CONSENSUS STATEMENT

Short Bouts of Accumulated Exercise: Review and Consensus Statement on Definition, Efficacy, Feasibility, Practical Applications, and Future Directions

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ABSTRACT

Background: Insufficient physical activity and prolonged sedentary behavior have emerged as major global public health challenges. Short bouts (≤10 min) of accumulated exercise (SBAE) throughout the day may be a promising strategy to mitigate the adverse effects of prolonged sitting and promote physical activity, ultimately promoting overall health. However, previous ambiguity in defining this concept has resulted in a fragmented and inconsistent evidence base, impeding practical applications, the development of guidelines, and policymaking.

Purpose: To establish an operational definition of SBAE by synthesizing systematic reviews, and research trials, alongside an expert consensus. Additionally, it seeks to evaluate acute and long-term efficacy and feasibility, providing evidence-based recommendations for practice and future research directions.

Method: A literature search was performed across PubMed and Web of Science, followed by systematic screening and summarization of eligible studies based on predefined inclusion criteria. Inclusion criteria included SBAE (bouts lasting ≤ 10 min, performed multiple times daily with at least ≥ 30 min intervals), including various modes such as aerobic and resistance exercise (both considered). Relevant systematic reviews and research trials were included. Methodological quality, risk of bias, and evidence certainty were assessed. Expert consensus was obtained through a survey to evaluate recommendations and agreement levels on findings.

Results: After analyzing 27 systematic reviews, 135 research studies, and an expert consensus that involved 48 researchers from 11 nations, SBAE are defined as any exercise mode of activity, regardless of intensity, that are accumulated in either continuous or intermittent bouts lasting ≤ 10 min per session (including multiple intermittent sets), that are performed multiple times (≥2) per day, with intervals between bouts being ≥ 30 min or allowing sufficient time for recovery. When used to interrupt prolonged periods of sedentary time, SBAE mitigates the acute adverse effects of sedentary behavior on more than ten clinical biomarkers of endocrine, cardiovascular, and brain health/function among adults of diverse ages and conditions. Moreover, SBAE was superior for improving acute glycemic control compared to a single continuous exercise session. As a long-term intervention (average of 11 weeks), SBAE can improve over twenty health outcomes, including peak oxygen uptake, resting blood pressure, and metabolic health. Additionally, SBAE might be more effective than continuous exercise for improving longer-term glycemic control and body composition. Long-term intervention completion rates of SBAE are generally high (95%), with low dropout rates (12%) and high adherence rate even without supervision (85%), and its safety has been preliminary validated.

Conclusion and Recommendations: An operational definition of SBAE and its classification and acute and long-term efficacy are provided. Practical exercise prescription recommendations and evidence-based strategies for various populations and contexts are provided. Future research should focus on generating high-quality evidence in five key areas for SBAE: quantification and monitoring, population-

specific responses, optimization of exercise prescriptions, intervention efficacy, and practical implementation. Additionally, addressing policy, environmental, and promotional barriers is crucial for transitioning from expert consensus to public consensus, and facilitating the application of this strategy from laboratory settings applications to real-world environments.

WHAT IS ALREADY KNOWN

► Various terms and definitions have emerged to describe approaches for interrupting sedentary behavior through regular, short bouts (≤10 min) of accumulated exercise (SBAE) throughout the day. These include concepts such as "accumulated exercise", "exercise snacks", "sedentary breaks", or "interrupting prolonged sitting".

► The evidence on the effect and feasibility of SBAE remains diverse and inconsistent, and current physical activity or exercise guidelines and related consensus statements provide insufficient clarity on SBAE recommendations.

► No study has comprehensively synthesized SBAE strategies from an integrative perspective, summarizing their operational definitions, effects, feasibility, associations with disease, application recommendations, and future directions, nor attempted to establish a consensus.

WHAT ARE THE NEW FINDINGS

► SBAE is defined as any exercise mode, regardless of intensity, that are accumulated in either continuous or intermittent bouts lasting ≤10 min per session (including multiple intermittent sets), that are performed multiple times (≥2) per day, with intervals between bouts being either ≥ 30 min or time to allow complete recovery.

