challenging. For example, three cut-points were found within the review for moderate-to-vigorous PA (1952, 1041 and 704 counts per minute), however, this lower limit falls below the commonly used cut-point for light PA. Cut-points for moderate-to-vigorous PA are yet to be established for an osteoarthritic population74 allowing for discrepancies in the literature. Using different cut-points poses clear challenges when interpreting the literature, as the same population could be classed as physically active or inactive depending on the cut-points used53,74,92. Lower cut-points for moderate-to-vigorous PA were opted for analysis purposes to best reflect the activity of an elderly population74,93.

Data collection methods consisted mainly of device-based measures such as accelerometers and inclinometers (Table 1). However, accelerometers, unlike inclinometers, do not measure posture, so are not truly assessing, by definition, SB but are instead measuring stationary time71. Therefore, data should be viewed with caution from studies using accelerometers to report SB, as standing stationary may contribute to overall SB. Future research should aim to standardise devices used to measure SB, utilising both accelerometers and inclinometers to measure PA and SB, respectively, to provide accurate and reliable data.

**Conclusion**

This review highlights that in adults with lower limb osteoarthritis, WHO aerobic PA guidelines were only met in 33% of the population from the included studies that measured moderate PA and moderate-to-vigorous PA. Furthermore, 58% of the population from the studies that measured SB spent more than eight hours a day in SB. Furthermore, factors associated with osteoarthritis, such as age and BMI, appear to impact PA and SB levels. Additionally, comparisons between studies were challenging due to various methodologies used for the assessment of PA and SB. Further research is needed to understand the PA and SB levels of an osteoarthritis population and the impact this has on long-term health risk.

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**Author Contributions**

ZD, AJB and SEC contributed to the conception and design of the study. ZD drafted the initial manuscript. All authors contributed to the critical revision of the manuscript and approve the final submission

