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REVIEW ARTICLE

Exercise Snacks and Other Forms of Intermittent Physical Activity for Improving Health in Adults and Older Adults: A Scoping Review of Epidemiological, Experimental and Qualitative Studies

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Abstract

Exercise snacks, including other variants of brief intermittent bouts, are an emerging approach for increasing physical activity, although their operationalisation is unstandardised and their health benefits remain unclear. This scoping review aimed to explore characterisations of exercise snacks and summarise their effects on health in adults and older adults. Clinical trial registers (clinicaltrials.gov and ANZCTR) and electronic databases (PubMed, CINAHL, CENTRAL, PsycINFO) were searched from inception to 1 June 2023, for ongoing and published studies of exercise snacks. Backwards and forwards citation tracking was also conducted to identify additional eligible studies. Studies were included if they investigated exercise snacks—brief intermittent bouts of physical activity spread across the day—in adults or older adults. We included epidemiological, experimental, quasi-experimental and qualitative studies that examined the effect of exercise snacks on any health outcomes or described barriers to and enablers of these approaches. Thirty-two studies were included (7 trial registers, 1 published protocol, 3 epidemiological studies and 20 trials reported across 21 studies). Three main terms were used to describe exercise snacks: exercise snack(ing), snacktivity and vigorous intermittent lifestyle physical activity (VILPA). Participants were predominantly physically inactive but otherwise healthy adults or older adults. Exercise snacks were feasible and appeared safe. Epidemiological studies showed steep, near-linear associations of VILPA with reduced all-cause, cardiovascular and cancer mortality as well as reduced incidence of major adverse cardiovascular events and cancer. The limited trial evidence showed exercise snacks had modest effects on improving cardiorespiratory fitness, whereas effects on physical function, mood, quality of life and other health outcomes were equivocal. In conclusion**,** exercise snacks appear feasible and safe for adults and older adults and may have promising health benefits, but this is mostly based on findings from a limited number of small quasi-experimental studies, small randomised trials or qualitative studies. More studies are needed in individuals with chronic disease. This emerging physical activity approach may have appeal for individuals who find structured exercise unfeasible.
Registration https://osf.io/qhu24/

Key Points

Exercise snacks are feasible and appear safe for physically inactive adults and older adults.

Exercise snacks are associated with reduced morbidity and mortality, whereas effects on other health outcomes are unclear.

More studies of exercise snacks are needed in people with chronic disease.

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1 Introduction

Globally, only 21% of adults and 13% of older adults meet the aerobic and muscle-strengthening physical activity guidelines [1]. The proportion of physical inactivity is even higher in people with obesity or those of a lower socioeconomic status [1], populations who may benefit even more from physical activity given their higher rates of chronic disease [2, 3]. The global cost of physical inactivity is estimated to be approximately US$500 billion between 2020 and 2030 if levels of physical activity do not improve [4], but there is little evidence this is happening [5]. Clearly, alternative strategies are needed to address the significant and growing global burden of physical inactivity.

Accumulating evidence shows that the greatest benefits of physical activity occur in people who go from doing nothing to doing something, even if total physical activity levels remain below those recommended by guidelines [6, 7]. Moreover, it is now recognised that physical activity is beneficial even when accumulated in short bouts across the day as opposed to longer, continuous bouts [8, 9]. For example, a systematic review by Jakicic et al. found that moderate-to-vigorous physical activity of any duration was associated with improved health outcomes [10]. This evidence was used to inform the most recent physical activity guidelines where accumulation of physical activity in bouts of 10 min or more is no longer recommended [11]. The review by Jakicic et al. also called for more research on the health effects of physical activity bouts lasting less than 10 min [10]. Together, these findings open up new possibilities for time-efficient strategies to promote physical activity and subsequently improve health. Exercise snacks are one such strategy.

Exercise snacks are one of several terms used to describe the physical activity approach of short bouts of high(er) intensity physical activity spread across the day [12]. Exercise snacks can include planned and structured activity that may be aerobic- (e.g. stair sprints), strength- (e.g. brief bodyweight circuits) or balance-based, or a combination of all three (e.g. carrying heavy shopping bags). Exercise snacks can also include other variants of brief, intermittent activity embedded into activities of daily living (e.g. fast walking while commuting). Given their brevity and lack of need for access to equipment or facilities, exercise snacks can address one of the most often cited barriers to physical activity, lack of time [13]. Therefore, exercise snacks may be an attractive and feasible strategy for individuals not able or willing to engage in traditional forms of leisure time physical activity that involves continuous exercise sessions.

Epidemiological evidence shows exercise snacks in the form of vigorous intermittent lifestyle physical activity (VILPA) are associated with reduced cardiovascular, cancer and all-cause mortality [9, 14], reduced incidence of major adverse cardiovascular events [14], as well as reduced incidence of total and physical activity-related cancer [15]. These associations are likely explained by the cumulative exposure to the transient benefits of brief but vigorous physical activity bouts [16] as well as the downstream effect this has on key health parameters such as cardiorespiratory fitness and cardiometabolic health [9, 14]. Recent small-scale studies also show exercise snacks are feasible and safe and improve some indices of health [12]. However, limitations to the exercise snack approach have also been identified including lack of motivation for performing multiple sessions daily or difficulties remembering to do so, as well as finding repetitive shorter physical activity bouts tedious or not challenging enough [17–19]. Thus, exercise snacks remain a relatively new, broadly defined and under-researched concept, and their acceptability and potential benefits for improving physical activity and health in people with and without chronic disease remain unclear.

Therefore, the objectives of this scoping review were threefold: (1) to explore the different definitions of exercise snacks, (2) to examine the effect of exercise snacks on health outcomes and (3) to identify evidence gaps to inform future studies.

2 Methods

This scoping review was conducted in accordance with the JBI methodology for scoping reviews [20] and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews [21]. The protocol was pre-registered on the Open Science Framework (https://osf.io/qhu24/).

2.1 Eligibility Criteria

We followed the participants, concept, context approach as recommended by the JBI methodology [20]. We included studies of adults (18–64 years) and older adults (65 + years) that investigated exercise snacks. There is still no agreed-upon definition of exercise snacks. Islam et al. defined exercise snacks as brief isolated bouts of vigorous exercise over the course of the day [12]. Sanders et al. described snacktivity as bite-size bouts (e.g. 2–5 min) of moderate-to-vigorous physical activity accumulated across the day [22]. Stamatakis et al. provided a preliminary definition of VILPA to include bouts lasting up to 5 min of relative (Borg rating of perceived exertion scale ≥ 14 or > 15) or absolute (> 6 metabolic equivalents) vigorous physical activity that occurs during activities of daily living [23]. This preliminary

definition was more recently revised on the basis of empirical evidence to specify bouts of incidental physical activity lasting up to 1 or up to 2 min [9]. The construct of exercise snacks for this scoping review was informed by these definitions and focused on brief, high(er) intensity bouts of (lifestyle) physical activity spread across the day [9, 12, 22]. Exercise snacks differ from movement breaks, which are often less prescriptive and aim to interrupt long periods of sedentary behaviour with light-to-moderate intensity activity (e.g. stretching or walking). Exercise snacks also differ from high-intensity interval training or sprint interval training, which are typically performed in a single session [24].

2.2 Information Sources and Search Strategy

Our search strategy aimed to locate both published and unpublished/ongoing studies in any language. We performed an initial limited search of PubMED ('exercise snack*'[All Fields] OR 'movement breaks'[All Fields] OR 'physical activity breaks'[All Fields]) to identify relevant articles. We included 'movement breaks' as a search term to capture any studies that described their intervention as a movement break but met our definition of exercise snack. The text words contained in the titles and abstracts of these relevant articles, and the index terms used to describe the articles, were used to develop the full search strategy for the electronic databases (PubMed, CINAHL, PsycINFO, CENTRAL) and clinical trial registers (clinicaltrials.gov, ANZCTR) (see Appendix 1 for full search strategy). The databases and trial registers were searched from inception to 1 June 2023. Backwards and forwards citation tracking of included studies was performed on 27 July 2023 and again on 10 November 2023 to identify additional eligible studies.