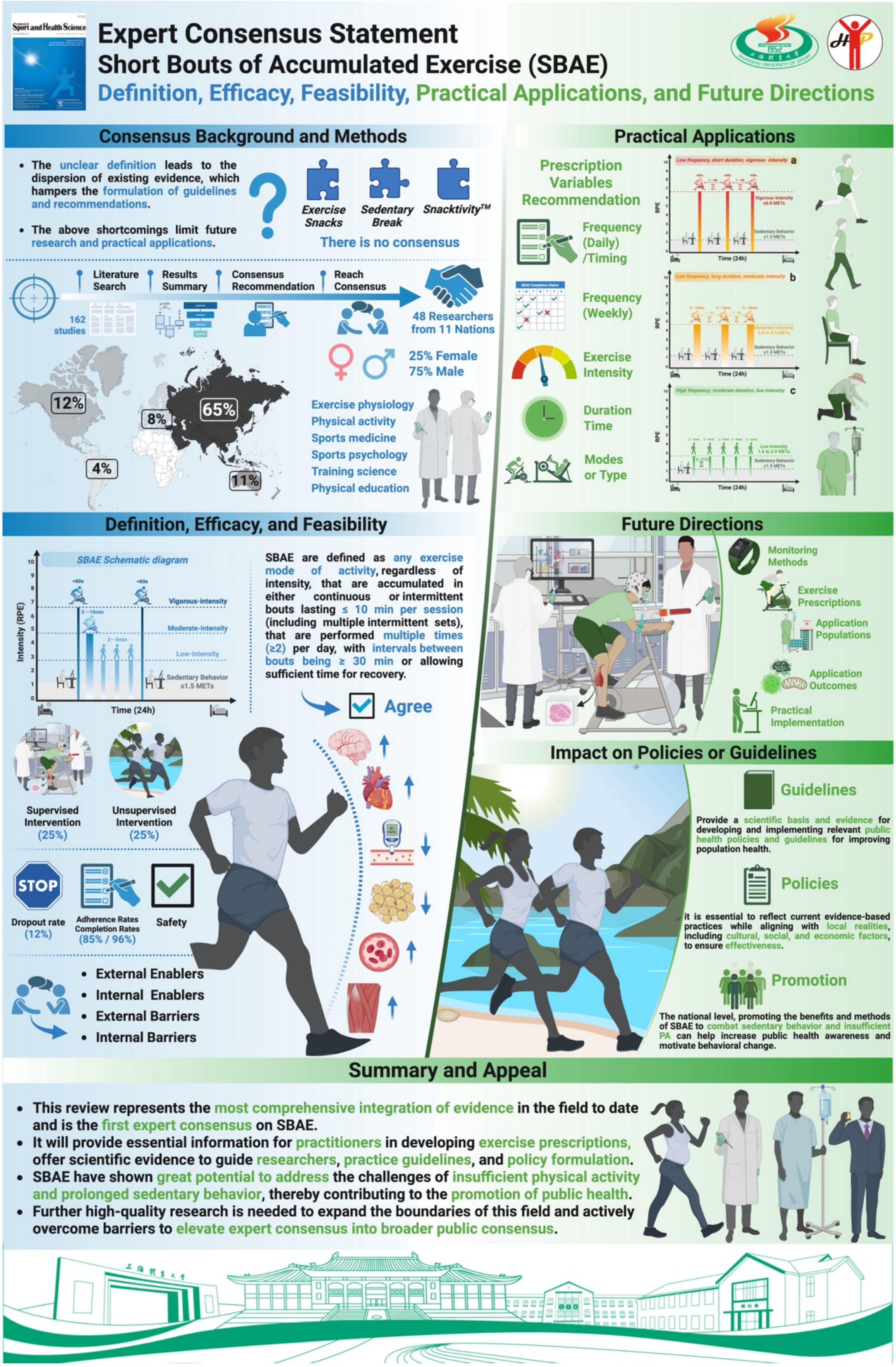
► When used to interrupt prolonged periods of sedentary time, SBAE mitigates the acute adverse effects of sedentary behavior on more than ten clinical biomarkers of endocrine, cardiovascular, and brain health/function. Moreover, SBAE is superior for acutely improving glycemic control compared to a single continuous exercise session.

► As a long-term intervention, SBAE can improve over twenty health outcomes, including peak oxygen uptake, resting blood pressure, and metabolic health. Additionally, SBAE may be more effective than continuous exercise for improving glycemic control and body composition. SBAE shows high feasibility in laboratory and real-world interventions, and its safety has been validated across diverse populations.

► Based on expert consensus, the SBAE protocol was classified, and recommendations were made for its application across various parameters, including frequency, duration, intensity, and modes. Current research challenges related to SBAE are outlined, and future research directions are proposed in five key areas:

quantification and monitoring, population-specific responses, optimization of exercise prescriptions, intervention efficacy, and practical implementation.