**Table 1:** Summary of study characteristics and quality assessment.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Author (Year) | Study Design | Osteoarthritis  (Diagnosis Method and Location) | Total Sample Size (Number) | Mean Age ± SD (Years) | Total Female (%) | Mean Body Mass Index ± SD (kg/m2) | Quality Assessment |
| Aunger et al., (2020)3 | Randomised, experimental | Awaiting surgery; Knee and Hip | 35 | 73 ± 6 | 57 | 30.7 ± 4.2 | Poor |
| Bartholdy et al., (2019)5 | Pilot RCT | Rheumatologist diagnosed; Knee | *Intervention Group:*  19 | 68 ± 7 | 79 | 28.3 ± 4.5 | Fair |
| *Control Group:*  19 | 62 ± 10 | 74 | 27.9 ± 4.0 |
| Bartholdy et al., (2020)6 | Prospective cohort | Radiographic; Knee | 124 | 59 ± 10 | 63 | 36.6 ± 5.8 | Good |
| Bartholdy et al., (2020)7 | Pragmatic prospective cohort | Physician80, Knee | 32 | 66 ± 8 | 75 | 28.9 ± 4.1 | Fair |
| Bennell (2014)9 | RCT | ACR criteria; Hip | *Intervention Group:*  49 | 65 ± 9 | 53 | 29.4 ± 3.5 | Good |
| *Control Group:*  53 | 63 ± 6 | 68 | 29.1 ± 5.3 |
| Bennell et al., (2017)8 | RCT | ACR criteria; Knee | *Intervention Group:*  84 | 61 ± 7 | 68 | 31.9 ± 7.5 | Good |
| *Control Group:*  84 | 63 ± 8 | 58 | 31.1 ± 6.7 |
| Bitar et al., (2020)10 | Longitudinal, cohort | Radiographic; Knee and Hip | 878 | 62 ± 9 | 69 | Range: 24.1 – 38.4 | Fair |
| Bossen et al., (2013)11 | RCT | Self-reported; Hip and Knee | *Intervention Group:*  100 | 61 ± 6 | 60 | 27.6 ± 4.6 | Good |
| *Control Group:*  99 | 63 ± 5 | 70 | 27.5 ± 4.5 |
| †Brandes et al., (2011)13 | Longitudinal, cohort | Awaiting surgery; Knee | 53 | 66 ± 6 | 64 | 30.7 ± 4.1 | Poor |
| Caliskan et al., (2020) | Retrospective, cohort | Awaiting surgery; Knee | 36 | 67 ± 7 | 86 | 33.2 ± 5.9 | Fair |
| Chmelo et al., (2013)17 | Cross-sectional | Radiographic; Knee | 160 | 66 ± 6 | 69 | 33.5 ± 3.8 | Fair |
| Collins et al., (2019)19 | Cross-sectional | NR; Knee | 15 | 68 ± 8 | 67 | 30 ± 6 | Poor |
| Daugaard et al., (2018)21 | Cross-sectional | ACR criteria; Knee | 54 | 62 ± 9 | 54 | 27.4 ± 4.9 | Fair |
| De Groot et al., (2008)22 | Prospective follow up | Radiographic; End Stage Hip or Knee | 84 | 62 ± 11 | 57 | 29.5 ± 5.5 | Fair |
| Deguchi et al.,(2022)23 | Cross-sectional | Physician diagnosed; Knee | 128 | 74 ± 4 | 100 | 24.0 ± 3.1 | Fair |
| De Hoop et al., 202044 | Cross-sectional | ACR criteria; Hip and Knee | 182 | 63 ± 9 | 67 | NR | Fair |
| aDunlop et al., (2011)26 | Prospective, longitudinal cohort | Radiographic; Knee | 111 | 62.1a | 55 | 29.0 | Fair |
| Falck et al., (2018)30 | RCT | Physician diagnosed; Knee | *Immediate Group:*  30 | 62 ± 9 | 73 | 29.2 ± 5.5 | Fair |
| *Delayed Group:*  31 | 63 ± 9 | 90 | 29.2 ± 4.8 |
| Farr et al., (2014)31 | Cross-sectional | Radiographic and ACR criteria; Knee | 255 | 55 ± 7 | 76 | 27.8 ± 4.3 | Fair |
| Focht et al., (2014)33 | RCT | Radiographic; Knee | *Control Group:*  40 | 64 ± 7 | 77 | 33.0 ± 7.1 | Good |
| *Intervention Group:*  40 | 63 ± 7 | 90 | 32.4 ± 7.1 |
| †bFrimpong et al., (2019)35 | Longitudinal, observational | Radiographic and ACR criteria; Knee | 79b | 64 ± 9 | 92 | 34.2 ± 7.5 | Good |
| Frimpong et al., (2020)34 | Longitudinal, observational | Radiographic and ACR criteria; Knee | 49 | 63 ± 9 | 90 | 33.8 ± 7.1 | Fair |
| Gilbert et al., (2018)37 | RCT | Radiographic; Knee | *Intervention Group:*  76 | 61 ± 13 | 58 | 31.1 ± 5.5 | Fair |
