Effect of exercise snacks on fitness and cardiometabolic health in physically inactive individuals: systematic review and meta-analysis

Miguel Ángel Rodríguez [1], Marcos Quintana-Cepedal,[1] Boris Cheval,[2] Cecilie Thøgersen-Ntoumani [3,4] Irene Crespo [5] Hugo Olmedillas [1,5]

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[1]Asturian Research Group in Performance, Readaptation, Training and Health (AstuRES), University of Oviedo, Oviedo, Spain
[2]Université de Rennes, École normale supérieure de Rennes, VIPS2, F-35000 Rennes, France
[3]Danish Centre for Motivation and Behaviour Science (DRIVEN), Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Syddanmark, Denmark
[4]School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, UK
[5]Department of Functional Biology, University of Oviedo, Oviedo, Spain

Correspondence to
Dr Hugo Olmedillas; olmedillashugo@uniovi.es

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ABSTRACT

Objectives To evaluate the effects of brief bouts of exercise spread throughout the day, termed 'exercise snacks', on cardiorespiratory and muscular fitness, and cardiometabolic health outcomes in physically inactive adults and older adults (aged ≥65 years).
Design Systematic review and meta-analysis.
Data sources Seven databases were searched from inception to April 2025.
Eligibility criteria Randomised controlled trials (RCTs) of adults and older adults, comparing exercise snacks with non-exercising controls.
Results 11 RCTs (n=414; 69.1% women, mean age 18.7±0.8 to 74.2±5.6 years) were included. Exercise snacks were defined as structured bouts lasting ≤5 min, performed at least twice daily, ≥3 times/week, for ≥2 weeks. The interventions varied in duration (4–12 weeks), frequency (3–7 days/week) and intensity (moderate-to-vigorous to near-maximal). Exercise snacks significantly improved cardiorespiratory fitness in adults (g=1.37, 95% CI 0.58 to 2.17; p<0.005; I^2=71.4 %, k=6) and muscular endurance in older adults (g=0.40, 95% CI 0.06 to 0.75; p=0.02; I^2=0 %, k=4), with moderate and very low certainty of evidence, respectively. No significant effects were observed for lower limb muscular strength or cardiometabolic outcomes, including body composition, blood pressure and blood lipid profiles. High compliance (91.1%) and adherence (82.8%) rates were observed.
Conclusions Moderate certainty of evidence indicated that exercise snacks improved cardiorespiratory fitness in physically inactive adults. However, evidence for benefits on muscular endurance in older adults was limited, and the current data do not support their effectiveness for improving other cardiometabolic health markers.
PROSPERO registration number CRD42024616514.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Globally, 31% of adults fail to meet recommended physical activity levels.
⇒ According to the WHO's principle that 'every move counts', even short bouts of physical activity contribute to health benefits.

WHAT THIS STUDY ADDS

⇒ Exercise snacks may be a time efficient alternative for improving cardiorespiratory fitness in physically inactive adults and muscular endurance in older adults.
⇒ Adherence rates for exercise snacks were notably high (82.8%), highlighting the potential feasibility and acceptability of this approach in real world unsupervised settings.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The time efficient nature of exercise snacks may help overcome common barriers to physical activity, such as perceived lack of time and low motivation.
⇒ Exercise snacks may enhance adherence to regular physical activity by providing short, flexible exercise bouts that are easier to integrate into daily routines.

INTRODUCTION

Physical inactivity is a critical global public health challenge, with the WHO estimating that approximately 1.8 billion adults are at increased risk of non-communicable diseases due to insufficient levels of physical activity (PA).[1] Despite the extensive and well documented benefits of regular PA, global participation rates remain alarmingly low. Currently, 31% of adults and 80% of adolescents fail to meet the minimum recommended PA levels.[1 2] These data underscore not only the widespread prevalence of physical inactivity but also the pressing need for evidence based interventions that can drive sustainable behavioural change.

One of the most commonly cited barriers to PA engagement is a perceived lack of time,[3–5] which may be influenced by individual perceptions or factors other than actual time constraints.[6] Emerging evidence suggests that substantial health benefits can be achieved with even minimal PA engagement, particularly among those transitioning from complete inactivity to modest levels of activity.[7 8] Engaging in as little as 10–59 min of PA per week has been associated with an 18% reduction in all cause mortality.[9] Similarly, achieving even half of the recommended weekly PA volume (150–300 min/week of moderate or 75–150 min/week of vigorous intensity PA)[10] confers significant mental health benefits, including an 18% lower risk of depression.[11] These findings highlight the potential of low volume, accessible PA strategies to produce significant health benefits, particularly among physically inactive adults.

Recent research has found no significant difference in health benefits between PA accumulated in short, sporadic bouts throughout the day and that performed in continuous sessions.[12] This paradigm

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shift has led to the emergence of innovative approaches such as 'exercise snacks'[13] and 'vigorous intermittent lifestyle PA' (VILPA).[14] Exercise snacks are intentionally structured, short duration bouts of PA, such as stair climbing or body weight exercises, that are deliberately incorporated into daily routines.[15] Snacktivity encourages the accumulation of short PA bouts (2–5 min) to achieve recommended weekly activity targets.[16] In contrast, VILPA refers to brief, intermittent bursts of vigorous activity that occur during daily tasks, such as carrying heavy groceries or brisk walking.[14] Conceptually, VILPA could be viewed as an incidental subtype of exercise snacks that relies entirely on the opportunities presented by daily life. While all of these strategies prioritise simplicity and adaptability, aligning with the WHO's 'every move counts' philosophy,[10] they differ in their delivery: exercise snacks are planned and structured, whereas VILPA is unplanned and integrated into everyday life.