2.3 Screening

All identified citations were collated and uploaded into Covidence (Veritas Health Innovation, Melbourne, Australia; available at www.covidence.org), and duplicates were removed. Titles and abstracts were then screened by two reviewers, and studies that were clearly ineligible were removed. The full texts of the remaining studies were then screened by two independent reviewers for inclusion. Disagreements during the title/abstract and full-text screening stages were resolved by discussion. Where multiple records for a single study were identified (e.g. a protocol, conference abstract and published manuscript, or two published manuscripts reporting different outcomes from the same trial participants), these were merged into a single study record. In these instances, data from the published manuscript(s) were prioritised during data extraction.

2.4 Data Extraction

Data from the included studies were extracted using separate purpose-built electronic spreadsheets for the ongoing studies (trial registers and protocols) and completed published studies. One reviewer extracted data from all studies which were then checked by another reviewer, with disagreements resolved by discussion. We extracted data related to study characteristics (e.g. study type and setting), participant characteristics (e.g. sample size, age and eligibility criteria), intervention characteristics (characterisation of, or rationale for, exercise snacks, frequency/intensity/time/type of exercise snacks), control group characteristics (where applicable) and outcomes. We did not originally plan to formally investigate the feasibility and acceptability of exercise snacks; however, these were commonly measured and, in some cases, were a primary outcome. Hence, these outcomes were included in our review. Authors of papers with missing data were contacted twice by email to request the relevant data before they were considered unavailable for inclusion in the analysis.

2.5 Synthesis of Results

Data are presented separately for ongoing studies and completed published studies. Data are presented in text and tables that outline the participants, concept and context relevant to our review question and aims. All results are synthesised narratively, complemented by numerical descriptives where appropriate. No quantitative synthesis of data, nor quality appraisal of the included studies, was performed as this was not the aim of this scoping review.

3 Results

3.1 Study Selection

The results of the study screening and inclusion process are shown in Fig. 1. The search identified 1970 references (as 1961 studies) of which 201 were duplicates. From the remaining 1760 studies, 1721 were excluded during title and abstract screening, leaving 39 studies for full-text review, of which 17 were excluded. Forward citation tracking identified nine additional eligible studies. One additional trial protocol was also identified. Thus, 32 studies were included in this review (7 trial registers [25–31], 1 published study protocol [32], 3 epidemiological studies [9, 14, 15] and 20 quasi-experimental, experimental or qualitative studies reported across 21 published studies [17–19, 33–50]).

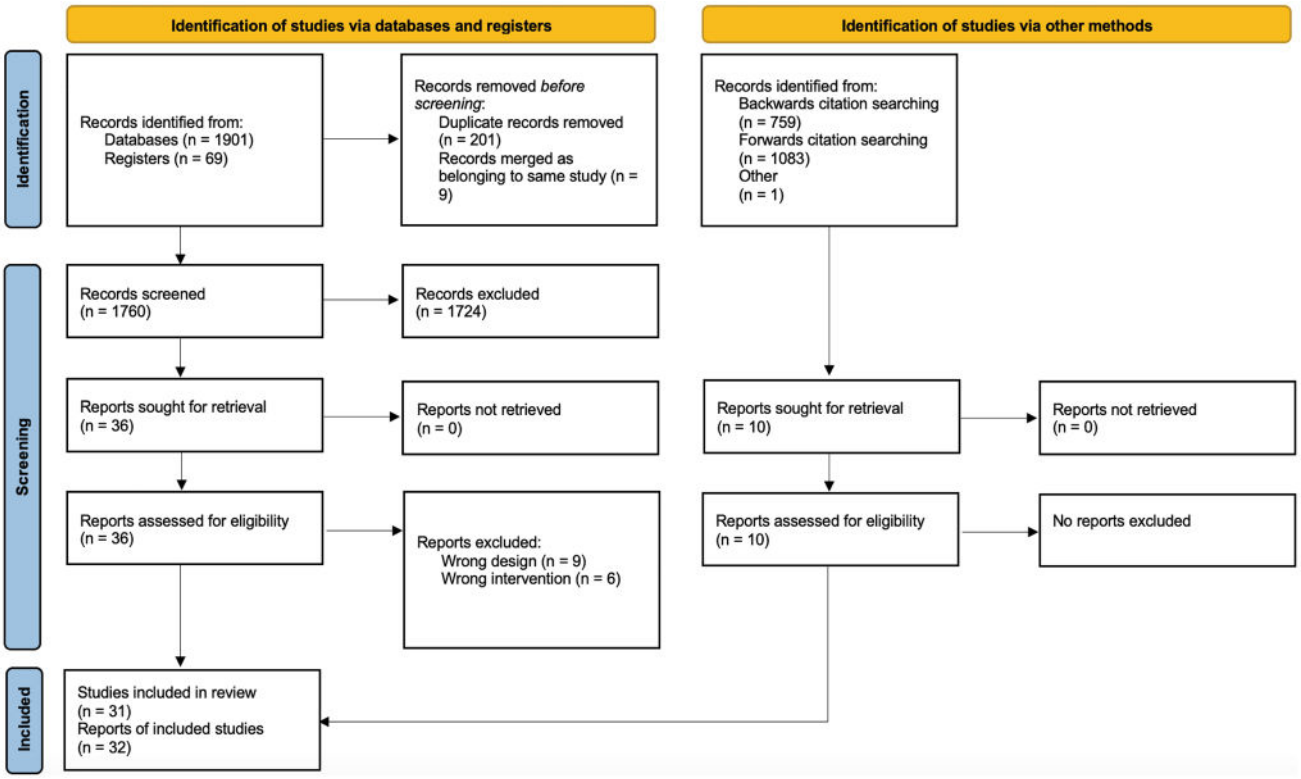

Fig. 1 PRISMA flow diagram outlining study identification and screening process

3.2 Study Types

The ongoing studies include randomised controlled feasibility pilot trials ($k=3$), randomised controlled trials ($k=4$) and a single cohort pre–post study ($k=1$). The completed studies include laboratory-based randomised crossover trials ($k=5$) [35, 36, 41, 43, 49], randomised controlled trials ($k=7$) [33, 34, 37, 39, 40, 42, 50], single cohort pre–post feasibility studies ($k=2$) [18, 38], prospective cohort epidemiological studies ($k=3$) [9, 14, 15], qualitative evaluations of exercise snacks ($k=6$) [17, 19, 44–47] and an intervention mapping and user testing study of an app designed to support exercise snacks [48].

3.3 Characterisation of Exercise Snacks

The descriptions of exercise snacks, including the rationale for their use, are presented in Table 1. Three main terms were used to describe this physical activity approach: exercise snack(ing), snacktivity and VILPA. All approaches involve brief bouts of physical activity spread across the day with the aim of increasing overall physical activity. Studies of VILPA involved shorter duration bouts (lasting up to 1 min and up to 2 min) [9] of vigorous intensity physical activity compared with studies that used the terms exercise snack(ing) (duration: ~ 15 s to 10 min; intensity: light to moderate) or snacktivity (duration: 2–5 min; intensity: moderate to vigorous). A variety of exercise snack types were used including aerobic, bodyweight resistance, Tai Chi and lifestyle physical activities. VILPA was defined as brief bouts (up to 1 or up to 2 min) [9] of non-exercise physical activity of vigorous intensity completed as part of daily living, i.e. outside the leisure time exercise domain. Of note, the bout length definition of VILPA was the only one derived from empirical evidence [9].