GRAPHIC ABSTRACT



1 INTRODUCTION

Insufficient physical activity (PA), defined as failing to accumulate at least 75 min/week of vigorous-intensity or 150 min/week of moderate-intensity PA or a combination of the two [1], poses a significant global public health challenge [1–3]. It is associated with increased incidence and mortality rates from non-communicable diseases, contributing to at least 5 million premature deaths annually [4], of which an estimated 3.9 million could be prevented through adequate PA [5]. Survey data from 1.9 million participants across 168 countries indicate that 27.5% of the global population engages in insufficient PA [6], with rates among adolescents reaching 81.0% [7].

Sedentary behavior is another pressing public health issue [8] and is defined as any waking behavior characterized by a low rate of energy expenditure [≤1.5 metabolic equivalents of task (MET)] while sitting or lying down[9]. Self-reported sedentary time among adolescents rose from 7.0 to 8.2 hours daily between 2001 and 2016 [10], while adults reported 8.8 hours daily [11]. Prolonged sedentary behavior negatively impacts glucose metabolism, lipid metabolism, and vascular function [12,13]. For instance, a single prolonged sitting session can increase postprandial blood glucose levels by 18.0% [14], reduce insulin sensitivity by 28.0% [15], and decrease flow-mediated dilation by 2.1% [16]. Chronic prolonged sedentary behavior also adversely affects body composition and the cardiovascular and musculoskeletal systems [13]. These acute and chronic pathophysiological effects ultimately increase the risk of developing non-communicable diseases, including neurological, cardiovascular, and chronic metabolic conditions, and increase the risk of all-cause mortality [12, 17].

Increasing PA and incorporating movement with large muscle groups to break up prolonged sitting are crucial strategies to address associated health challenges. Traditional efforts to promote continuous aerobic exercise have largely been unsuccessful, as current PA levels remain low and have not improved in recent years [18]. Numerous studies, including interviews and surveys, suggest an important barrier to PA participation is the perceived lack of time [19,20]. Therefore, shortening the duration of each exercise bout may be a more promising strategy for promoting participation in exercise. While traditional exercises, such as regular moderate-intensity continuous sessions, offer significant health benefits and can increase total physical activity levels [1], they can be limited in their ability to counteract the adverse effects of extended sitting periods, including elevations in postprandial glucose [21]. In contrast, incorporating short bouts of accumulated exercise between periods of sitting—i.e., regularly interrupting sedentary behavior—may more effectively prevent the immediate adverse effects of prolonged sitting on glucose, lipid metabolism, and vascular function [12,13,22–24]. These findings highlight the importance of increasing PA and regularly interrupting sedentary behavior as complementary lifestyle strategies. Therefore, accumulating short bouts of exercise is a promising approach to mitigate the adverse effects of prolonged sitting and promote PA, ultimately promoting health.

Epidemiological evidence supports associations of interrupting sedentary time with metabolic health, disease prevention, and the reduction of all-cause mortality. Healy et al. [25] first confirmed that moderate-to-vigorous intensity activity, mean intensity during breaks, and more frequent interruptions in sedentary time, were beneficially associated with metabolic risk variables, particularly adiposity measures, the concentration of triglycerides, and plasma glucose levels. Cohort studies also indicate that sitting for 60 min or more is associated with an increased risk of all-cause mortality, while sitting in shorter bouts of one to 29 min is linked to a reduced risk [26]. Additionally, vigorous intermittent lifestyle PA (VILPA)/moderate to vigorous intermittent lifestyle physical activity [27], involving brief (~1 min) multiple bouts of incidental PA (e.g., stair climbing) performed during daily living activities [28,29], can lower mortality and disease incidence rates [30–32]. This further highlights the potential benefits of accumulating short bouts of exercise for improving metabolic markers, preventing disease, and reducing long-term mortality risk.

In the scientific literature, various terms describe strategies for interrupting sedentary behavior through regular short bouts of accumulated exercise throughout the day, including "accumulated exercise" [33–35], "exercise snacks" [36–41], "sedentary breaks or interrupting prolonged sitting" [389,12,13,16,21,42–54]. Although these terms have different operational definitions, they all share the same principle: accumulating multiple short bouts of exercise to reduce or break up prolonged sedentary periods and/or increase overall PA to promote health. For clarity, we will consistently use the term "short bouts (≤10 min) of accumulated exercise" (SBAE) in this paper to refer to these strategies.