Both exercise snacks and VILPA have demonstrated potential benefits for cardiometabolic health and can mitigate some of the negative effects of prolonged sitting.[15] Epidemiological evidence links engaging in <5 min of VILPA per day to a 40% reduction in the risk of all cause and cancer specific mortality.[17] However, while exercise snacks are conceptually broader and more flexible, they lack standardised definitions of duration, intensity or frequency, which complicates their evaluation in both research and practice.[18 19]

Despite their potential, evidence for the effectiveness of exercise snacks remains limited, with most studies relying on quasi-experimental designs or qualitative analyses. To fill this gap, the aim of this meta-analysis was to evaluate randomised controlled trials (RCTs) that examined the effects of exercise snacks on cardiorespiratory fitness (CRF), muscular fitness and cardiometabolic health outcomes. By synthesising the available evidence, our aim was to clarify the role of exercise snacks as a practical, scalable strategy to address physical inactivity and its associated health burden, even in the absence of adherence to traditional PA guidelines.

METHODS

This systematic review and meta-analysis followed the methodological framework established by Cochrane,[20] and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[21] The protocol was publicly preregistered in PROSPERO (CRD42024616514).

Search strategy

The initial search was conducted from inception to November 2024 and included seven electronic databases: PubMed/Medline, Scopus, Web of Science, PsycINFO, SPORTDiscus, Embase (via Cochrane Library), and CINAHL. Reference lists of the included articles were also searched for additional studies. No language or publication date restrictions were imposed. The following terms were combined using the Boolean operator "OR": ("exercise snack*" OR "movement snack*" OR "snacktivity" OR "movement break*" OR "physical activity break*" OR "active break*" OR "vigorous intermittent lifestyle physical activity" OR "VILPA" OR "exercise snacking" OR "interrupting prolonged sitting' OR "sedentary interruptions" OR "micro workout*" OR "short exercise bout*" OR "accumulated exercise" OR 'stair climbing" OR "exercise burst*" OR "physical activity burst*" OR "breaking sedentary time"). A secondary database search was performed in April 2025, and one additional study was included. Details of the search strategy for each database are shown in online supplemental material 1.

Selection criteria

Studies involving adults and older adults were included.

Intervention

RCTs including exercise snacks were selected. We defined exercise snacks as bouts of moderate-to-vigorous intensity where the effective exercise time, excluding warm-up, cool-down and intermediate recovery periods, was ≤5 min. To avoid confusion with high intensity interval training (HIIT) protocols, which are typically performed once a day, our inclusion criteria specified at least two bouts per intervention day. To examine the medium and long term effects, we decided to include only studies with interventions lasting >2 weeks. The comparator was required to be a control group that did not engage in physical exercise intervention.

Outcome measures

The primary outcomes assessed in this systematic review were CRF, muscular strength and endurance, blood lipid profiles (total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C) and triglycerides), and body composition measures, such as body mass index, body fat percentage and regional fat distribution (visceral and subcutaneous fat). Secondary outcomes were balance, blood pressure, mental health and wellbeing outcomes, including anxiety, depressive symptoms, vitality and life satisfaction, and compliance/adherence to the interventions.

Data management and selection procedure

Searches were combined in Zotero and duplicates were removed. One reviewer (MAR) conducted an initial search to identify potential studies for inclusion. Two reviewers (MAR and HO) independently screened the titles and abstracts to determine eligibility. Full texts of potentially eligible studies were retrieved and independently assessed for inclusion by two reviewers (MAR and MQ-C). Any discrepancies were resolved through discussion until consensus was reached. A third reviewer (IC) was available to adjudicate disagreements; however, no instances required discussion for resolution.

Data extraction and risk of bias assessment

The following data were extracted from each study: authors and year of publication, participant characteristics (such as sex, age and body mass index), details of the intervention, including the exercise protocol (frequency, intensity, time, type and density (defined as the temporal distribution of bouts within a day[22]) and control group, main outcome measures and statistically significant between group differences. Mean compliance and adherence to interventions were extracted, and the mean was calculated as follows:

$$Weighted\ mean = \frac{\sum(\mathrm{xi{\cdot}wi})}{\sum \mathrm{i}}$$

where x_i represents each individual value, w_i denotes the weight associated with each value (number of participants), $\sum(x_i.w_i)$ is the sum of the products of each value and its corresponding weight and $\sum w_i$ is the sum of all the weights. Risk of bias of the studies was assessed by two researchers (MAR and MQ-C) using the Cochrane revised tool (RoB-2),[23] with conflict resolved by consensus.

Certainty of evidence

The certainty of the evidence was evaluated following the Grading of Recommendations, Assessment, Development and

Evaluation (GRADE) approach.[24] This evaluation was conducted independently by two authors (MAR and MQ-C).

The certainty of the evidence was classified as high, moderate, low or very low. Because all of the studies included in the review were RCTs, the initial certainty of evidence was rated as high. This rating was adjusted based on the confidence in the effect estimate, considering factors such as risk of bias, result inconsistency, indirectness of the evidence and imprecision. Quality was downgraded to moderate, low or very low when one of the following factors was rated as serious or very serious: risk of bias,[25] inconsistency,[26] indirectness,[27] imprecision[28] or publication bias. Publication bias was accepted due to $k<10$ in all meta-analyses, which prevented us from performing the Egger's regression test or visually inspecting funnel plots to evaluate asymmetry. Criteria used for downgrading evidence are detailed in online supplemental material 2.