| *Control Group:*  79 | 65 ± 12 | 62 | 31.5 ± 6.9 |
| Herbolsheimer et al., (2016)40 | Cross-sectional | ACR criteria; Knee | 410 | 74 ± 5 | 66 | 29.4 ± 4.8 | Fair |
| Hirata et al., (2019)42 | Retrospective cohort | Radiographic; Hip | 65 | Median (range) 50 (30-71) | 100 | Median (range) 21.4 (14.5-27.8) | Fair |
| Holsgaard-Larsen et al., (2012)43 | Observational, cross-sectional | Awaiting surgery; Hip and Knee | 51 | 68 ± 5 | 49 | 28.4 ± 4.6 | Fair |
| Hoorntje et al., (2020)45 | RCT | Diagnosed and awaiting surgery; Knee | 97 | 58 ± 5 | 58 | 31.4 ± 5.5 | Good |
| Ijima et al., 201846 | Cross-sectional | Radiographic; Knee | *Depression Group:*  43 | 75 ± 7 | 72 | 24.0 ± 3.3 | Good |
| *Without Depression Group:*  52 | 74 ± 8 | 64 | 24.1 ± 3.8 |
| Kahn and Schwarzkopf (2015)48 | Longitudinal, observational | Radiographic; Knee | *Non-TKA group:*  395 | 64 ± 9 | 51 | 29.4 ± 4.8 | Fair |
| ‡Kloek et al., (2018)50 | Cluster RCT | ACR criteria; Hip and Knee | *Intervention Group:*  109 | 64 ± 9 | 68 | 27.8 ± 4.2 | Fair |
| *Control Group:*  99 | : 62 ± 9 | 68 | 27.9 ± 4.9 |
| Li et al., (2017)54 | RCT | Physician diagnosed; Knee | 34 | 56 ± 9 | 82 | 27.2 ± 4.7 | Good |
| Li et al., (2018)53 | Proof of concept RCT | Physician diagnosed; Knee | 61 | 62 ± 9 | 82 | 29.2 ± 5.1 | Good |
| Li et al., (2020)52 | RCT | Physician diagnosed; Knee | 51 | 65 ± 9 | 82 | 29.4 ± 7.7 | Good |
| Martire et al., (2013)57 | Retrospective cohort | Physician diagnosed; Knee | *OA Group:*  141 | 65 ± 10 | 57 | 31.4 ± 5.8 | Fair |
| †Master et al., (2018)58 | Longitudinal, observational cohort | Radiographic; Knee | 1925 | 65 ± 9 | 55 | 28.4 ± 4.8 | Fair |
| Moellenbeck et al., (2020)61 | Cross-sectional | Awaiting surgery; Hip and Knee | 32 | 70 ± 7 | 59 | 27.0 ± 3.8 | Poor |
| Nguyen et al (2022)64 | Prospective, cohort | NICE criteria; Knee | 253 | 62 ± 8 | 72 | 30.5 ± 6.7 | Fair |
| Oka et al., (2020)65 | Prospective, cohort | Radiographic; Knee | 82 | 72 ± 6 | 82 | 26.1 ± 3.7 | Good |
| Robbins et al., (2013)74 | Cross-sectional | ACR criteria, radiographic; Knee | 38 | 54 ± 7 | 26 | 30.4 ± 4.2 | Fair |
| Rosemann et al., (2008)75 | Descriptive | ACR criteria; Hip and Knee | *Men:*  347 | 65 ± 15 | 0 | 28.4 ± 4.3 | Fair |
| *Women:*  674 | 67 ± 15 | 100 | 28.1 ± 5.2 |
| Sliepen et al, (2018)81 | Cross-sectional | ACR criteria; Knee | 61 | 61 ± 10 | 56 | 27.3 ± 4.7 | Fair |
| †Thewlis et al., (2019)85 | Exploratory longitudinal | Awaiting surgery; Hip | 51 | 64 (range: 24 – 87) | NR | 30.0 (range: 18.6 -40.7) | Fair |
| Verlaan et al., (2015)87 | Case control | Awaiting surgery; End stage Knee | 30 | 69 ± 7 | 63 | 29.6 ± 5.7 | Fair |
| Vilardaga et al., 202288 | Feasibility RCT | NR; Hip and Knee | 39 | 72 ± 5 | 85 | NR | Good |
| †Webber et al., (2017)93 | Case control | Awaiting surgery; Knee | 32 | 70 ± 5 | 66 | 32.7 ± 6.7 | Fair |
| White et al., (2014)96 | Longitudinal, observational, cohort | Radiographic; Knee | *Radiographic Group:*  1003 | 68 ± 8 | 60 | 31.4 ± 6.2 | Fair |
| *Symptomatic Group*:  390 | 67 ± 8 | 64 | 32.1 ± 6.7 |
| White et al., (2017)95 | Longitudinal, observational, cohort | Radiographic; Knee | *Radiographic Group:*  1123 | 66 ± 9 | 54 | 29.0 ± 4.7 | Fair |
| *Symptomatic Group:*  480 | 65 ± 9 | 52 | 29.6 ± 4.8 |
| Zhaoyang et al., (2020)99 | Retrospective cohort | Physician diagnosed; Knee | 143 | 65 ± 10 | 58 | NR | Poor |