A growing body of research evidence has prompted the World Health Organization [1] to emphasize the importance of "reducing sedentary behavior" in its latest PA guidelines (2020 edition). The guidelines address "sedentary behavior" and strongly recommend that "replacing sedentary time with physical activity of any intensity (including light intensity) provides health benefits". This evidence builds on the recommendation of accumulating 75–150 min of vigorous-intensity or 150–300 min of moderate-to-vigorous intensity PA per week [1]. Additionally, it recommends regular muscle-strengthening activity for all age groups. For older adults, the guidelines emphasize varied multicomponent physical activity that includes functional balance and strength training at moderate or greater intensity on three or more days a week to enhance functional capacity and prevent falls. As part of these guidelines, SBAE should involve recommendations regarding frequency, intensity, duration, and exercise parameters tailored to different populations and contexts [1]. However, inconsistent terminology has led to fragmented evidence regarding the health benefits of SBAE, resulting in a limited understanding of this lifestyle approach [55]. Despite its potential health benefits and feasibility, the lack of consistency in concepts and definitions on SBAE and relevant evidence remains significantly less than that for single sessions of moderate-to-vigorous intensity continuous exercise, which limits its practical application. Additionally, a comprehensive review and synthesis of the available evidence is needed to understand SBAE fully. Reaching a consensus would offer evidence-based practical recommendations and contribute essential insights for updating PA or exercise prescription guidelines [1,56,57].

Our study draws on 27 systematic reviews [16,21,33–35,42–54,58–66] and 135 original studies, including 87 acute randomized crossover trials [67–153], 37 longitudinal controlled intervention trials[154–190], and 11 feasibility/qualitative studies [153,160,162,191–198]. Based on expert consensus, this paper proposes an operational definition of SBAE, and summarizes its effects across two key dimensions: breaking up sedentary behavior (acute efficacy) and promoting health (including long-term chronic efficacy/effectiveness and feasibility). It also aims to categorize evidence-based practice recommendations by application contexts, anticipated outcomes, and target populations, guiding non-pharmacological lifestyle prevention, interventions for various non-communicable diseases, and developing an exercise prescription database [199–201]. Finally, based on expert consensus, the paper aims to identify research challenges and future directions for the field of SBAE in increasing PA, reducing sedentary behavior, improving health, and preventing disease.

2 METHODS

The first step in this consensus process involved systematically organizing and summarizing all available evidence on SBAE. A search was conducted across various literature databases. Following this, experts in the field were invited to form a consensus group, where they evaluated the strength of recommendations and the level of agreement for each item to finalize the consensus.

2.1 Information Sources and Search Strategy

The PubMed (NCBI) and Web of Science (Core Collection) databases were searched from their inception to July 2024, with updates in October 2024. Included studies were full-text articles written in English or Chinese. No date or sample restrictions were applied during the search for this review. We conducted a comprehensive search for terms related to SBAE, including "multiple short bouts of exercise," "accumulated exercise," "exercise snacks," "sedentary breaks," "interrupting prolonged sitting," Snacktivity™, and VILPA. The search strategy and results are presented in **Supplementary File 1**. No restrictions were applied to populations, outcomes, study designs, or comparator groups, as we aimed to provide a complete review of SBAE literature.

2.2 Selection Process

De-duplication of records was performed manually by an independent reviewer (HKZ) using EndNote X9. Two researchers (MYY and HKZ) exported and screened the deduplicated records in Zotero 7.0, applying predefined inclusion and exclusion criteria to titles and abstracts. Discrepancies were resolved through discussion, with a third researcher (YML) assisting if needed. The two researchers (MYY and HKZ) then reviewed the full texts to finalize inclusion, following the same resolution protocol for discrepancies.

2.3 Eligibility Criteria

A priori inclusion and exclusion criteria were applied to evaluate study eligibility under the PICOS framework. i) Participants: humans of all ages and health statuses. ii) Interventions: focused on SBAE, where each bout lasts ≤ 10 min, regardless of intensity and including various modes such as aerobic and resistance exercise, and is performed multiple times a day (≥ 2 sessions), with recovery or rest intervals of ≥ 30 min between sessions. The choice of "each bout lasts ≤ 10 min" is based on our current focus on short bouts. Previous PA guidelines have often used "10 min" as a cutoff/minimum threshold for what is defined as a bout of continuous exercise [202]. The inclusion criterion of "multiple daily sessions (≥2/day) with ≥30-minute inter-session intervals" aligns with two key considerations. First, it operationalizes the accumulated exercise paradigm central to SBAE. Second, the 30-minute threshold reflects epidemiological evidence on sedentary behavior segmentation and corresponds with most SBAE research conventions, where ≥30-minute intervals are used [26]. However, studies on exercise performed in a single session, such as high-intensity interval training (characterized by repeated short bursts of vigorous-intensity exercise followed by periods of low-intensity exercise or passive recovery lasting seconds to minutes [203]), were excluded. iii) Comparisons: include a no-PA/exercise control group, where participants maintain their usual daily PA habits, and an exercise control group, where activities/exercises were performed in a single session. iv) Outcomes: were based on existing literature, with no exclusions to ensure a comprehensive presentation of results. Study designs: eligible for inclusion encompassed cross-sectional acute studies, longitudinal controlled trials (randomized or non-randomized), and systematic reviews (including meta-analyses). Editorials, abstracts, and narrative reviews were excluded.