Data synthesis and analysis

All data analyses were conducted using R V.4.3.3 (The R Foundation for Statistical Computing), with the 'meta' package.[29] Means (SDs) were used, with imputations performed when necessary according to the Cochrane guidelines.[20] For missing SDs, the following formula was applied:

$$SD\ change = \sqrt{SD^2 baseline + SD^2 final - (2 \cdot corr \cdot SD\ baseline \cdot SD\ final)}$$

Effect sizes with 95% CIs were calculated from the comparison of the original data using the change score from the exercise snack and control groups.[30]

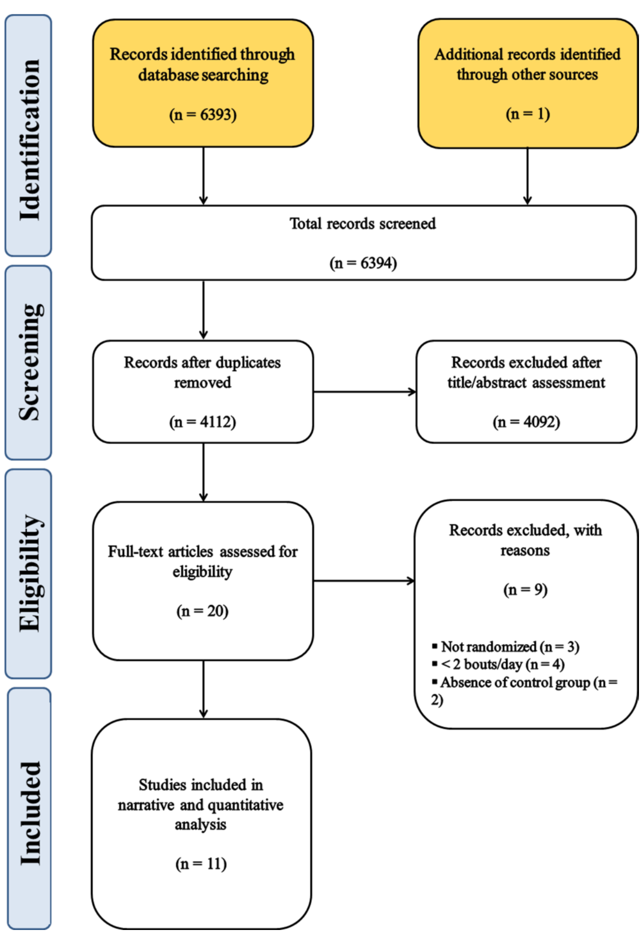

Figure 1 Flowchart of the study selection process.

Two different effect sizes were used: mean difference (MD) was applied for variables measured on the same scale across all studies (muscular strength, TC, HDL-C, LDL-C, TC:HDL-C ratio, triglycerides and systolic and diastolic blood pressure), while Hedge's g (g) was used when variables with different units were pooled (CRF, muscular endurance and body fat). MD (for outcomes measured on the same scale) or standardised mean difference (g) and 95% CIs were estimated using a random effects model. Statistical heterogeneity was assessed using I^2.[31] When substantial heterogeneity was detected ($I^2 > 50\%$), subgroup and sensitivity analyses were conducted to explore potential sources of this heterogeneity.[32] In cases where the results showed significant heterogeneity, the study responsible for this was excluded, and both sets of results are presented. Effect sizes were classified as small (≤0.4), moderate (0.5–0.7) or large (≥0.8).[33] Finally, meta-regression was performed to assess the impact of compliance rate as a potential effect modifier when a minimum of five studies were available.

Protocol deviations

Several deviations from the original PROSPERO protocol occurred and are clarified here. We added a certainty of evidence evaluation (GRADE approach) to strengthen methodological rigour, although it was not initially planned. We also conducted subgroup analyses, sensitivity analyses and a meta-regression on compliance rates in response to observed heterogeneity, despite these not being pre-specified.

The evaluation of acceptability, safety and cost effectiveness could not be performed due to insufficient data. Regarding the population, we excluded children to reduce heterogeneity and improve clinical applicability, and no eligible studies in active individuals were identified. For the intervention, we expanded the maximum exercise snack duration to 5 min, in line with emerging literature.[19] Finally, only studies with non-exercising comparators were included.

Equity, diversity and inclusion statement

This systematic review and meta-analysis included adults and older adults of any nationality, sex, gender or age. We aimed to investigate the effects of sex on outcomes, but the lack of sex disaggregated data in the studies prevented this analysis. Our diverse research team is composed of two women and four men and includes both early and senior career researchers with different nationalities and languages, reflecting a wide range of experiences and backgrounds.

RESULTS

Search results and overview

As shown in figure 1, the search strategy gave 6393 records. One study was retrieved from other sources. After removing duplicates, 2282 studies were excluded, followed by the exclusion of 4092 studies based on title and/or abstract screening. The full texts of the remaining 20 articles were reviewed, resulting in the exclusion of nine publications. Reasons for exclusion were: non-RCT design,[34–36] <2 bouts per day of intervention[37–40] and absence of a non-exercise control group.[41 42] Finally, 11 RCTs met the eligibility criteria and were selected for narrative and statistical analysis.[43–53] A summary of the characteristics of the included studies is provided in online supplemental material 3.