As shown in Tables 2 and 3, reporting of the frequency, intensity, time and type of exercise snacks was generally sufficient. Frequencies ranged from several days per week to multiple times daily. Intensities were prescribed and monitored using subjective (e.g. brisk but comfortable pace, as fast and safe as possible, rating of perceived exertion) and objective (e.g. percentage of heart rate maximum or maximal aerobic capacity) intensity metrics as a guide. No study used a formal intervention reporting guideline to fully describe all key aspects of their interventions. Several strategies were used to enhance adoption of exercise snacks including the use of technology (e.g. Amazon Alexa, PhysiTrack™, activity trackers and a purpose-built SnackApp) [17, 37, 38, 44, 47, 48] and video resources (e.g. exercise demonstrations) or written resources (e.g. logbooks for recording physical activity) [18, 39]. Several of the ongoing trials will use similar strategies as well as

Table 1 Characterisation of exercise snacks

Study	Characterisation of, or rationale for, exercise snacks
Trial register/protocol	
McVeigh [29] (ACTRN12623000493640)	"The types of **VILPA** will depend on the participant's physical capability and daily activities. Some examples of VILPA are climbing a few flights of stairs, brisk walk from home to bus stop, walking uphill, carrying a small load of shopping for more than 50 m, playing with or carrying a small child, vacuuming, and mowing the lawn"
Gudarzi [26] (IRCT20230225057528N1)	"**Exercise snacks: High intensity short intervals of bodyweight exercise lasting about 5 min, three times a day, three days a week for 6 weeks**. The exercises are as follows: First day: Jumping Jacks, High Knee Taps, Burpee. Second day: Air Squats, Push Ups, Skater Hops. Third day: Seal Jacks, Squat Kicks, Calf Raises"
Daley [25] (ISRCTN60667435)	"**Snacktivity** is based on the idea that **small, frequent doses of physical activity throughout the day**, called 'physical activity snacks', can help people accumulate at least 150 min of moderate-intensity physical activity per week"
Oppezzo [30] (NCT05360485)	"Recent research has shown that some benefits of **moderate to vigorous physical activity** can be accrued in motivationally accessible **short, 2–5 min bouts throughout the day** rather than needing to be a single, longer, continuous bout. The MOV'D intervention is a novel, remotely-delivered, social-media-based intervention to interrupt prolonged sitting with short bouts of MVPA, compared with a Fitbit-only control"
Little [28] (NCT05574426)	"…"**exercise snacks" (short movement breaks throughout the day**)"; "…or 2) Cardiovascular movement breaks (designed to raise heart rate). Both groups will be encouraged to perform 3–4 daily movement breaks on at least 3 days of the week"
Liang [27] (NCT05758727)	"One novel way that aims to address typical barriers to participation in older adults is through the promotion of **exercise 'snacks'**, as opposed to a more traditional, lengthy structured exercise session at a leisure centre. Exercise snacking describes **short bursts** of exercise that are designed to be undertaken over a **short period** in the home environment and without the need for any specialised exercise clothing or equipment"
Perkin [31] (NCT05439252)	"Previous research has identified a **homebased, non-loaded, lower limb only, 'exercise snacking'** model that does not require exercise equipment or supervision as a viable alternative exercise strategy to traditional resistance exercise, with potential to improve leg muscle strength in healthy older adults"
Daley et al. [32]	"Rather than focusing on promoting 150 min of physical activity per week (e.g. ~ 30 min per day over 5 days), **Snacktivity** focuses on encouraging **small, but frequent, doses of regular MVPA** throughout the whole day such that at least 150 min of MVPA is accumulated weekly. **A physical activity 'snack' lasts between 2 to 5 min**, and examples include walk-talk conversations, walking coffee breaks, using stairs instead of the lift, pacing whilst using the telephone, or parking the car a little further away and walking to the destination"
Published studies	
Ahmadi et al. [14]	"For most adults, incorporating **moderate-to-vigorous intermittent lifestyle physical activity (MV-ILPA)** into their day, **defined as brief bouts (< 10 min) done as part of activities of daily living**, might be more feasible than sustained bouts of planned and structured exercise"
Boreham et al. [33]	"Stair climbing provides an ideal model to examine the effects of **accumulating short bouts of exercise throughout the day**. Relatively little is known about the accumulation of benefit, and of the studies performed to date, none have examined **multiple bouts of vigorous activity lasting only a few minutes**, which is characteristic of stair climbing in an everyday setting"
Boreham et al. [34]	"One strategy advocated to meet this activity goal is to **accumulate exercise in short bouts throughout the day**…However, to date only one stair climbing study has shown that accumulating **very short bouts of exercise lasting about two minutes** can also confer health benefits"
Caldwell et al. [35]	"The notion of exercise "**snacks**" performed as stair climbing sprints in attractive as it suggests that **brief, vigorous exercise** may be integrated into a typical sedentary workday without the need for specialized equipment or dedicated time to a workout session"
Francois et al. [36]	"**small doses of intense exercise** before meals ('exercise snacking')"
Fyffe et al. [37]	"There has been increased interest in pragmatic and **time-efficient exercise modalities (e.g., bodyweight exercise, stair climbing)** as potentially more feasible approaches to improving health and fitness"; "To date, most studies of pragmatic exercise strategies (sometimes termed 'exercise snacking') have focused on exercise for improving cardiorespiratory fitness and/or markers of metabolic health"

Table 1 (continued)

Study	Characterisation of, or rationale for, exercise snacks
Jansons et al. [38]	"During the intervention, each participant was encouraged to complete a **ten minute 'exercise snack'** twice per day for the first four weeks of the intervention, three times per day for the second four weeks of the intervention, and four times per day for the final four weeks of the intervention. **Each 'exercise snack' involved four body weight only exercises for the upper and lower body** (e.g. marching on the spot, sit to stand, calf raise, wall push up, tandem walking)"
Jansons et al. [17]	"Emerging evidence suggests a **home-based, brief (≤ 10 min) but frequent (e.g. 2–4 times per day) 'exercise snacking'** program involving minimal-to-no equipment may be a feasible, safe and effective strategy for engaging older adults to participate in home-based exercise programs"
Jenkins et al. [50]	"…coined the term "exercise snacks" to describe breaking up a single session of continuous exercise into **several shorter bouts spread throughout the day**"
Krouwel et al. [47]	"…we have proposed an alternative 'whole day' approach to promoting physical activity called **Snacktivity**, which encourages people to take **short but frequent 'activity snacks' of 2–5 min of MVPA throughout the day**, to achieve at least 150 min of MVPA per week"
Liang et al. [39]	"Home-based exercise snacking has been identified as an accessible and low-risk alternative to traditional resistance exercise in older adults with the potential to improve leg strength without the need for specialist facilities"
Liang et al. [19]	"The term **'exercise snacks'** has been used to describe **breaking up a single session of continuous exercise into several short periods of exercise spread throughout the day**"
Little et al. [40]	"One option that could potentially make SIT more appealing, even more time efficient, and potentially easier to implement, is to increase the rest periods between sprints. Such a protocol could involve **each sprint being performed several hours apart as exercise "snacks" within the same day**. We define a "sprint snack" as an isolated single sprint performed during the day that is not a part of a traditional SIT workout"
Maylor et al. [41]	"Thus, investigating the appetite regulating effects of breaking up prolonged sitting with **short bouts of high-intensity physical activity across the day**, which may be more achievable for individuals to complete, could be valuable to inform weight management strategies"
Perkin et al. [42]	"**Short bouts of exercise spread across the day**, termed "**Exercise snacks**", have received attention as a time-efficient exercise strategy"
Rafiei et al. [43]	"Recently, the concept of "**sprint snacks**" – whereby **brief isolated bursts of exercise lasting ~ 20 s are performed with hour of rest in between** – has emerged."
Sanders et al. [48]	"An alternative integrative approach to promoting physical activity that could engage and motivate people to be more physically active and break up sedentary time is a **concept called *Snacktivity***. Rather than emphasizing at least 150 min per week of physical activity, **Snacktivity focuses on promoting short but frequent bouts of moderate- to vigorous-intensity physical activity (MVPA; known as *activity snacks*) throughout the day**, such that people accumulate at least 150 MVPA minutes over the week. **An *activity snack* lasts between 2 and 5 min**, for example, walking during coffee breaks, squats while waiting for the kettle to boil, lunges while vacuuming, or getting off the bus a stop early or parking further away."
Stamatakis et al. [9]	"**VILPA** refers to brief and sporadic (for example, **up to 1 or up to 2 min long**) bouts of **vigorous-intensity** physical activity done as part of daily living, such as bursts of very fast walking while commuting to work or moving from place to place, or stair climbing"
Stamatakis et al. [15]	"Vigorous intermittent lifestyle physical activity **(VILPA) refers to brief and sporadic (eg, up to 1–2 min [min]) bouts of VPA during daily living**, eg, bursts of very fast walking or stair climbing"
Stawarz et al. [44]	"Incorporating **short bouts of exercise across the day or exercise snacking** represents an innovative approach to PA promotion among older adults. It is **similar to Snacktivity**, which is mostly used in the context of aerobic PA. Both promote opportunities to engage in exercises that are safe and compatible with individuals' surroundings and lifestyle"
Stork et al. [49]	"**"Exercise snacks"** have been recently defined as **sporadic, short-duration bouts (≤ 1 min) of vigorous exercise performed throughout the day**"
Thøgersen-Ntoumani et al. [45]	"Vigorous Intermittent Lifestyle Physical Activity **(VILPA) refers to brief, vigorous bouts of incidental physical activities lasting 1 or 2 min** that are done during activities of daily living, such as carrying shopping bags, carrying children, or walking uphill. VILPA offers a more flexible approach to being physically active than traditional structured exercise and does not encroach on people's time, nor does it require preparation or access to facilities, thus circumventing some identified barriers (e.g., time, perceived lack of resources) to being physically active and allowing people to achieve physical activity guidelines in a time-efficient manner."