Data are present as mean ± standard deviation (SD), unless otherwise stated.

RCT, randomised control trial; ACR, American College of Rheumatology; NR, not reported; OA; osteoarthritis; NICE,National Institute for Health and Care Excellence.

a Data for participant characteristics (n=1223), data for final analysis (n=1111).

b Data for participant characteristics (n=73), Data for outcome measures (n=79)

† Mean and standard deviations were made available from the authors after data request

‡ Mean and standard deviation were not made available after data request.

**Table 2:** Summary of data collection methods and physical activity variables from the studies reporting physical activity outcomes.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Author (Year) | Device-Based Data Collection (Method, Wear Time) | Physical Activity Outcome (mins/week or steps/day) | | Self-Reported Data Collection (Method, Recall Period) | Physical Activity Outcome (mins/week) |
| Aunger et al., (2020)3 | Inclinometer; activPAL3; 3-7 days | Steps/day (n): 5088.3 ± 3374.1 | | NR | NR |
| Bartholdy et al., (2019)5 | Triaxial accelerometer; SENS-motion system; 6 weeks | *Intervention Group:*  Time spent in movement: 1802.5 ± 473.2c | | NR | NR |
| *Control Group:*  Time spent in movement: 1911.7 ± 466.2c | | NR | NR |
| Bartholdy et al., (2020)6 | Triaxial accelerometer; SENS-motion system; 9 weeks | Time spent in movement: 1601.6 ± 498.4c | | NR | NR |
| Bartholdy et al., (2020)7 | Triaxial accelerometer; SENS-motion system; 6 to 8 weeks | Time spent in movement: 1829.8 ± 522.9 | | NR | NR |
| Bennell et al., (2014)9 | Pedometer; HJ-005, Omron Healthcare; NR | *Intervention Group:*  Steps/day (n): 7186 ± 3870 | | NR | NR |
| *Control group:*  Steps/day (n): 7858 ± 3897 | |
| Bennell et al., (2017)8 | Inclinometer; activPAL Professional; 7 consecutive days | *Intervention Group:*  Steps/day (n): 8116 ± 2755 | | Active Australia Survey; 7-days | *Intervention Group:*  Total Activity: 277.0 ± 326.0 |
| *Control Group:*  Steps/day (n): 7879 ± 2750 | | *Control Group:*  Total Activity: 238.0 ± 229.0 |
| Bitar et al., (2020)10 | NR | NR | | Modified Activity Questionnaire; 12-month | MPA (n = 625): 234.0 ± 270.0c |
| Bossen et al., (2013)11 | Triaxial accelerometer; ActiGraph, Model GT3X; 5 consecutive days | *Intervention Group:*  Total PA: 2583.0 ± 2469.5 b,c | | NR | NR |
| *Control Group*:  Total PA: 2765.0 ± 2562.1b, c | | NR | NR |
| †Brandes et al., (2011)13 | Triaxial accelerometer; ADL McRoberts and Step activity monitor, SAM; 7 consecutive days | Steps/day (n): 9984 ± 4340 | | NR | NR |
| Caliskan et al., (2020)15 | Accelerometer; ActiCal; 7 consecutive days | Steps/day (n): 2528 ± 1665b  LPA: 123.2 ± 69.6b | | NR | NR |
| Chmelo et al., (2013)17 | Uniaxial accelerometer; Kenz Lifecorder EX, Model NL-2200; 7 consecutive days | Steps/day (n): 6209 ± 2554  LPA: 917.0 ± 273c  MPA: 70.0 ± 58.1c  MVPA: 74.2 ± 62.3c  VPA: 4.2 ± 11.2c | | NR | NR |
| Collins et al., (2019)19 | Triaxial accelerometer; ActiGraph, Model GT3X; 7 consecutives days | | *Wrist:*  Steps/day (n): 9131 ± 3349  MVPA: 299 ± 142c  *Hip:*  Steps/day (n): 5093 ± 2826d  MVPA: 112 ± 175 c,d | NR | NR |
| Triaxial accelerometer; Fitbit, Charge 2; 7 consecutive days | | Steps/day (n): 6732 ± 4155  MVPA: 70 ± 147c |
| Daugaard et al., (2018)21 | Triaxial accelerometer; X16-mini; 5.5 consecutive days | Steps/day (n): 7964 ± 2332 | | NR | NR |
| De Groot et al., (2008)22 | Triaxial accelerometer; ADXL, Model 201; 2 days | Movement-related activity:  osteoarthritis hip (n = 40): 889.0  osteoarthritis knee (n = 44): 819.0 | | NR | NR |