Study characteristics

Participant characteristics

A total of 414 participants were included in the narrative analysis. The number of participants ranged from 15[45] to 90.[51] Two studies included only women,[44 45] while the remaining investigations assessed samples of men and women.[46–49] Four studies focused on older adults.[43 50–52] A combined total of 127 men and 286 women were enrolled in the studies. Mean age of participants ranged from 18.7±0.8[45] to 74.2±5.6[51] years. Participants were sedentary or physically inactive individuals, with body mass index values ranging from normal weight[45 46 48] to overweight and obese classifications.[43 47 49–53] Two studies did not report body mass index values.[44 50]

Intervention and control characteristics

Investigations took place in Australia,[43] Canada,[46] China[48,49] and the UK.[44 45 47 50–53] Interventions varied in duration from four[43 50 52] to 12 weeks[49 51 53] (mean duration 7.5 weeks) and were conducted in university,[44 45 48] laboratory,[46 49] workplace[47] and home settings.[43 50–53] Six of the studies were conducted under supervision,[44–49] while the remaining five were unsupervised.[43 50–53]

The exercise protocols implemented across the included studies varied in frequency, intensity, time (duration), type and density. Protocols were performed 3,[48] 4,[49] [44–47]5 or 7 days per week.[43 50–53] Exercise bouts per day ranged from 2[43 50–52] to 10.[53] Intensity levels were protocol specific and included moderate-to-vigorous efforts[44 45 47] or near-to-maximal exertion[46 48 49] for adults. One study did not specify the intensity.[53] For older adults, the protocols emphasised performing 'as many repetitions as possible'.[43 50–52] Time per bout varied from 14 to 20 s[46] to a maximum of 5 min of effective exercise time.[43 50–53] The types of exercises for adults mainly consisted of stair climbing, either as continuous bouts[44 45 47–49] or repeated intervals into a bout.[46] Leg focused strength exercises and tai chi movements were the dominant forms of activity among older .[43 50–52] Density was either explicitly reported or inferred from the protocol descriptions, typically allowing sufficient recovery periods between exercise bouts (≥1 hour). Control groups varied across the studies, with most control groups maintaining their usual PA levels and refraining from structured exercise interventions.

Outcome measures

Online supplemental material 3 shows an overview of the outcome measures included in the studies. Six studies assessed CRF, using maximal oxygen uptake (VO_2max),[45 47 49] peak oxygen uptake (VO_2peak)[46 48] or oxygen uptake (VO_2).[44] Figure 2 illustrates the percentage change in CRF observed in the intervention and control groups. Four studies evaluated lower limb muscular strength and endurance using the five times sit-to-stand (5-STS) and 30/60-STS test, respectively.[43 50–52] These studies also included balance assessments. One study assessed lower limb muscle strength using a dynamometer in a squatting position.[53] Three studies measured blood lipids,[44 45 47] while body fat was evaluated in five studies.[44 47–49 52] Two studies included mental health and wellbeing measures, assessing symptoms of anxiety