Table 1 (continued)

Study	Characterisation of, or rationale for, exercise snacks
Tyldesley-Marshall et al. [46]	"Guidance that could motivate the public to be more active and also break up sedentary behaviour is a concept we have called **Snacktivit**, which promotes **short 'snack' size bouts of MVPA throughout the whole day**, to progress towards meeting the guidance target of 150 min of MVPA per week. A physical activity snack would typically **last 2–5 min**, and examples might include brisk walking during a coffee break, walking when using a mobile phone, dancing while cooking, calf raises while teeth brushing, and leg raises when watching television. Crucially, such activity snacks can be integrated with other activities, so they do not necessarily require additional time"
Western et al. [18]	"**Exercise snacking** is a mode of exercise that aims to have maximum impact on physical function at minimum 'cost' to the patient in terms of time, money and no requirement for specialist exercise facilities or equipment. In other words, the exercise snacks, which are **movements designed to increase muscle strength and balance**, are to be **performed in the home environment over very short periods of time that fit with the current lifestyle of the patient**"

NB: bold text added for emphasis

MVPA moderate-to-vigorous physical activity, *PA* physical activity, *SIT* sprint interval training, *VILPA* vigorous intermittent lifestyle physical activity, *VPA* vigorous physical activity

online support groups and behaviour change techniques such as goal setting [25, 29–32].

3.4 Participants

Participant characteristics for the ongoing and completed published studies are outlined in Tables 2 and 3, respectively. For the ongoing studies [25–32], most will examine exercise snacks in physically inactive older adults who are living independently, physically able and cognitively intact. Intended sample sizes for these trials range from 21 to 110. One trial is also recruiting adults with non-alcoholic fatty liver disease [26], while another is recruiting women who are pregnant [25]. For the completed published studies [9, 14, 15, 17–19, 33–50], participants were mostly healthy, physically inactive adults or older adults who were physically and cognitively able. One study specifically recruited adults with insulin resistance or type 2 diabetes [36], and another specifically recruited a group of adults who were overweight or obese according to body mass index [43]. Only three studies included participants with chronic disease [36–38]. Sample sizes for the published studies ranged from 9 to 66 except for the three large prospective cohort studies of participants from the UK Biobank ($n = 22{,}398$ and $n = 25{,}241$) [9, 14, 15].

3.5 Measured Outcomes and Effects on Health

Outcomes for the ongoing studies are presented in Table 2. The outcomes and results of the published studies are summarised in Table 4. Feasibility and acceptability of exercise snacks were the most common outcomes amongst included studies. Changes in physical function (e.g. leg strength, balance, mobility) and cardiorespiratory fitness were also regularly assessed. Other outcomes included physical activity, blood markers, exercise cognitions (e.g. perceived competence, self-efficacy, enjoyment and expected benefits of exercise), mood and quality of life. The epidemiological studies assessed all-cause, cardiovascular and cancer mortality as well as cancer incidence (total and physical activity-related) and major adverse cardiovascular event incidence. The qualitative studies primarily assessed barriers to and enablers of exercise snacks, snacktivity and VILPA.

3.5.1 Feasibility and Acceptability

Exercise snacks were reported to be feasible and acceptable in all studies where this was assessed [18, 19, 37–39, 42, 47]. Retention rates in these trials were high (90–100%), and there was good adherence to the interventions (80–100%). Most participants rated these types of interventions as enjoyable and planned to continue doing them.

3.5.2 Safety

There were few adverse events associated with exercise snacks. One study reported two adverse events (from 1317 exercise snack sessions) that required modifications to the exercises but did not prevent participants from continuing [37]. Eight other minor adverse events (mostly musculoskeletal complaints) were also noted but did not affect participation [37]. Another study reported five adverse events during the intervention, of which only one was deemed to be related to the exercise snacks (exacerbation of an existing injury) [39]. Other studies reported no adverse events [18, 38, 42] or did not measure this as an outcome.

Table 2 Characteristics of ongoing studies

Trial register/protocol	Study type (status); setting	Sample size; eligibility	Exercise snack group (frequency, intensity, time, type)	Control group	Outcomes
McVeigh [29] ACTRN12623000493640	Feasibility RCT (not yet recruiting); home/leisure	*N* = 80; physically inactive older adults (50–80 years) transitioning to retirement	F: not specified I: vigorous T: 1–2 min T: activities of daily living Duration: 12 weeks Other: supported by a booklet, Fitbit, WhatsApp group and weekly checklists	Wait list, physical activity advice	*Primary*: feasibility and acceptability *Secondary*: physical activity, quality of life (SF-36), resting heart rate and blood pressure, habit formation
Gudarzi [26] (IRCT20230225057528N1)	Factorial RCT (recruitment complete); home/leisure	*N* = 40; sedentary adults with non-alcoholic fatty liver disease	F: 3/day I: high T: 5 min T: bodyweight exercise Duration: 6 weeks Other: with or without turmeric supplementation	No intervention	*Primary:* liver enzyme (alanine transaminase) *Secondary:* liver enzymes (aspartate transaminase, alkaline phosphatase), fatty liver grade
Daley [25] (ISRCTN60667435)	RCT (recruiting); hospital	*N* = 90; women between 10 and 16 + 0 weeks' gestation with singleton pregnancy	F: daily I: moderate to vigorous T: 2–5 min T: not specified Duration: 24 weeks Other: activity tracker and SnackApp	Standard antenatal care programme and physical activity advice	*Primary:* feasibility of subsequent phase III RCT *Secondary:* total physical activity, sedentary time, gestational weight gain, depression, fatigue
Oppezzo [30] (NCT05360485)	Feasibility pilot RCT (active, not recruiting); home/leisure	*N* = 72; adults and older adults employed full-time in a sedentary job	F: not specified I: moderate to vigorous T: 2–5 min T: not specified D: 4 weeks Other: online peer-support and behaviour change techniques	Fitbit and digital account to monitor physical activity	*Primary*: active workday hours and MVPA post-intervention *Secondary*: active workday hours and MVPA at 1 month follow-up
Little [28] (NCT05574426)	RCT (recruiting); home/leisure	*N* = 80; physically inactive adults or older adults, normal or overweight	F: 3–4/day, 3 + days/week I: increase heart rate T: 30–60 s T: not specified Duration: 12 weeks	Mobility snacks (stretching) for same dose	*Primary*: VO_{2peak} *Secondary*: plasma insulin and glucose, insulin resistance, inflammatory cytokines, body composition, movement breaks
Liang [27] (NCT05758727)	RCT (recruiting); home/leisure	*N* = 110; physically inactive older adults who are functionally independent	F: not specified I: as many as possible T: 10 min (1 min on/off × 5) T: bodyweight and Tai Chi Duration: 12 weeks	Usual care	*Primary*: SPPB *Secondary*: leg strength, balance, agility, quality of life, physical activity level, exercise confidence, self-efficacy and attitudes, acceptability

Table 2 (continued)

Trial register/protocol	Study type (status); setting	Sample size; eligibility	Exercise snack group (frequency, intensity, time, type)	Control group	Outcomes
Perkin [31] (NCT05439252)	Single cohort pre–post (completed); home/leisure	$N = 21$; physically inactive older adults, no cognitive impairment	F: 2/day, every day I: as many as possible T: 10 min(1 min on/off × 5) T: bodyweight Duration: 4 weeks Other: logbook to record activity	Not applicable	*Primary*: acceptability *Secondary*: attitudes, confidence and satisfaction with exercise, quality of life, mental health, SPPB, balance, mobility, cognition
Daley et al. [32]	Feasibility RCT (recruiting); home/leisure	$N = 80$; physically inactive adults or older adults	F: daily I: moderate to vigorous T: 2–5 min (for 30 min/day) T: not specified Duration: 12 weeks Other: goal setting and action planning, SnackApp, physical activity self-monitoring	Usual care, physical activity advice, leaflet	*Primary*: feasibility and acceptability *Secondary*: physical activity, sleep, body composition, blood pressure, leg strength, exercise enjoyment and self-efficacy, habit formation, anxiety and depression, hospital costs