| De Hoop et al., (2020)44 | Triaxial accelerometer; ActiGraph, Model GT3X; 5 consecutives days | MVPA: 70 ± 100.1c | | NR | NR |
| aDunlop et al., (2011)26 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | *Men (n = 504):*  No to Very Light: 4257.4 ± 636.3c  LPA: 1835.4 ± 526.4c  MVPA: 144.9 ± 144.9c  VPA: 64.4 ± 102.9c | | NR | NR |
| *Women (n = 607):*  No to Very Light: 4100.6 ± 669.2c  LPA: 2017.4 ± 564.2c  MVPA: 86.1 ± 100.1c  VPA: 37.8 ± 76.3c | | NR | NR |
| Falck et al., (2018)30 | Triaxial multisensory body monitor; SenseWear Mini; 7 consecutive days | *Immediate Group:*  MVPA: 584.1 ± 425.6c | | NR | NR |
| *Delayed Group:*  MVPA: 603.3 ± 603.3c | | NR | NR |
| Farr et al., (2008)31 | Uniaxial accelerometer; MTI ActiGraph, Model 7164; 7 consecutive days | *Weekday:*  MPA (3.0–6.0 METS): 123.5 ± 89.5c  VPA (>6.0 METS): 5.0 ± 20.0c  MVPA (>3.0 METS): 129.6 ± 99.5c | | NR | NR |
| *Weekend:*  MPA: 41.6 ± 44.0c  VPA: 1.6 ± 6.4c  MVPA: 43.2 ± 47.2c | | NR | NR |
| Focht et al., (2014)33 | Accelerometer; LIFECORDER Plus; 7 consecutive days | *Control Group:*  Total PA: 352.5 ± 229.5  MVPA: 51.7 ± 70.0 | | NR | NR |
| *Intervention Group:*  Total PA: 351.0 ± 196.8  MVPA: 52.4 ± 63.3 | | NR | NR |
| †bFrimpong et al., (2019)35 | Triaxial accelerometer; ActiGraph, Model GT3X+; 7 consecutive days | Steps/day (n): 3677 ± 2650b  LPA: 1902.4 ± 824.5b  MVPA: 58 ± 144.7b | | NR | NR |
| Frimpong et al., (2020)34 | Uniaxial inclinometer; activPAL; 7 consecutive days | Steps/day (n): 2559 ± 1540  Stepping time: 553.0 ± 294.0c | | NR | NR |
| Gilbert et al., (2018)37 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | *Intervention Group:*  Activity time: 3551.1 ± 737.1c  MVPA: 159.1 ± 129.6c | | NR | NR |
| *Control Group:*  Activity time: 3293.5 ± 694.7c  MVPA: 121.4 ± 149.0c | | NR | NR |
| Herbolsheimer et al., (2016)40 | NR | NR | | Longitudinal Aging Study Amsterdam Physical Activity Questionnaire; 7-day recall | Total PA: 525.7 ± 499.1c |
| Hirata et al., (2006)42 | Uniaxial accelerometer; Lifecorder; 7 days | Steps/day (n): 6646 ± 2420  Total PA: 492.1 ± 172.2c  LPA: 372.4 ± 123.2c  MPA: 111.3 ± 80.5c  VPA: 8.4 ± 10.5c | | NR | NR |
| Holsgaard-Larsen et al., (2012)43 | Multisensory body monitor; SenseWear Pro2 Armband; 5 consecutive days | Steps/day (n): 6632 ± 3070  Time >3 METS (MVPA): 869.4 ± 508.2c | | NR | NR |
| Hoorntje et al., (2020)45 | Triaxial accelerometer; Activ8; 7 consecutive days | Active time:  1071.0 ± 392.0c | | NR | NR |
| Kahn and Schwarzkopf, (2016)48 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | LPA: 1967.6c  MPA: 115.2c  MVPA: 120.3c  VPA: 5.0c | | NR | NR |
| Ijima et al., (2020)46 | Pedometer; Yamax power Walker; EX-300; 14 consecutive days | *Depression Group:*  Steps/day (n): 4950 ± 2390 | | NR | NR |
| *Without Depression Group:*  Steps/day (n): 4073 ± 2661 | |
| ‡Kloek et al., (2018)50 | Accelerometer; ActiGraph, Model GT3x; 5 consecutive days | *Intervention Group:*  Total PA: 176.4 ± 161.7c | | Short Questionnaire to Assess Health Enhancing Physical Activity; 7-day | *Intervention Group:*  Total PA: 688.8 ± 828.8 |
| *Control Group:*  Total PA: 157.5 ± 152.6 | | *Control Group:*  Total PA: 749.0 ± 723.1 |
| Li et al., (2017)54 | Triaxial multisensory body monitor; SenseWear Mini; 7 consecutive days | *Immediate Group (n = 17):*  MVPA (≥3 METs)  10 mins: 289.1 ± 361.2c  MVPA (≥4 METs)  10 mins: 105.7 ± 195.3c | | NR | NR |
| *Delayed Group (n = 17):*  MVPA (≥3 METs)  10 mins: 465.5 ± 497.0c  MVPA (≥4 METs)  10 mins: 198.8 ± 324.1c | | NR | NR |