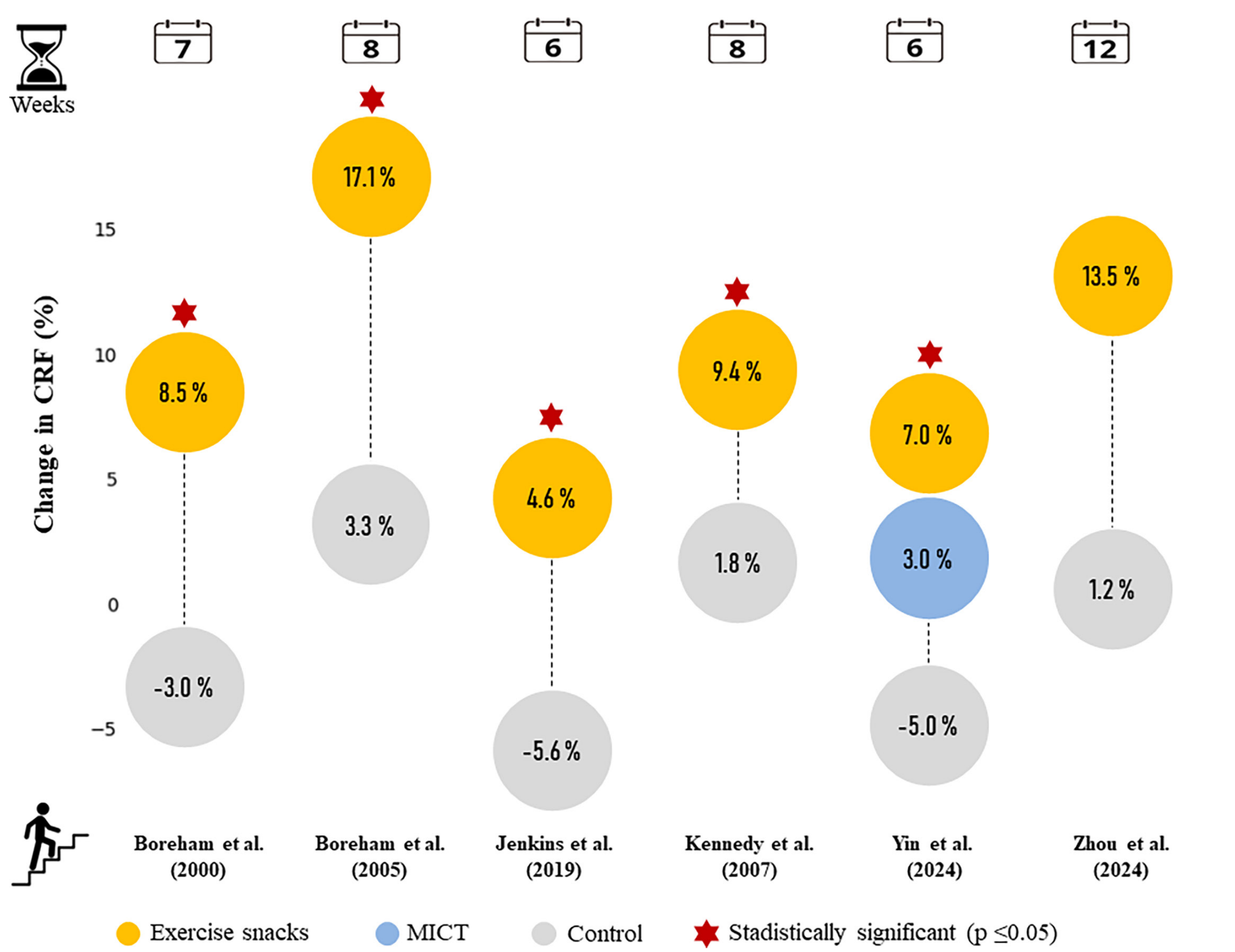

Figure 2 Percentage changes in cardiorespiratory fitness (CRF) from baseline following exercise interventions. Bars represent the mean percentage change in CRF for each group: exercise snacks, moderate intensity continuous training (MICT) and control. Intervention duration (weeks) is indicated above each bar. A red asterisk denotes a statistically significant difference in favour of the exercise snacks group (p≤0.05).

and depression.[50 53] Six studies reported compliance with the intervention,[44–49] while five studies reported adherence.[43 50–52] The participant weighted mean compliance rate was 91.1%, while the corresponding adherence rate reached 82.8%.

Risk of bias

The risk of bias rating for each study is provided in online supplemental material 4. Overall, most studies were rated as having 'some concerns', primarily due to issues in the randomisation process (D1) and deviations from intended interventions (D2). In contrast, the risk of bias due to missing outcome data (D3) and selective reporting (D5) was generally low across studies. When outcome level specific risk of bias was performed, the muscular strength outcome from Daley *et al*[53] was identified as having a potentially higher risk of bias due to notable missing data (14 participants in the exercise snacks group vs 9 in the control group).

Importantly, no study was judged as high risk in any domain, and all included studies had at least two domains rated as low risk. While domain specific concerns did not result in the exclusion of any study, they were considered in the interpretation of findings and addressed in the GRADE assessment. In this regard, the presence of some methodological limitations contributed to downgrading the certainty of evidence in several outcome domains.

Meta-analysis

In comparison with the control groups, exercise snacks significantly increased CRF (g=1.37, 95% CI 0.58 to 2.17; $p<0.005$; I^2=71.4%, k=6). After examining the forest plot, one outlier was identified. After the study by Boreham *et al*[44] was removed from the analysis, heterogeneity was reduced (g=1.02, 95% CI 0.61 to 1.43; $p<0.001$; I^2=0%, k=5) and similar results were obtained (figure 3). Exercise snacks also showed a significant improvement in muscular endurance, although the effect size was limited (g=0.40, 95% CI 0.06 to 0.75; p=0.02; I^2=0%, k=4). No statistically significant between group differences were observed for muscular strength (g=0.33, 95% CI −0.09 to 0.76; p=0.13; I^2=40%, k=4). For the remaining outcomes, our meta-analysis did not show statistically significant differences for TC (MD=0.09, 95% CI −0.24 to 0.43; p=0.57; I^2=42.7%, k=3), HDL-C (MD=0.01, 95% CI −0.15 to 0.17; p=0.9; I^2=39.4%, k=3), LDL-C (MD=0.15, 95% CI −0.23 to 0.53; p=0.43; I^2=64.6%, k=3), TC:HDL-C ratio (MD=0.21, 95% CI −0.23 to 0.65; p=0.34; I^2=26.8%, k=3), body fat (g=0.12, 95% CI −0.22 to 0.45; p=0.49; I^2=0 %, k=5), triglycerides (MD=−0.02, 95% CI −0.22 to 0.17; p=0.79; I^2=0%, k=2), systolic blood pressure (MD=−0.47, 95% CI −3.67 to 2.72; p=0.77; I^2=0%, k=3) and diastolic blood pressure (MD=1.4, 95% CI −1.04 to 3.85; p=0.28; I^2=0%, k=3). Means, SDs and units of measurement for each outcome included in the meta-analyses are presented in online supplemental material 5.

Meta-regression

Compliance rate was not a significant moderator of the relationship between exercise snack interventions and CRF (p=0.82). No meta-regression was performed for any other outcome due to insufficient number of studies available.