MVPA moderate-to-vigorous physical activity, *RCT* randomised controlled trial, *SF-36* short-form 36 survey, *SPPB* short physical performance battery, *VILPA* vigorous intermittent lifestyle physical activity, VO_{2peak} peak aerobic capacity

3.5.3 Physical Health, Mental Health and Quality of Life

Compared with non-exercise controls, exercise snacks led to small improvements across several physical indices of health including cardiorespiratory fitness (~ 10–17%) [34, 50], peak workload (~ 25 W) [50] and exercise economy (− 2.3 ml/kg/min)[33], as well as peripheral vascular function (i.e. femoral blood flow and mean shear rate) [35]. Compared with exercise controls (sprint interval exercise), changes in cardiorespiratory fitness, peak power, time trial performance and physical activity were similar [40, 49]. Changes in physical function (e.g. 5 times sit to stand, 30 s or 60 s sit to stand, lower limb strength, balance) [37–39, 42] and blood markers (e.g. insulin, glucose, triglycerides, cholesterol) [33, 34, 36, 41, 43] were equivocal, whereas changes in body composition [33, 34, 42] and cerebral vascular function [35] were not different from controls. Few studies ($k = 3$) assessed the effect of exercise snacks on mental health or quality of life, and those that did found minimal effect on these outcomes [18, 38, 42].

3.5.4 Mortality and Incidence of Chronic Disease

Three epidemiological studies measured associations between VILPA and type-specific mortality or incidence of major adverse cardiovascular events or cancer. The first study found participation in a mixture of vigorous physical activity and VILPA was inversely associated with all-cause, cardiovascular and cancer mortality risk in non-exercisers. At the sample median dose of VILPA (three bouts per day lasting 1 or 2 min each), reductions in all-cause and cancer mortality risk were 38–40% and reductions in cardiovascular disease mortality risk were 48–49% compared with those who did no VILPA [9]. The second study found participation in VILPA (bouts of up to 1 min for a median of 4.5 min/day) was associated with a 20% lower risk for cancer incidence and a 31% lower risk for physical activity-related cancer incidence compared with those who performed no VILPA [15]. The third study found that, compared with those who performed moderate-to-vigorous intermittent lifestyle physical activity in bouts of < 1 min, participation in bouts of 1–3 min, 3–5 min or 5–10 min was associated with reductions in mortality of 34%, 44% and 52%, respectively. The corresponding risk reductions of major adverse cardiovascular events were 29%, 38% and 41%, for bouts of 1–3 min, 3–5 min and 5–10 min, respectively [14].

3.5.5 Barriers to and Enablers of Exercise Snacks

There were common themes identified regarding barriers to and enablers of exercise snacks. Flexibility of the approach, motivation and perceived health benefits were common enablers [37, 44–46]. Participants also reported feedback,

Table 3 Characteristics of published studies

Study	Study type; setting	Participants *N*, M/F	Age; BMI	Eligibility criteria	Exercise snack group (frequency, intensity, time, type)	Control group
Ahmadi et al. [14]	Prospective cohort; home/leisure based	*N* = 25,241, 11,063/14,178	62 ± 8 years; 28 ± 5	Physically inactive adults from UK Biobank with accelerometry data	F: not specified I: moderate to vigorous T: 1 min to < 10 min bouts T: lifestyle (MV-ILPA) Duration: not applicable	10% percentile of MV-ILPA volume and MV-ILPA bouts shorter than 1 min
Boreham et al. [33]	RCT; university	*N* = 22, 0/22	20 ± 0 years; NR	Sedentary but otherwise healthy young adults	F: 5 days/week (1/day in week 1 progressing to 6/day in weeks 6 and 7) I: brisk but comfortable T: ~ 2 min 15 s per stair climb bout T: stair climb Duration: 7 weeks	Usual activity
Boreham et al. [34]	RCT; university	*N* = 15, 0/15	19 ± 1 years; 21 ± 2	Sedentary but otherwise healthy young adults	F: 5 days/week (2/day in week 1 progressing to 5/day in weeks 7 and 8) I: brisk but comfortable T: ~ 2 min 15 s per stair climb bout T: stair climb Duration: 8 weeks	Usual activity
Caldwell et al. [35]	Randomised crossover trial; laboratory	*N* = 10, 10/0	24 ± 4 years; 24 ± 2	Healthy young adults	F: 1/h for 6–8 h I: fast and safe as possible T: 14–20 s/sprint T: stair climb sprint Duration: single session	Prolonged sitting
Francois et al. [36]	Randomised crossover trial; laboratory	*N* = 9, 7/2	48 ± 6 years; 36 ± 8	Adults with insulin resistance or type 2 diabetes	F: 3/day I: 90% HR_{max} T: 6 min (1 min on/1 min off) T: treadmill walking or treadmill walking plus resistance band exercises Duration: single session Other: fed standardised meals	Continuous exercise (30 min walking at 60% HR_{max}

Table 3 (continued)

Study	Study type; setting	Participants *N*, M/F	Age; BMI	Eligibility criteria	Exercise snack group (frequency, intensity, time, type)	Control group
Fyffe et al. [37]	Pilot RCT; home-based	*N* = 38, 14/24	70 ± 4 years; 27 ± 5	Community-dwelling older adults who were physically and cognitively able and not engaged in regular structured exercise	F: 1, 2 or 3/day I: As many as possible T: 9 min (1 min on/1 min off) T: 5 multi-joint bodyweight exercises Duration: 4 weeks Other: remotely delivered via an app	Usual activity
Jansons et al. [38]	Prospective single-arm feasibility; home-based	*N* = 15, 6/9	70 ± 4 years; NR	Community-dwelling older adults who were physically and cognitively able, not engaged in regular structured exercise, and had at least one chronic condition	F: 2, 3 or 4/day for weeks1–4, 5–8 and 9–12, respectively I: RPE 4–6 T: 10 min (1 min on/1 min off) T: bodyweight exercises Duration: 12 weeks Other: facilitated by Amazon Alexa	Not applicable
Jansons et al. [17]	Qualitative	*N* = 15, 6/9	70 ± 4 years; NR	Community-dwelling older adults who were physically and cognitively able, not engaged in regular structured exercise, and had at least one chronic condition	F: 2, 3 or 4/day for weeks 1–4, 5–8 and 9–12, respectively I: RPE 4–6 T: 10 min (1 min on/1 min off) T: bodyweight exercises Duration: 12 weeks Other: facilitated by Amazon Alexa	Not applicable
Jenkins et al. [50]	RCT; laboratory	*N* = 24, 5/19	20 ± 2 years; 23 ± 3	Sedentary young adults	F: 3/day, 3 days/week I: fast and safe as possible T: 14–20 s/sprint T: stair climb sprint Duration: 6 weeks Other: supervised, 1–4 h between bouts	Waitlist control

Table 3 (continued)

Study	Study type; setting	Participants *N*, M/F	Age; BMI	Eligibility criteria	Exercise snack group (frequency, intensity, time, type)	Control group
Krouwel et al. [47]	Qualitative mixed methods; home-based	*N* = 11, 3/8	62 ± 10 years; NR	Inactive or moderately inactive	F: daily I: moderate to vigorous T: 2–5 min T: not specified Duration: 3 weeks Other: supported by activity tracker and SnackApp	Not applicable
Liang et al. [39]	Feasibility RCT; home-based	*N* = 63, 29/34	72 ± 5 years; NR	Older adults who were physically inactive but otherwise healthy (no chronic disease)	F: 2/day for 28 days I: as many as possible T: 10 min (1 min on/1 min off) T: 5 bodyweight exercises, 5 Tai Chi exercises, or combination of both Duration: 4 weeks Other: written and video exercise instructions	Physical activity advice
Liang et al. [19]	Qualitative	*N* = 66, 20/43 NR	73 ± 5 years	Older adults who were physically inactive but otherwise healthy (no chronic disease)	F: daily I: as many as possible T: 10 min (1 min on/1 min off) T: 5 bodyweight exercises or 5 Tai Chi exercises Duration: 3 days each	Not applicable
Little et al. [40]	RCT; laboratory	*N* = 28. 14/14	22 ± 4 years; 23 ± 4	Young adults who were physically inactive but otherwise healthy	F: 3/day, 3 days/week I: all-out T: 20 s T: cycle ergometer Duration: 6 weeks Other: supervised, 1–4 h between bouts	Traditional sprint interval training (3 × 20 s all-out cycle sprint separated by 3 min rest, 3 days/week)
Maylor et al. [41]	Randomised crossover; laboratory	*N* = 14, 7/7	29 ± 10 years; 26 ± 6	Adults who were physically inactive but otherwise healthy	F: 1/h for 8 h I: 85% $VO_{2reserve}$ T: 2 min 32 s T: treadmill Duration: single session Other: fed standardised meals	1) prolonged sitting 2) continuous moderate intensity exercise (30 min at 60% $VO_{2reserve}$) after 30 min sitting, then prolonged sitting