| Li et al., (2018)53 | Triaxial multisensory body monitor; SenseWear Mini; 7 days | *Immediate Group (n = 30):*  MVPA (3+ METS)  10 mins:  434.7 ± 382.2c  MVPA (4+ METS)  10 mins:  168.0 ± 216.3c  Steps/day (n): 7069.2 ± 3375.3 | | NR | NR |
| *Delayed Group (n = 31):*  MVPA (3+ METS)  10 mins:  457.1 ± 541.8c  MVPA (4+ METS)  10 mins:  117.6 ± 214.9c  Steps/day (n): 7556.6 ± 5054.1 | | NR | NR |
| Li et al., (2020)52 | Triaxial multisensory body monitor; SenseWear Mini; 7 days | *Immediate Group (n = 26):*  MVPA: 217.0 ± 261.1c  Purposeful PA: 77.7 ± 136.5c  Steps/day (n): 6294.0 ± 3418.0 | | NR | NR |
| *Delay Group (n = 25):*  MVPA: 499.1 ± 698.6c  Purposeful PA: 294.7 ± 561.4c  Steps/day (n): 7030.1 ± 3921.6 | | NR | NR |
| Martire et al., (2013)57 | Triaxial accelerometer; ActiGraph, Model GT1M or GT3X; 22 days | MPA: 451.2 ± 272.5c  Steps/day (n): 4329.5 ± 1998.2  Steps/min (n): 5.07 | | NR | NR |
| †Master et al., (2018)58 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | Steps/day (n): 6166 ± 2924 | | NR | NR |
| Moellenbeck et al., (2020)61 | Triaxial accelerometer; ActiGraph, Model wGTX3-BT; 4-7 days | Steps/day (n): 5484 ± 2313  MVPA: 270.5 ± 174.7c | | NR | NR |
| Nguyen et al., (2022)64 | NR | NR | | Short-form International Physical Activity Questionnaire; 7-days | Total PA (METs-min/week): 4997.3 ± 3565.6 |
| Oka et al., (2020)65 | Triaxial accelerometer; Active Style Pro, Model HJA-350IT; 7 days | Steps/day (n): 3724 ± 1996 | | NR | NR |
| Robbins et al., (2013)74 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | MVPA (cut-point 1041): 546.0 ± 259.0c  MVPA (cut-point 1952):  147.0 ± 105.0c | | NR | NR |
| Rosemann et al., (2008)75 | NR | NR | | Short-form International Physical Activity Questionnaire; 7-days | *Men*:  Total PA (METs-min/week): 2356.2 ± 1982.5  MPA (METs-min/week): 135.0 ± 159.1  VPA (METs-min/week): 112.0 ± 167.1  Walking (METS min/week): 277.8 ± 293.8 |
| *Women:*  Total PA (METS-min/week): 2108.3 ± 1879.6  MPA (METs-min/week): 99.2 ± 122.9  VPA (METs-min/week): 72.1 ± 113.4  Walking (METS min/week): 279.5 ± 288.6 |
| Vilardaga et al, (2022)88 | Accelerometer; Garmin VivoFit 4.0 consumer grade fitness tracker; 7 consecutive days | *Intervention Group:*  Total weekly steps/day (n): 5,102 ± 3920 | | NR | NR |
| *Control Group:*  Total weekly steps/day (n): 4024 ± 2988 | |
| Sliepen et al, (2018)81 | Triaxial accelerometer; AX3; 7 consecutive days | Steps/day (n): 7934 ± 2326  Time walking: 672.0 ± 168.0c | | NR | NR |
| †Thewlis et al., (2019)85 | Accelerometer; GeneActiv; 7 consecutive days | LPA: 1512.0 ± 1020.4b, c  MPA: 315.0 ± 572.4b, c  VPA: 1.4 ± 5.1b, c | | NR | NR |
| Verlaan et al., (2015)87 | Triaxial accelerometer; Gcdataconcept; 4 consecutive days | Steps/day (n): 4402 ± 2960 | | Short Questionnaire to Assess Health Enhancing Physical Activity; 7-days | Total PA: 3085 ± 2236 |
| †Webber et al., (2017)93 | Triaxial accelerometer; ActiGraph, Model GT3X+; 7 consecutive days | Step/day (n): 4145 ± 2055  LPA (Freedson cut-point): 1848.0 ± 513.1c  MVPA (Freedson cut-point): 17.01 ± 41.44c  MVPA (Lifestyle cut-point): 175.7 ± 202.3c | | NR | NR |
| White et al., (2014)96 | Activity monitor; StepWatch Activity Monitor; 7 consecutive days | *Radiographic Group:*  Steps/day (n): 6823 ± 2868 | | NR | NR |
| *Symptomatic Group:*  Steps/day (n): 6476 ± 2613 | |
| White et al., (2017)95 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | *Radiographic Group:*  LPA: 1962.1 ± 553.0c  MVPA: 116.2 ± 126.0c | | NR | NR |
| *Symptomatic Group:*  LPA: 1950.9 ± 569.8c  MVPA: 109.2 ± 117.6c | |
| Zhaoyang et al., (2020)99 | Triaxial accelerometer; CSA/MTI ActiGraph, Model GT1M or GT3X; 22 consecutive days | MVPA: 487.2 ± 302.4c | | NR | NR |