2.4 Data Extraction

Data extraction was performed by the two reviewers (MYY and HKZ) using a customized Excel worksheet, finalized before the full-text screening. They independently extracted author and study details, participant information, intervention protocols, and outcomes. Discrepancies were resolved by a third researcher (YML). Authors were contacted for missing or graphical data; if unsuccessful, data were extracted using WebPlotDigitizer 4.1, which has high reliability and validity [204].

2.5 Risk of Bias and Methodological Quality

Two reviewers (HKZ and HHY) independently assessed the quality of the included systematic reviews using the AMSTAR 2 tool based on 16 items related to review planning and delivery. Reviews were rated as "high," "moderate," "low," or "critically low" based on identified weaknesses [203] (**Supplementary File 2**). The risk of bias in acute cross-sectional and longitudinal controlled trials was assessed using the Cochrane RoB 2 tool [206], covering random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting. Additionally, recognizing that risk of bias and methodological quality are distinct concepts [207,208], the methodological quality of the acute cross-sectional and longitudinal controlled trials was evaluated using the PEDro scale [209]. For longitudinal controlled trials, we also applied the TESTEX scale [210] to evaluate the quality of control measures and reports related to their long-term exercise training process (**Supplementary File 3**).

2.6 Calculation of Effect Size

When outcome indicators lacked systematic review or meta-analytic evidence and included multiple original trials, the mean difference and standard deviation from the experimental and control groups were extracted to determine an accurate effect estimate. A random-effects model, based on the inverse variance method and the DerSimonian-Laird [211], was used to combine the main effects and calculate the effect size (ES) and 95% confidence interval (95% CI) [211]. Given the small sample sizes of most included studies, Hedge's g, an unbiased and corrected ES indicator, was employed. ES were classified as follows: 0–0.2 as *negligible*, 0.2–0.5 as *small*, 0.5–0.8 as *medium*, and greater than 0.8 as *large* [212]. These calculations were conducted using the meta package in R Studio. Additionally, the statistical power of the primary pooled effect was calculated, and precision was assessed using the GRADE approach. Statistical power calculations were conducted using the *metameta* package [213].

2.7 Certainty of the Evidence

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology was used to rate the certainty of the evidence as "high", "moderate", "low" or "very low" [214]. GRADE was completed by the lead author (MYY), and evidence was rated based on the following criteria: 1) the risk of bias, downgraded by one level if "some concerns" and two levels of "high risk" of bias; 2) inconsistency, downgraded by one level when if statistical heterogeneity (I^2) is moderate (> 25%) and by two levels when high (> 75%). If the body of evidence primarily comprised meta-analyses, inconsistency was considered a serious concern when the aggregated results demonstrated variation (for instance, different authors may report inconsistent results when pooling data). Conversely, if inconsistency was not observed in the pooled outcomes, it was considered not serious; 3) imprecision: downgraded by one level when statistical power was < 80% and if there was no clear direction of the effects [215]; 4) risk of publication bias: downgraded by one level if Egger's test result was < 0.05. All results are detailed in **Supplementary File 4**.

The hierarchy of evidence types for addressing a specific question was as follows: meta-analysis > systematic review > single original trial. If an outcome indicator included meta-analysis and single original trial data, the meta-analysis was prioritized to avoid duplication because it typically involved a larger sample size and provided a more precise effect estimate. In such cases, single original trials were not reported. When multiple meta-analyses were available for a particular outcome, all relevant meta-analyses were included, as differences in populations, interventions, and outcomes might have existed between them. These results were considered collectively to determine the final evidence level and the degree of recommendation.

2.8 Formulation of Recommendations

Recommendations were formulated using the GRADE Evidence to Decisions (EtD) framework, which provides a systematic, transparent approach to guideline recommendations. This framework integrates research evidence, its certainty, expert opinion, and relevant expertise. It evaluates the balance between benefits and harms, confidence in the evidence, participants' values, resource use, potential effects on health inequalities, and the acceptability and feasibility of recommendations. Each recommendation was based on a comprehensive evaluation of evidence across key outcomes, leading to a consensus recommendation score.