Table 3 (continued)

Study	Study type; setting	Participants *N*, M/F	Age; BMI	Eligibility criteria	Exercise snack group (frequency, intensity, time, type)	Control group
Perkin et al. [42]	Pilot RCT; home-based	*N* = 20, 6/14	72 ± 5 years; 26 ± 3	Community-dwelling older adults who were physically inactive but otherwise healthy	F: 2/day for 28 days I: as many as possible T: 10 min (1 min on/1 min off) T: 5 bodyweight exercises Duration: 4 weeks Other: with yoghurt supplementation	Usual activity
Rafiei et al. [43]	Randomised crossover trial; laboratory	Healthy weight: *N* = 10, 10/0 Overweight or obesity: *N* = 11, 3/8	23 ± 4 years; 24 ± 2 50 ± 14 years; 35 ± 6	Healthy young adults Adults with overweight or obesity	F: 1/h for 6–8 h I: fast and safe as possible T: 14–20 s/sprint T: stair climb sprint Duration: single session Other: standardised meals provided	Prolonged sitting
Sanders et al. [48]	Intervention mapping and user testing; home-based	*N* = 15, 7/8	53 ± 15 years; 27 ± 4	Physically inactiveadults	F: not specified I: moderate to vigorous T: 2–5 min T: not specified Duration: 4 weeks Other: activity tracker and SnackApp	Not applicable
Stamatakis et al. [9]	Prospective cohort; home/leisure-based	*N* = 25,241, 11,063/14,178	62 ± 8 years; 27 ± 5	Physically inactive adults from UK Biobank with accelerometry data	F: at least 3/day I: vigorous T: 1–2 min bouts T: lifestyle (VILPA) Duration: not applicable	Participants who engaged in no VILPA
Stamatakis et al. [15]	Prospective cohort; home/leisure-based	*N* = 22,398, 10,122/12,276	62 ± 8 years; NR	Physically inactive adults from UK Biobank with accelerometry data	F: at least 3/day I: vigorous T: 1–2 min bouts T: lifestyle (VILPA) Duration: not applicable	Participants who engaged in no VILPA

Table 3 (continued)

Study	Study type; setting	Participants *N*, M/F	Age; BMI	Eligibility criteria	Exercise snack group (frequency, intensity, time, type)	Control group
Stawarz et al. [44]	Qualitative (used-centred design)	*N* = 16, 6/10	74 ± 5 years; NR	Prefrail older adults who are physically inactive	F: not specified I: not specified T: not specified T: bodyweight and Tai Chi Duration: single session Other: presented with technologies to support home-based exercise snacks	Not applicable
Stork et al. [49]	Randomised crossover trial; laboratory and workplace	*N* = 14, 2/12	39 ± 10 years; NR	Adults aged 18–65 years who worked at least 3 full days/week for 6 h/day and no contraindications to exercise	F: 3/day I: as fast and safe as possible T: < 1 min T: stair climb Duration: 1 week	High-intensity interval training (3 × stair ascent separated by 2 min recovery)
Thøgersen-Ntoumani et al. [45]	Qualitative	*N* = 78, 18/59	35–76 years; NR	Physically inactive middle-aged and older adults	F: not specified I: not specified T: not specified T: not specified Duration: not applicable	Not applicable
Tyldesley-Marshall et al. [46]	Qualitative	*N* = 31, 11/20	NR; NR	Adults who are physically inactive	F: daily I: light to vigorous T: 2–5 min T: bodyweight, lifestyle Duration: 5 days	Not applicable
Western et al. [18]	Pilot, single arm pre–post; home/leisure	*N* = 21, 17/4	78 ± 8 years; 26 ± 4	Physically inactive older adults, no cognitive impairment	F: 2/day, every day I: as many as possible T: 9 min (1 min on/off × 5) T: bodyweight Duration: 4 weeks Other: logbook to record activity and adverse events	Not applicable

BMI body mass index, *FITT* frequency, intensity, time, type, HR_{max} age-predicted maximum heart rate, *MV-ILPA* moderate-to-vigorous intermittent lifestyle physical activity, *NR* not reported, *RCT* randomised controlled trial, *RPE* rating of perceived exertion, *VILPA* vigorous intermittent lifestyle physical activity, $VO_{2reserve}$ difference between resting and maximum aerobic capacity

Table 4 Outcomes and results of published studies

Study	Outcomes	Results
Ahmadi et al. [14]	All-cause mortality and major adverse cardiovascular events	Compared with reference group (bouts of < 1 min), lower mortality risk by 34%, 44% and 52% for bouts of 1–3 min, 3–5 min and 5 to < 10 min, respectively. Compared with reference group, lower major adverse cardiovascular event risk by 29%, 38% and 41% for bouts of 1–3 min, 3–5 min and 5 to < 10 min, respectively
Boreham et al. [33]	Blood lipids, cardiorespiratory fitness, exercise economy, anthropometry	Significant improvements in HDL-C, total:HDL ratio, cardiorespiratory fitness and exercise economy in the intervention group compared with usual activity control; no significant differences between groups for total cholesterol, body mass or sum of skinfolds
Boreham et al. [34]	Blood lipids, cardiorespiratory fitness, anthropometry, homocysteine, adherence	Good compliance with training [average 114/130 (88%) sessions completed]; significant improvements in cardiorespiratory fitness and LDL-C in intervention group compared with usual activity control; no significant between group differences for BMI, total cholesterol, HDL-C, triglycerides or homocysteine
Caldwell et al. [35]	Peripheral and cerebral vascular function	Improved femoral blood flow, vascular conductance and mean shear rate compared with sedentary control; no difference in global cerebral blood flow, conductance, shear patterns, flow-mediated dilation or neurovascular coupling compared with sedentary control
Francois et al. [36]	Blood glucose control and insulin sensitivity	Improved mean 3 h postprandial glucose concentration following breakfast and dinner and improved 24 h glucose concentration compared with continuous exercise control; no difference in glycaemic variability or insulin sensitivity compared with continuous exercise control
Fyfe et al. [37]	Acceptability, adherence, safety and physical function	100% participant retention with high adherence (> 80%) and only two adverse events from 1317 sessions; 75% rated it as enjoyable and 82% planned to continue; no differences in improvements in 5 times sit to stand, 30 s sit to stand or balance compared with usual activity control
Jansons et al. [38]	Feasibility, safety, usability, quality of life and physical function	100% retention rate and high adherence (115% participants completed more exercises than they were prescribed), no adverse events reported; above-average usability (75/100); no significant improvements in quality of life or 30 s sit to stand
Jansons et al. [17]	Barriers to and enablers of home-based exercise snacking	Flexibility (easily integrate with activities of daily living), time efficiency (more acceptable than longer sessions), motivation (due to pragmatic nature of exercise programme) and perceived health benefits (e.g. pain, balance flexibility and strength) were enablers. Lack of time and motivation to complete three or more snacks per day), as well as lack of prescribed upper body exercise and equipment for the home-based programme, were barriers
Jenkins et al. [50]	Cardiorespiratory fitness, peak workload and adherence	Modest increases in cardiorespiratory fitness (~ 5%) and peak workload (~ 12%) for the exercise group that were significantly different compared with non-exercise control; participants completed all scheduled training sessions

Table 4 (continued)