Data are present as mean ± SD, unless otherwise stated; data are presented as minutes a week (mins/week) for PA.

N, number; NR, not reported; mins/week, minutes a week; MET, metabolic equivalent of task; METs-min/week, metabolic equivalent minutes a week; steps/day, steps per day; mins, minutes; PA, physical activity; MVPA, moderate-to-vigorous physical activity; VPA, vigorous physical activity.

a Data for participant characteristics (n=1223), data for final analysis (n=1111).

b Data were converted from means and 95% confidence intervals to means ± SD

c Data were converted to mins/week

d Data were combined and averaged as two values were reported for ActiGraph worn on the hip

† Mean and standard deviations were made available from the authors after data request

‡ Mean and standard deviation were not made available after data request.

**Table 3:** Summary of data collection methods and sedentary behaviour variables from the studies reporting sedentary behaviour outcomes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Author (Year) | Device-Based Data Collection (Method, Wear Time) | Mean ± SD Sedentary Outcome (hrs/day or number (n)) | Self-Report Data Collection (Method; Recall Period) | Mean ± SD Sedentary Outcome (hrs/day) |
| Aunger et al., (2020)3 | Inclinometer; activPAL3; 3-7 days | 9.8 ± 1.9c  Time spent in sitting bouts:  >30mins: 5.3 ± 2.4c  >60mins: 2.9 ± 2.3c | The Measure of Older Adults Sedentary Time Questionnaire; 7 days | 8.9 ± 2.9c |
| Bartholdy et al., (2019)5 | Triaxial accelerometer; SENS-motion system; 6 weeks | *Intervention Group:*  17.5 ± 1.6c | NR | NR |
| *Control Group:*  17.5 ± 1.6c | NR | NR |
| Bartholdy et al., (2020)6 | Triaxial accelerometer; SENS-motion system; 9 weeks | 18.0 ± 1.9c | NR | NR |
| Bartholdy et al., (2020)7 | Triaxial accelerometer; SENS-motion system; 6 to 8 weeks | 17.6 ± 1.6 | NR | NR |
| Bitar et al., 202010 | NR | NR | Modified Activity Questionnaire; 12-month | (n = 644): 4.1 ± 2.3 |
| Bossen et al., (2013)11 | Triaxial accelerometer; ActiGraph, Model GT3X; 5 consecutive days | *Intervention Group:*  9.5 ± 6.3b,c | NR | NR |
| *Control Group:*  9.3 ± 6.3b,c | NR | NR |
| Collins et al., (2019)19 | Triaxial accelerometer; ActiGraph, Model GT3X; 7 consecutives days | *Wrist:*  2.3 ± 1.3  *Hip:*  6.7 ± 1.9d | NR | NR |
| Triaxial accelerometer; Fitbit, Charge 2; 7 consecutive days | 8.5 ± 2.2 |
| Deguchi et al., (2022)23 | NR | NR | The Measure of Older Adults Sedentary Time Questionnaire; 7 days | 8.1 ± 3.1c |
| De Hoop et al., (2020)44 | Triaxial accelerometer; ActiGraph, Model GT3X; 5 consecutives days | Total SB (2-minute bouts): 6.2 ± 1.5  Total prolonged SB (30-minute bouts): 2.2 ± 1.4 | NR | NR |
| Falck et al., (2018)30 | Triaxial multisensory body monitor; SenseWear Mini; 7 consecutive days | *Immediate Care Group:*  >20 mins SB: 11.4 ± 1.9c | NR | NR |
| *Delayed Care Group:*  >20 mins SB: 11.7 ± 2.7c |
| †aFrimpong et al., (2019)35 | Triaxial accelerometer; ActiGraph, Model GT3X+; 7 consecutive days | 10.8 ± 2.1b  Breaks per day from SB (n): 85.2 (95% CI 80.4 – 90.1)  Duration of breaks (mins/break): 3.2 (95% CI 3.0-3.5) | NR | NR |
| Frimpong et al., (2020)34 | Uniaxial inclinometer; activPAL; 7 consecutive days | Sitting time: 9.1 ± 3.2d | NR | NR |
| Holsgaard-Larsen et al., (2012)43 | Multisensory body monitor; SenseWear Pro2 Armband; 5 consecutive days | 21.1 ± 1.2 | NR | NR |
| Hoorntje et al., (2020)45 | Triaxial accelerometer; Activ8; 7 consecutive days | 10.7 ± 1.9 | NR | NR |
| ‡Kloek et al., (2018)50 | Accelerometer; ActiGraph, Model GT3x; 5 consecutive days | *Intervention Group:*  8.3 ± 3.4b,c | NR | NR |
| Accelerometer; ActiGraph, Model GT3x; 5 consecutive days | *Control Group:*  8.6 ± 3.3 |
| Li et al., (2017)54 | Triaxial multisensory body monitor; SenseWear Mini; 7 consecutive days | *Immediate Group (n = 17):*  Sedentary time >20 mins: 9.1 ± 2.8c | NR | NR |
| *Delayed Group (n = 17):*  Sedentary time >20 mins: 7.6 ± 3.0c | NR | NR |
| Li et al., (2018)53 | Triaxial multisensory body monitor; SenseWear Mini; 7 days | *Immediate Group (n = 30):*  Sedentary time >20 mins: 7.7 ± 2.3c | NR | NR |
| *Delayed Group (n = 31):*  Sedentary time >20 mins: 8.3 ± 3.3c | NR | NR |
| Li et al., (2020)52 | Triaxial multisensory body monitor; SenseWear Mini; 7 days | *Immediate Group (n = 31):*  Sedentary time > 20 mins:  9.5 ± 3.1c | NR | NR |
| *Delayed Group (n = 31):*  Sedentary time > 20 mins:  9.2 ± 3.9c | NR | NR |
| Moellenbeck et al., (2020)61 | Triaxial accelerometer; ActiGraph, Model wGTX3-BT; 4-7 days | 5.1 ± 2.0c | NR | NR |
| Rosemann et al., (2008)75 | NR | NR | Short-form International Physical Activity Questionnaire; 7-days | *Men:*  Sitting time: 5.1 ± 2.1c |
| *Women:*  Sitting time: 5.9 ± 2.4c |
| Sliepen et al, (2018)81 | Triaxial accelerometer; AX3; 7 consecutive days | Time spent sitting: 8.9 ± 1.8  Sedentary periods (n):  0-10s: 3.6 ± 2.7  10-60s: 15.4 ± 9.1  1200-1800s: 2.6 ± 0.9  1800s: 4.6 ± 1.7 | NR | NR |
| †Thewlis et al., (2019)85 | Accelerometer; GeneActiv; 7 consecutive days | >30 mins SB: 10.3 ± 1.9c  Sedentary bout length (min/bout): 50 ± 7  Sedentary bouts  30 mins (n): 8.0 ± 2.5 | NR | NR |
| Verlaan et al., (2015)87 | Triaxial accelerometer; GCdataconcepts; 4 consecutive days | Sitting events < 1min (n): 8 ± 3  Sitting events > 1 min (n): 29 ± 13 | NR | NR |
| †Webber et al., (2017)93 | Triaxial accelerometer; ActiGraph, Model GT3X+; 7 consecutive days |  30 mins bouts: 9.3 ± 1.4 | Sedentary and Light Intensity Physical Activity Log – Sedentary Behaviour; 7-days | (n = 28): 7.2 ± 2.7 |
| Longitudinal Aging Study Amsterdam Physical Activity Questionnaire; 7-days | (n = 23): 11.2 ± 4.1 |
| White et al., (2017)95 | Uniaxial accelerometer; ActiGraph, Model GT1M; 7 consecutive days | *Radiographic Group:*  9.8 ± 1.5c | NR | NR |
| *Symptomatic Group:*  9.8 ± 1.6c | NR | NR |
| Zhaoyang et al., (2020)99 | Triaxial accelerometer; CSA/MTI ActiGraph, Model GT1M or GT3X; 22 consecutive days | 9.6 ± 1.5 | NR | NR |