2.9 Consensus Group and Consultation

Two authors (MYY and YML) developed the inclusion criteria for potential Expert Consensus Group members. To participate in this consensus, experts must hold a doctoral degree in PA, or exercise, and sports science, and meet at least one of the following criteria:

- Have published academic papers related to SBAE in peer-reviewed national (Chinese language) and/or international journals (English language);
- Have a significant influence on the promotion of a healthy lifestyle through exercise or PA, ultimately providing broad and diverse perspectives on SBAE.

Potential Expert Consensus Group members were contacted via email and WeChat to gauge their interest in participating in this consensus statement. Two authors (MYY and YML) outlined the major topics for agreement in this article, including the definition and characteristics of SBAE, specific program derivations, acute efficacy during long-term sitting, longer-term (chronic) health effects, feasibility evaluation, recommendations for practical application, and future research directions. Two authors (MYY and YML) contacted the proposed *Expert Consensus Group* members to invite them to participate in manuscript revision and discussion. The *Expert Consensus Group* members evaluated the recommendation levels and degree of agreement on all conclusions and opinions presented in this statement.

In the first survey round, we used the WJX online platforms (*www.wjx.cn*) and Google Forms to create links and collect the experts' opinions. There were 113 questions included, focusing on recommendation-level assessment related to SBAE. These questions addressed acute exercise effects when applied to break up sedentary behavior, its chronic effects on various health biomarkers, the feasibility of applying it in different populations, and recommendations for exercise variables and protocols to optimize its benefits. The grading of recommendations was based on whether the desirable effects of an intervention outweighed the undesirable effects. The GRADE system categorized recommendations into four levels: "strong recommendation," "weak recommendation," "weak non-recommendation," and "strong non-recommendation":

- Strong recommendation is given when there is clear evidence that the benefits of the intervention outweigh the risks, with a firm recommendation for all groups to adopt the intervention.
- Weak recommendation is made when the benefits likely outweigh the risks, but the intervention is recommended only for specific groups based on individual circumstances.
- Weak non-recommendation is issued when the risks likely outweigh the benefits, advising against the intervention for certain groups under specific circumstances.
- Strong non-recommendation is given when there is clear evidence that the risks outweigh the benefits, with a strong recommendation for all groups to avoid the intervention.

The items assessing the degree of recognition included SBAE: 1) terminology; 2) classification; 3) exercise variables and protocol recommendations; 4) future research directions. A five-point Likert scale from strongly disagree to strongly agree was used to assess the degree of recognition. Additionally, two open-ended questions were included to obtain experts' supplementary insights and suggestions for practical applications and future directions. The final recommendation level and degree of approval are based on the mean of the expert ratings.

The list of experts in the field includes key contributors who responded to our invitation, as well as practitioners in SBAE and/or those focused on promoting a healthy lifestyle through exercise or PA. The group was carefully selected to ensure diversity, including individuals with strong scientific backgrounds and those with practical experience in implementing physical activity programs. Thirty-eight experts completed the final consensus survey, while the remaining experts provided valuable feedback and suggestions for refining the consensus process.

3 CHARACTERISTICS OF THE CONSENSUS GROUP

The final expert group comprises 48 members, with 25.0% female representation. All members have publishing experience or international influence in exercise and sport science, with expertise spanning areas such as exercise physiology, physical activity, sports medicine, sports psychology, training science, and physical education. Each member holds a doctoral degree, and the group includes 31 professors/China researchers equivalent to professors (65%), 7 associate professors/China associate researchers equivalent to associate professors (15%), 5 lecturers (10%), 3 postdoctoral researchers (6%), 1 senior researcher (2%), and 1 PhD researcher (2%). Many members are recognized leaders in key areas such as “exercise snacks,” “sedentary behavior interventions/breaks,” and “low-volume high-intensity interval training,” and have contributed to influential global projects and research. Geographically, the experts are first-affiliated with institutions in 11 countries across 5 continents, representing diverse cultural and academic backgrounds. These countries include China (28, 59%), Australia (5, 11%), Canada (3, 6%), the United States (3, 6%), the United Kingdom (3, 6%), the

United Arab Emirates (1, 2%), Brazil (1, 2%), Singapore (1, 2%), Thailand (1, 2%), Ireland (1, 2%), and Chile (1, 2%). The sample size is large enough to support consensus-building, and the geographical and disciplinary diversity strengthens the robustness of the consensus process. This collaborative effort ensures that the final consensus reflects the collective expertise and perspectives of leading professionals in the field.