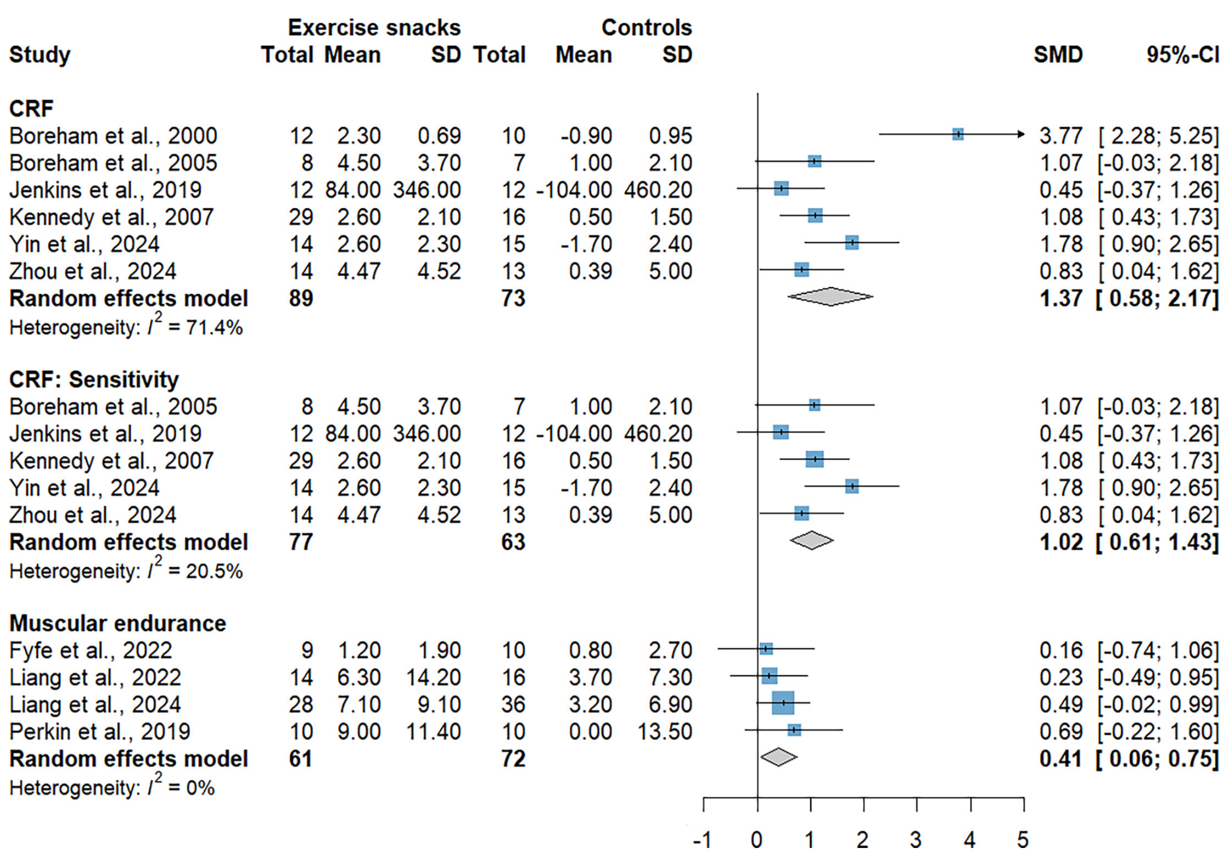

Figure 3 Forest plot summarising the effects of exercise snacks compared with control conditions on cardiorespiratory fitness (CRF), CRF sensitivity analysis and muscular endurance. Data are presented as standardised mean differences (SMD) with 95% CI using a random effects model. Positive values favour the exercise snack intervention. Heterogeneity across studies was quantified using the I² statistic.

Certainty of evidence

The certainty of evidence was low for CRF (moderate after performing the sensitivity analysis) and very low for the remaining outcomes. The GRADE evidence profile is presented in online supplemental material 6.

DISCUSSION

Our findings indicate that exercise snacks result in statistically significant improvements in CRF in physically inactive adults (mean age 18.8–44.3 years) and muscular endurance in older adults (mean age 69.8–74.0 years), with moderate and very low certainty of evidence, respectively. These improvements were observed even when the total exercise volume was substantially lower (~4.5–67.5 min per week) than current PA guidelines, indicating that brief, vigorous intensity exercise bouts performed frequently throughout the day can induce favourable physiological adaptations. However, the evidence regarding changes in muscular strength and cardiometabolic markers was limited.

Comparison with previous studies

Our results add to the growing body of evidence supporting the efficacy of low volume, intermittent exercise strategies in improving CRF (g=1.37, p<0.005).[12] The studies discussed in this review reported CRF improvements ranging from 4.6%[46] to 17%[45] following supervised exercise snack protocols. These improvements were similar to or slightly better than those obtained following brisk walking interventions, which led to a 9% improvement in CRF in inactive individuals.[54] However, since the meta-analysis did not include comparisons with moderate intensity continuous exercise (MICT), we cannot determine whether the benefits of exercise snacks are equivalent to those achieved with longer sessions. The only study directly comparing exercise snacks with MICT found that, over 6 weeks, three daily 30 s all-out stair climbing bouts resulted in a ~7% improvement in CRF, more than doubling (~3%) gain achieved with 30–50 min of MICT.[48] These results are consistent with those of Gist *et al*, who showed an 8% improvement in CRF with sprint interval training protocols.[55] In this regard, the effect size improvement in CRF of 1.37 is comparable with or slightly greater than the pooled effect sizes reported in HIIT interventions (characterised by session durations ranging from 20 s to 50 min and intensities between 75% and 100% of maximum heart rate, VO_2max, or peak power output), which range from 0.79 to 1.19.[56 57] Notably, participants included in our meta-analysis did not achieve the recommended 75 min per week of vigorous activity, underscoring that significant CRF improvements can be attained with lower exercise volumes (~5–67.5 min/week). This is particularly relevant for physically inactive individuals, who are most likely to benefit from small increases in PA and for whom short, time efficient approaches, such as exercise snacks, may be especially motivating.[58] Research indicates that even among individuals who meet the recommended 150 min of weekly moderate to vigorous PA, most (68.6%) engage in little to no vigorous activity,[59] indicating that brief bouts of higher intensity activity could offer additional benefits for cardiometabolic health.[60]