Data are present as mean ± SD, unless otherwise stated; data are presented as hours a day (hrs/day) for SB values unless otherwise stated.

CI, confidence interval; N, number; NR, not reported; hrs/day, hours a day; mins/break, minutes per break; mins, minutes; SB sedentary behaviour.

a Data for outcome measures (n=79), data for participant characteristics (n=73)

b Data were converted from means and 95% confidence intervals to means ± SD

c Data were converted to hrs/day

d Data were combined and averaged as two values were reported for Actigraph worn on the hip

† Mean and standard deviations were made available from the authors after data request

‡ Mean and standard deviation were not made available after data request.

**Table 4:** Calculated averages for physical activity and sedentary behaviour variables for device-based and self-reported methods from mean data reported in the included studies.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PA and SB Variables | Device-Based | Range of Reported Means; Device-Based (min - max) | Self-Reported | Range of Reported Means; Self-Reported (min - max) |
| *Physical Activity* | | | | |
| Total PA (mins/week) | 1232.6 ± 694.0 | 77.7 - 3551.0 | 927.3 ± 807.0 | 238.0 – 3085.0 |
| Light-intensity PA (mins/week) | 1492.3 ± 500.7 | 123.2 - 2017.4 | NR | NR |
| Moderate PA (mins/week) | 204.6 ± 233.4 | 70.0 - 451.2 | 234.0 ± 270.0 | NA |
| Moderate-to-vigorous PA (mins/week) | 260.6± 245.5 | 17.0 - 869.4 | NR | NR |
| Vigorous PA (mins/week) | 18.3 ± 38.7 | 1.4 - 64.4 | NR | NR |
| Step count (steps/day) | 6060 ± 2880 | 2528 - 9984 | NR | NR |
| *Sedentary Behaviour* | | | | |
| Total SB (hrs/day) | 10.6 ± 2.5 | 5.1-21.1 | 7.9 ± 3.0 | 4.1 - 11.2 |
| Sitting time (hrs/day) | 6.2 ± 2.4 | 2.9-9.1 | 5.2 ± 2.3 | 5.1 - 5.9 |

PA, physical activity; SB, sedentary behaviour; mins/week, minutes a week; steps/day, steps per day; hrs/day, hours per day; min, minimum mean value reported; max, maximum mean value reported; NR, not reported; NA, not applicable.

**Figures**

Studies identified from:

PUBMED (n = 778)

Science Direct (n = 25)

Cochrane (n= 714)

CINAHL (n= 413)

Total records: 1930

Studies removed *before screening*:

Duplicate studies removed

(n = 265)

**Identification of studies via databases and registers**

**Identification**

Studies screened – title and abstract (n = 1665)

Studies excluded

(n = 1422)

Studies excluded:

No quantitative time values for PA and/or SB (n = 76)

Did not identify LL OA population or included RA (n = 22)

Protocol papers (n = 15)

Review studies (n = 3)

Included an ‘at risk’ of an OA population without diagnosis (n = 7)

Included data from a joint replacement population (n = 9)

Same cohort data (n = 15)

Abstracts or unpublished studies (n= 41)

Unable to obtain full text or raw data on request (n = 8)

Ongoing trial (n = 6)

Full article not available in in English (n = 2)

Studies retrieved for full text screening

(n = 243)

**Screening**

Total excluded from full text (n = 204)

Additional studies from manual searches (n = 9)

**Included**

Studies included in review

(n = 48)

**Figure 1:** PRISMA flow diagram for study selection

PA, physical activity; SB, sedentary behaviour; LL, lower limb; RA, rheumatoid arthritis; OA, osteoarthritis; n, number.