4 DEFINITION OF TERMS

4.1 Physical Activity, Exercise, and Sedentary Behavior

Physical activity (PA) is any bodily movement produced by skeletal muscles that results in energy expenditure [216]. PA is categorized into light-intensity (1.6–2.9 METs) [1,217], moderate-intensity (3.0–5.9 METs) [1,217], and vigorous-intensity physical activity (≥ 6.0 METs) [1,217]. The intensity classification of exercises also follows this standard [1].

Insufficient PA refers to levels of PA that do not meet the current recommendations of 150–300 min of moderate-intensity or 75–150 min of vigorous-intensity PA per week or a combination of the two [1].

Vigorous intermittent lifestyle physical activity (VILPA) describes brief and sporadic bouts of vigorous-intensity PA, typically lasting around one minute, that occur in daily life [28–30]. An example is climbing stairs as part of routine activities [218].

Low- to moderate-intensity intermittent lifestyle physical activity (Snacktivity™) involves moderate-duration, isolated bouts of low- to moderate-intensity PA, typically lasting 2–5 min, such as brisk walking integrated into daily routines [191,196,198].

Exercise is a subset of PA that is planned, structured, and repetitive with the improvement or maintenance of physical fitness as the final or intermediate objective [1,216].

Exercise snacks are isolated bouts of vigorous exercise lasting ≤ 1 min and performed periodically throughout the day [36–40].

Physical fitness is a set of attributes that are either health- or skill-related. The degree to which people have these attributes can be measured with specific tests [216].

Sedentary behavior refers to activities such as sitting, reclining, or leaning in a waking state with an energy expenditure of 1.0 to 1.5 METs [1,9]. Sedentary behavior includes tasks like office desk work, driving, or watching television.

Sedentary breaks or interrupting prolonged sitting refers to any non-sedentary period that breaks up extended bouts of sitting [1,9].

4.2 Short Bouts (⩽ 10 min) of Accumulate Exercise (SBAE)

SBAE is defined as any physical activity performed in any mode and at any intensity, with a continuous or intermittently accumulated duration of ≤ 10 min per bout, conducted in multiple bouts (≥ 2) throughout the day. Recovery intervals between sessions, which differ from interval training, can allow for complete recovery or last ≥

30 min. The consensus group ultimately reached an average approval rating of "agree" for this operational definition.

Establishing cutoff points or thresholds for continuous variables can be challenging; however, ≤ 10 min is generally accepted as a threshold for SBAE for several reasons: 1) previous PA guidelines have often used "10 min" as a cutoff/minimum threshold for what is defined as a bout of continuous exercise [202]; 2) the American College of Sports Medicine defines moderate-intensity continuous exercise as reaching 64–76% of HR_{max} within sessions lasting longer than 10 min [219]; thus, using ≤ 10 min distinguishes SBAE from moderate-intensity continuous exercise and reduces confusion; 3) most existing any-intensity accumulated exercise sessions last ≤ 10 min [33,35].

For structured exercise studies, the choice of ≥ 30 min as the rest interval was based on several factors: 1) all known longitudinal intervention trials involving SBAE have used intervals greater than one hour; 2) the majority of studies on SBAE and acute interruptions in sedentary behavior report intervals of ≥ 30 min [16,21,42–54,58–60,62,65,66]; 3) prospective cohort studies suggest that accumulated sedentary periods of 1 to 29 min has a minimal association with increased risk of all-cause mortality, while sedentary periods lasting ≥ 30 min are significantly associated with increased mortality risk [26]; 4) from a practical perspective, intervals shorter than 60 min may not be perceived as "time-saving" and are less likely to be adopted in real-world settings, such as workplaces [220]. It is important to note that ≥ 30 min is a reference point; as long as each exercise interval allows for complete recovery, it can be classified as SBAE. It is difficult to give a specific operational definition of "complete recovery," as a bout of exercise may have physiological or molecular effects on the bodily systems that last for several hours or days [221]. Here, we refer to "complete recovery" as, when during the recovery interval, the individual can comfortably engage in daily tasks or activities unrelated to SBAE and this period is no longer considered part of the SBAE session. This distinguishes it from interval training, where intervals allow for only incomplete recovery [222].