Even modest improvements in CRF (3 mL/kg/min) have been associated with a 15% reduction in mortality risk.[61] A median daily duration of 4.4 min of VILPA has been linked to a 26–30% reduction in all cause and cancer mortality risk and a decrease of 32–34% in cardiovascular disease mortality risk in older adults.[17] Due to their similarities with VILPA in terms of frequency, intensity and duration, exercise snacks may provide comparable benefits in reducing mortality. Remarkably, untrained individuals typically experience greater adaptations to lower intensity endurance training compared with those with higher baseline CRF levels.[62] This aligns with the principle of diminishing returns, whereby training adaptations become less pronounced as baseline fitness improves.[63] In this regard, participants included in the primary studies were initially physically inactive, so they were expected to achieve greater improvements with exercise snacks. However, due to the absence of empirical evidence on the effects of exercise snacks in trained individuals, meaningful comparisons cannot be drawn.

We did not find any significant effects of exercise snacks on other cardiometabolic parameters, including body fat, blood lipid profiles and blood pressure. This may be attributable to the inclusion of predominantly healthy young to middle aged participants with favourable baseline profiles, thereby limiting the potential for significant changes.[64] The lack of improvement observed in body fat (g=0.12) aligns with the conclusions of a previous meta-analysis on low volume (≤500 MET-min/week) HIIT interventions, which found no significant effects (ES=0.063).[56] Of the studies analysed, Zhou *et al* uniquely reported significant reductions in body fat percentage (4.6%) and total fat mass (2.45 kg), including epicardial adipose tissue, abdominal visceral fat and subcutaneous fat area.[49] This discrepancy may be explained by the inclusion of overweight and obese participants (mean BMI: 27.5 ± 5.3 kg/m²; mean % fat max: 41.8 ± 4.7%), who may experience greater improvements due to the principle of diminishing returns discussed earlier. This is in line with the findings of a meta-analysis on the effects of HIIT (~20–25 min per session and typically >85% of maximum heart rate) on fat mass, which reported no significant changes in normal-weight individuals (ES=−0.335), while a reduction was observed in overweight and obese individuals (effect size=0.21).[65] Alternatively, the reduction in body fat could also be attributed to the longer intervention period of 12 weeks, compared with the 6–8 weeks in the other studies. This may suggest that longer protocols may be necessary to achieve more substantial improvements in body composition, given the dose–response relationship between intervention duration and fat oxidation.[66]

Our results did not show significant effects of exercise snacks on plasma lipoproteins. As mentioned above, the duration of the exercise programmes and the favourable baseline cholesterol levels of the included participants (4–5 mmol/L) may explain the absence of statistically significant changes. In this context, aerobic exercise has been shown to elicit modest increases in HDL-C levels, with longer sessions proving more effective, particularly in individuals with elevated cholesterol or a lower body mass index.[67] Regarding LDL-C and triglycerides, other studies have reported no significant improvements following HIIT protocols in physically inactive individuals,[68 69] suggesting that short intense bouts are insufficient to elicit positive changes in metabolic profile. In any case, incorporating exercise snacks into daily routines may also interrupt prolonged periods of sedentary time, reducing the health risks associated with sitting.[70] Evidence suggests that frequent interruptions to sedentary behaviour are significantly more effective in reducing glucose levels than longer, less frequent activity bouts (effect size=−0.30).[71] In individuals with lower baseline CRF, the metabolic benefits of interrupting prolonged sitting with frequent light intensity walking bouts are more pronounced, compared with those with higher baseline CRF.[72] However, none of the included studies assessed glucose levels, and given that exercise significantly improves insulin sensitivity in skeletal muscle,[73] this is an important area for future research.

Our meta-analysis identified significant gains in muscular endurance following the implementation of a daily, unsupervised strength and balance snack intervention in older adults, although the effect size was small (g=0.40, p=0.02). The limited sample size underlying these results represents a notable constraint, potentially affecting the statistical power and the generalisability of the findings. In terms of muscular strength, no significant differences were observed (g=0.33, p=0.13). When examining the studies individually, only two of them showed significant improvements in muscular strength (MD=−3.34, p<0.001)[51] and endurance (MD=4.8, p<0.001[51]; g=1.40, p<0.01)[22] compared with the control group. This is particularly noteworthy, given that for beginners, muscular fitness gains in the first 12 weeks can be achieved with just 1 weekly resistance training session, using intensities of <50% of one-repetition maximum (1RM) and performing fewer than three sets per multi-joint exercise.[74]