Study	Outcomes	Results
Krouwel et al. [47]	Feasibility, experiences	Snacktivity was able to be incorporated into daily lives, particularly at home. Snacktivity was acceptable to participants and viewed as a useful means to achieving meaningful participation in physical activity. Perceived challenges were lack of space, not doing it at work due to social norms, and family/social commitments preventing participants from doing it later in the day
Liang et al. [39]	Feasibility, acceptability, safety, physical function, physical activity, exercise cognitions, mood, wellbeing	High retention (89% completed follow-up assessment) and adherence to the intervention (83–90% of sessions completed); intervention was acceptable and safe (no adverse events during functional assessments and only five adverse events during the intervention, of which only one was deemed related to the intervention); small improvements in physical function (5 times sit to stand, 60 s sit to stand, single leg balance), physical activity and sedentary time and exercise cognitions; minimal change in anxiety, depression or self-reported quality of life
Liang et al. [19]	Acceptability	Participants had positive feelings towards exercise snacks and did not perceive the protocols as overly burdensome. Participants from the UK or with lower physical function preferred Tai Chi snacking. Those with higher physical function found the exercise snacks too short and not challenging enough. Most believed the 1-week protocol was too short to perceive any health benefits but believed these would be apparent if they stuck with the intervention for longer
Little et al. [40]	Cardiorespiratory fitness, 150 kJ time trial performance and exercise enjoyment	Significant increase in cardiorespiratory fitness for both groups (4–6%), with no difference between groups; significant increase in time trial performance for both groups (9–13%), with no difference between groups; preference for exercise increased from first to last session for sprint interval group but not exercise snack group
Maylor et al. [41]	Subjective appetite and hunger hormones	Area under the curve for overall appetite 11% lower after intervention versus continuous exercise but was not different from sedentary control; no difference in total peptide-YY and ghrelin between the groups; lower ad libitum relative energy intake (760 kJ) after intervention versus sedentary control but not different from continuous exercise group
Perkin et al. [42]	Leg strength, leg muscle size, physical function, adherence, safety and physical activity	98% adherence to the intervention and no adverse events reported; large improvement in 60 s sit to stand score for intervention group compared with control ($d=1.40$); small-to-moderate improvements (3–6%) in leg press velocity, force and power, but these were not significantly different from control; no significant improvements or differences between groups for per cent body fat, lean mass or leg lean mass

Table 4 (continued)

Study	Outcomes	Results
Rafiei et al. [43]	Area under the curve for insulin, plasma glucose, non-esterified fatty acids and triglycerides	Healthy participants: small ($d=0.4$–0.5), non-significant differences compared with sedentary control for insulin, glucose, non-esterified fatty acids and total triglycerides Participants with overweight/obesity: large and significant improvements compared with sedentary control for insulin ($d=0.94$) and non-esterified fatty acids ($d=1.2$); small, non-significant improvements for glucose ($d=0.34$) and triglycerides
Sanders et al. [44]	Engagement with, and acceptability of, SnackApp	Average SnackApp time use of 12.6 (SD 47) min per week. Engagement with the app was higher among males than females. Most interactions were with the SnackApp dashboard and the 'my stats' and 'my goals' pages. Overall app quality score was 3.5 (SD 0.6) out of 5, and participants agreed the SnackApp increased their awareness, knowledge and attitude towards increasing physical activity and their intention to be more active
Stamatakis et al. [9]	All-cause, cancer and cardiovascular disease mortality	In non-exercisers, 38–40% reduction in all-cause mortality and cancer mortality and a 48–49% reduction in cardiovascular disease mortality compared with participants who engaged in no VILPA; similar results were obtained when repeating the analysis in exercisers
Stamatakis et al. [15]	Total cancer and physical activity-related cancer incidence	In non-exercisers, 17–18% reduction in total incident cancer risk and 31–32% reduction in physical activity-related cancer incidence compared with participants who engaged in no VILPA; similar results were obtained in sensitivity analysis excluding participants who were underweight or in poor health and when other confounders (body mass index, smoking, alcohol) were controlled for
Stawarz et al. [44]	Attitudes towards home-based exercise snacking and technology	Barriers to exercise were a dislike towards leisure settings, lack of motivation to exercise, and physical limitation or perceived safety/injury risk; exercise considered important for health and wellbeing and to build confidence and social engagement; exercise snacking has potential but needs to be tailored to the individual; exercise in the home environment could be facilitated by cues to exercise (prompt when sitting, home activities as prompts) and needs to consider location (floor space) and safety (objects to hold on to, soft furnishing); technology needs to be simple and easy to use, provide feedback and visual prompts, and be incorporated as part of everyday routines
Stork et al. [49]	Perceived exertion, affective valence, exercise enjoyment, exercise self-efficacy, exercise preferences and liking, physical activity and sedentary behaviour	For the acute responses, there was a lower rise in rating of perceived exertion and a more positive valence during snacks than high-intensity interval training, with no difference for exercise enjoyment. Following the intervention period there were no differences between groups for exercise self-efficacy or adherence to the interventions. More participants preferred snacks (64%) than high-intensity interval training (36%). Engagement in snacks or high intensity interval training led to more sit-to-stands in a 24 h period and more MVPA (~16 min/day), but differences between groups for these outcomes could not be assessed

Table 4 (continued)

Study	Outcomes	Results
Thøgersen-Ntoumani et al. [45]	Barriers and enablers	Barriers to VILPA were physical limitations, perceptions of aging, need for knowledge, environmental constraints, perceptions of effort and energy, and fear. Enablers included convenience, reframing physical activity as purposeful movement, use of prompts and reminders, normalisation of taking the active option, gamification, sense of achievement, health improvements, personally salient rewards, identity fit and habit formation
Tyldesley-Marshall et al. [46]	Acceptability, barriers and enablers	Common types of snacktivity were walking, stair climbing and housework; participants understood snacktivity as a concept and liked it because it was flexible, easy or manageable, and had perceived health benefits; most were positive overall towards snacktivity; facilitators were technology and reminders, encouragement from others, accountability and goals, feedback on progress and making it a habit; barriers were forgetting to do it, work and prioritising other things, and lack of time or being busy with other things
Western et al. [18]	Acceptability, adherence self-efficacy, enjoyment, burden, safety, barriers and enablers	85% adherence to the intervention with high acceptability (based on self-efficacy, affective response, ethicality, coherence, effectiveness) and low burden and opportunity cost. There were significant improvements in physical function based on the short physical performance battery ($d=1.29$), 60 s sit to stand ($d=0.74$), timed up and go ($d=0.77$) and single leg balance scores on the left ($d=0.61$) but not the right ($d=-0.02$). Qualitative data indicated participants found the programme simple to engage with and recognised benefits for their physical, mental and cognitive health. However, the programme was considered tedious by more active participants, and those with more severe cognitive impairment struggled to remember to complete it daily

BMI body mass index, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol, *MVPA* moderate-to-vigorous physical activity, *VILPA* vigorous intermittent lifestyle physical activity

prompts and technology (if simple and easy to use), reframing physical activity as purposeful movement, and changing from effortful deliberation to habitual action as enablers [17, 44–46]. Lack of time and motivation, particularly when needing to complete multiple exercise snacks per day, were identified as barriers, as were physical limitations, environmental constraints, perception of effort and energy, and potential safety concerns (e.g. performing exercises unsupervised at home) [17, 44–46].

4 Discussion

This scoping review identified that the broader concept of an exercise snack is defined in different ways, with bouts ranging from 15 s to 10 min, spanning light to vigorous intensity (but usually of at least moderate intensity), and using a variety of activities (e.g. non-exercise activities of daily living, aerobic, muscle strengthening, Tai Chi, lifestyle). The bout lengths definition for the VILPA concept was derived empirically, and the associations of VILPA with long-term outcomes are supported by evidence from large epidemiological studies [9, 14, 15], whereas evidence for the other exercise snack approaches derives from small quasi-experimental studies, small randomised trials or qualitative data. Most studies to date have been, or will be, conducted in non-exercisers or physically inactive but otherwise healthy adults and older adults. The results of these studies suggest exercise snacks are feasible, safe and well adhered to. Epidemiological studies show VILPA to be associated with significant morbidity and mortality benefits in non-exercisers, whereas the effect of exercise snacks on improving physical activity and other health outcomes remains unclear.