The enhancement in muscular endurance, rather than muscular strength, following an exercise snack protocol may be attributed to the nature of the exercises and the age of the participants (≥65 years). Exercise snacks focus primarily on sustained effort over shorter durations, which enhances muscular endurance, whereas improvements in muscular strength typically require higher intensities and greater loads.[75 76] This may be due to the use of bodyweight exercises, which might not have provided the necessary overload to achieve a significant cumulative training effect on the body. The frequency of exercise snacks may be more effective for developing endurance, but insufficient for improving strength, which may necessitate a more volume focused training approach.[77] In this regard, increasing training volume and incorporating high velocity exercises should be considered to enhance physical performance in older adults.[78]

Finally, it is also remarkable that three studies did not include familiarisation sessions, two of which concluded that there were no differences in muscular fitness compared with the control group.[43 50] Including a familiarisation session may be necessary to prevent the overestimation of strength gains due to potential learning effects between tests.[79] However, one of these studies, conducted by Liang *et al*, did show significant gains (27% in 5-STS and 31% in 60-STS), which may be attributed to a longer intervention period (12 vs 4 weeks).[51] The study by Perkin and colleagues included familiarisation sessions with the functional tests, which could explain the significant improvement observed in the snack group (22% in 60-STS) compared with controls after 4 weeks of intervention.[52]

Exercise snacks achieved high compliance rate (91.1%), comparable with MICT (92.5%) and HIIT (89.4%).[80] In the context of adherence to unsupervised exercise protocols, exercise snacks achieved a notably high adherence rate (82.8%), significantly exceeding that of MICT (68.2%) and HIIT (63%).[80] These findings underscore the potential of exercise snacks as a feasible, scalable and well tolerated strategy to enhance unsupervised PA engagement in physically inactive populations. It is worth noting that the four studies conducted in older individuals were performed at home, with adherence rates ranging from 81% to 98%.[43 50–52] This indicates that exercise snacks may be a viable alternative for independent adherence to a home based exercise programme in older age.

Strengths and limitations

The key strength of our meta-analysis was the systematic synthesis of randomised controlled trial data, which enhanced the internal validity of our conclusions regarding the efficacy of exercise snacks. We also adopted a deliberately conservative GRADE approach, downgrading the certainty of evidence for risk of bias based on consistent concerns across studies regarding deviations from intended interventions and, in most cases, lack of outcome assessor blinding. An additional downgrade was applied for suspected publication bias, due to the small number of studies per outcome.

Nevertheless, several limitations should be acknowledged. Firstly, only a limited number of studies with limited sample size and fair methodological quality have examined exercise snack interventions. The potential to perform subgroup analyses by age, gender, health status or baseline PA was constrained by the small number of studies available, considerable between study heterogeneity and lack of detailed subgroup reporting. Furthermore, most of the outcomes included in the meta-analyses (11/12) were rated as 'very low' to 'low', based on the GRADE quality rating. Thus the current evidence regarding the health effects of exercise snacks in physically inactive individuals remains limited.

Secondly, the incomplete reporting of descriptive characteristics of control groups remains a concern, despite their critical role in determining the observed effects. The lack of detailed information on demographics and baseline characteristics may hinder the accurate interpretation and validity of the comparisons. Thirdly, the heterogeneity of protocols between studies introduces biases that complicate comparisons and interpretation. This lack of standardisation across key elements such as frequency, intensity, duration and supervision hinders the identification of the most effective configurations and limits the development of targeted, evidence based public health strategies. Fourthly, none of the studies quantified total PA levels via device based measures, which limits our ability to account for potential confounding effects of habitual activity outside the exercise snack interventions on the observed outcomes. Fifthly, the sex imbalance across included studies, characterised by a predominance of female participants (69.1%), may restrict the generalisability of the findings. Thus the effect observed needs to be interpreted in the light of the gender distribution of the samples included in the meta-analysis. Lastly, all studies conducted on young and middle aged adults focused exclusively on stair climbing interventions, with no exploration of resistance based exercise snacks. Furthermore, all research on strength based interventions was conducted with older adults, making direct comparisons between age groups inappropriate.

Clinical implications

According to the guidelines from WHO, adults should accumulate 150–300 min/week of moderate or 75–150 min/week of vigorous intensity PA, or an equivalent combination. Additionally, they emphasise minimising sedentary time by increasing movement throughout the day, reinforcing the principle that any activity is better than none.[10] Since conventional time efficient HIIT protocols remain controversial for physically inactive individuals due to their demanding nature,[81 82] exercise snacks may be an alternative to enhance adherence to PA. Their easy integration into daily routines addresses common barriers, such as lack of time and low motivation, facilitating PA promotion. In addition to research efforts, public health policies should aim to integrate exercise snacks into daily life by encouraging movement breaks throughout the day.

CONCLUSIONS

Based on a rigorous systematic review with meta-analysis of RCTs, moderate certainty of evidence supports the efficacy of exercise snacks in eliciting improvements in CRF among physically inactive adults. Although statistically significant effects on muscular endurance have been observed in older populations, the overall certainty of this evidence was very low. Current data do not provide sufficient evidence to support the use of exercise snacks as an effective strategy for improving other cardiometabolic health outcomes.

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ORCID iDs
Miguel Ángel Rodríguez http://orcid.org/0000-0001-9708-7015
Cecilie Thøgersen-Ntoumani http://orcid.org/0000-0003-0255-1263
Irene Crespo http://orcid.org/0000-0002-0440-1157
Hugo Olmedillas http://orcid.org/0000-0003-4625-2759

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