The terms exercise snack(ing), snacktivity and VILPA were the most used to describe this physical activity approach. The term snacktivity was coined to describe a whole-day approach to physical activity that promotes small (2–5 min) but frequent bouts of moderate-to-vigorous physical activity spread across the day that can be done at work or at home [22]. In 2018, Stamatakis et al. proposed the use of short and sporadic bouts of high-intensity activity embedded incidentally/secondary to activities of daily living [51], an approach now referred to as VILPA [23]. The operationalisation of VILPA, the bout length of which was derived empirically in a laboratory-based study [9], differs from snacktivity due to its emphasis on vigorous intensity activity (> 6 metabolic equivalents on an absolute scale or > 14–15/20 on the Borg rating of perceived (relative) exertion scale [52]) being incorporated into everyday life. Studies that used the term snacktivity or VILPA were usually more similar in their definition of the duration, intensity and type of exercise compared with studies that used the term exercise snack(ing) where there was more variation in these parameters. Reporting of exercise interventions is usually poor [53], which may limit evidence synthesis, evaluation and implementation. Encouragingly, reporting of the frequency, intensity, time and type of the exercise snack interventions included in this review was reasonable. However, other key information (e.g. supervision, tailoring, adherence) was not reported in sufficient detail and no study used a formal reporting guideline to fully describe its interventions. Therefore, it is important for future exercise snack studies to fully and clearly describe their interventions, preferably using established intervention reporting guidelines [54, 55] so that they can be properly evaluated and implemented into practice if effective.

The epidemiological studies showed clear evidence for inverse dose–response associations between VILPA and incidence of cancer (total and physical activity related) and major adverse cardiovascular events as well as all-cause, cardiovascular and cancer mortality [9, 14, 15]. Importantly, these associations were robust to different sensitivity analyses and adjustment for confounding. The effects of exercise snacks on improving health outcomes in the other studies were mixed. While significant improvements in cardiorespiratory fitness were usually observed, they were modest in magnitude. However, even small increases in cardiorespiratory fitness (i.e. 1 metabolic equivalent) are associated with improved morbidity and mortality [56], so these small increases in fitness may still be important. Improvements in other objective outcomes such as strength, balance, physical function, anthropometry and blood markers were equivocal, as were improvements in self-reported outcomes such as mood, quality of life and exercise cognitions (e.g. perceived competence, self-efficacy, enjoyment and expected benefits of exercise). Moreover, some of these results were from quasi-experimental studies as opposed to randomised controlled trials, limiting our ability to determine the effect of exercise snacks on these outcomes. Interestingly, changes in physical activity were seldom measured in the published studies, though several ongoing studies will assess changes in physical activity levels as an outcome. Taken together, except for cardiorespiratory fitness, the results of these studies do not clearly demonstrate an effect of exercise snacks on improving physical activity or health in adults or older adults. While the ongoing trials will add to the existing small body of evidence, many of these list feasibility or acceptability as the primary outcome and may not be powered to detect clinically meaningful between-group differences in physical activity or health outcomes. Large, high-quality randomised trials are needed to appropriately investigate the benefits of exercise snacks on physical activity and health. These results would be complemented by additional large epidemiological studies investigating associations between device-measured physical activity compatible with the exercise snack

approach and morbidity/mortality across a range of conditions and in different populations.

A common justification for the use of exercise snacks, and analogous concepts such as VILPA, is that they are time efficient and can be easily incorporated into daily living, thereby increasing the likelihood of adherence. Encouragingly, this seems to be the case, with adherence to exercise snacks slightly higher than that observed for more traditional physical activity interventions for which the average adherence is 74% for clinic-based and 80% for home-based programmes [57]. However, there may be a few reasons for this. First, exercise snack studies were shorter in duration (4–12 weeks) compared with the systematic review by Bullard et al. where all studies were at least 12 weeks long and the average intervention length was 20 weeks [57]. It is plausible that adherence would decrease over the course of a longer intervention, and indeed during follow-up, so this needs to be further investigated for exercise snacks. Second, the systematic review included participants with cardiovascular disease, diabetes or cancer [57], which contrasts with participants in the current scoping review who were predominantly physically inactive but otherwise healthy. These differences in participants' health status may influence motivation for, and engagement with, physical activity. Future studies should investigate adherence to exercise snacks over the longer term, and in people with chronic disease, to better understand the use of this strategy for promoting sustained engagement in physical activity.

Stamatakis et al. [23] outlined four research key priorities for studies of VILPA, including the need for an empirical definition (which was included in a recent publication [9]), validated methods for measurement, better understanding of the health effects, and the role of VILPA as a behavioural intervention. These same research priorities could also apply to the other variants of exercise snacks identified in this scoping review. For example, exercise snacks remain broadly defined and applied. Indeed, many such interventions to date have been feasibility studies which are less contingent upon a stringent definition of exercise snack compared with randomised trials which are currently lacking in this space. Therefore, there remains a need for a more standardised and evidence-based definition to enable better research synthesis and translation. Moreover, current understanding of the health effects is limited, particularly in people with chronic health conditions as they have seldom been studied. Finally, there remains a need for more implementation research to better understand how to scale up these exercise snack interventions, particularly amongst adults who are insufficiently active or those who find more traditional exercise less feasible. Thus, there exists considerable scope to strengthen the evidence base for exercise snacks as an approach to increasing physical activity and improving health in people with and without disease.

4.1 Limitations

There were some limitations of this scoping review. First, we did not include studies in children or adolescents, which means the characterisations, feasibility and health effects of exercise snacks in these populations who are also insufficiently active [1, 58] are unknown. However, children tend to be physically active in a pattern more consistent with exercise snacks anyway (e.g. brief and sporadic) [59], and this approach may therefore have less relevance for them. Second, participants in most of the included studies were mostly healthy, so the benefits of exercise snacks for people with chronic disease are unclear. Third, few studies investigated the effects of exercise snacks on self-reported outcomes such as mood or quality of life, and this requires further study.

5 Conclusion

This scoping review showed exercise snacks are a broadly applied concept. The little available evidence suggests that exercise snacks appear feasible, well adhered to and safe. The few observational studies suggest that small amounts of snacks of higher intensity were associated with striking effects sizes in terms of mortality, cardiovascular disease and cancer risks. However, existing observational studies need to be replicated in other countries and contexts, and controlled trials are lacking. Hence, the effects of exercise snacks on improving physical activity and health in adults and older adults are inconclusive, especially in those with chronic disease.

Appendix 1: Search Strategy for Electronic Databases and Trial Registers

PubMed

("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")[All fields].

CINAHL

TX exercise snacks OR TX exercise snacking OR TX snacktivity OR TX (movement breaks or activity break or active break) OR TX physical activity breaks. Expanders—Also search within the full text of the articles; Apply equivalent subjects. Search modes—Boolean/Phrase.

PsycINFO

Exercise snack* OR movement snack OR snacktivity OR movement breaks OR physical activity breaks OR active break OR vigorous intermittent lifestyle physical activity OR

VILPA [mp = title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh word].

CENTRAL

("Exercise snack*" OR "movement snack*" OR "snacktivity" OR "movement breaks" OR "physical activity breaks" OR "active breaks" OR "vigorous intermittent lifestyle physical activity" OR "VILPA"):ti,ab,kw. Word variations have been searched.

Clinicaltrials.gov

"Exercise snack", "movement snack", "snacktivity", "movement break", "physical activity break", "active breaks", "vigorous intermittent lifestyle physical activity", "VILPA". Each phrase will be searched individually using the 'other terms' search feature. Study type: all studies. Study results: All studies.

ANZCTR

"Exercise snack", "movement snack", "snacktivity", "movement break", "physical activity break", "active breaks", "vigorous intermittent lifestyle physical activity", "VILPA". Each phrase will be searched individually.

Declarations

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Conflict of interest E.S. is the originator of the VILPA concept and lead author of two reviewed papers. The remaining authors have no conflict of interest, financial or otherwise, to be declared.

Availability of data and material All data generated or analysed during this study are included in this published article.

Ethics approval Not applicable.

Author contributions The idea for the article was conceived by M.D.J. and M.T.G. M.D.J. performed the literature search, and M.D.J., B.K.C. and M.T.G. screened articles for inclusion and extracted data from relevant studies. All authors provided interpretation of the results. M.D.J. drafted the article, which was critically revised by E.S., B.K.C. and M.T.G. All authors read and approved the final version.

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