4.3 Classification of SBAE

Current SBAE research primarily categorizes these bouts into three protocols. They are:

i) Low frequency, short duration, and vigorous intensity, such as a single exercise session comprising a single 20–30 s bout of cycling at full sprint, performed thrice daily with one- to 6-hour recovery intervals in between. In our categorization, the classification of "short duration" within a single session aligns with the current operational definitions of “exercise snacks”, which refers to “isolated bouts of vigorous exercise lasting ≤ 1 min and performed periodically throughout the day” [36–40]. The “short duration and vigorous-intensity” classification is supported by prospective epidemiological VILPA evidence from objective accelerometer data on 25,241 adult participants in the UK Biobank study that 95% of all vigorous bouts last up to 1 minute [30].

ii) Low frequency, long duration, and low-to-moderate intensity, such as walking for 5–10 min at 65% HR_{max}, performed thrice daily with recovery intervals in between. The "long duration" classification aligns with early longitudinal intervention designs focused on low-frequency, moderate-to-low-intensity exercise [33–35].

iii) High frequency, moderate duration, and low- to moderate intensity. This protocol may include walking for 2–5 min at 50% HR_{max} every 30 min during prolonged sitting (e.g., over 6 hours). These less intense, high-frequency sessions of SBAE are commonly prescribed in acute randomized crossover trials aimed at interrupting prolonged sitting. The "moderate duration" classification aligns with the existing majority of acute cross-sectional and longitudinal controlled intervention protocols.

The intensity classification above adheres to established definitions found in current PA [1] and exercise prescription guidelines [223]. The rationale for the above SBAE protocols derivations is based on several key rationales: 1) different exercise protocols correspond to various application contexts and are associated with distinct expected health benefits (see Section 7.2 for details); 2) prospective cohort studies (VILPA) support the cutoff classifications for "single exercise bout duration" [30]; 3) existing intervention protocols are primarily designed around these three categories mentioned above. Given the robust evidence supporting these protocols, subsequent summaries of application outcomes and evidence-based recommendations will primarily focus on these models.

However, variables such as frequency, single exercise bout duration, and exercise intensity can be combined in different ways to create more specific prescription schemes, many of which have yet to be thoroughly explored or validated in research. Thus, this consensus provides a comprehensive classification of SBAE from a prospective perspective, considering daily frequency, single exercise duration, and intensity (see **Table 1**). This classification aims to guide further research, expand the conceptual boundaries of SBAE, and enrich the body of evidence in this field.

While outside the scope of this study, the SBAE protocol can be further expanded into various subtypes, such as aerobic SBAE, resistance/muscle strengthening SBAE [40], balance SBAE, and combined/multimodal SBAE, depending on the targeted health outcomes. The definitions of these subtypes will align with current guidelines to address different health targets [1]. Future research should further develop this framework and integrate diverse exercise methods and types into the SBAE protocol to enhance its applicability and impact.

Table. 1. Here

5 ACUTE EFFECTS OF SBAE TO BREAK SEDENTARY BEHAVIOR

Research on SBAE aimed at mitigating the adverse effects of prolonged sedentary behavior explores three comparative approaches regarding acute impacts on glucose-lipid metabolism, cardiovascular function, and brain health (see **Table 2**): 1) comparing intermittent sedentary behavior interspersed with SBAE to continuous sedentary behavior without interruption; 2) examining variations in frequency, intensity, modes, duration, or combinations of short-bout protocols; and 3) comparing SBAE during sedentary periods to a single continuous exercise session (typically performed before initiation of sedentary behavior). Most studies are conducted during non-discretionary time (i.e., controlled laboratory settings), employing acute (<7 days), randomized crossover designs with a 3- to 7-day washout period between trials. While most participants are healthy adults, some studies also include clinical populations and individuals with chronic conditions (e.g., individuals living with prediabetes or diabetes). The short-bout exercise protocols generally emphasize high-frequency sessions (every 30–60 min), moderate duration (2–5 min per bout), and low-intensity activities.

******Table. 2. Here******

5.1 Acute Effects (vs. Uninterrupted Prolonged Sitting)

5.1.1 Glucose and Lipid Metabolism

Primary indicators of glucose-lipid metabolism include the concentration of blood glucose, C-peptide, insulin, and triglycerides, with regular measurements typically taken over several hours and in response to several meals throughout the day. Chastin et al. [48] conducted the first meta-analysis on the acute effects of SBAE, which included six studies, and reported that low-to-moderate intensity SBAE significantly reduced postprandial blood glucose, insulin, and C-peptide concentrations in both healthy adults and individuals with type 2 diabetes (T2D), compared to continuous sedentary behavior. Saunders et al. [42] performed a subsequent analysis of 20 studies and similarly found that SBAE significantly reduced postprandial blood glucose (ES = –0.36 [–0.50, –0.21]) and insulin (ES = –0.37 [–0.53, –0.20]) in healthy individuals of all ages. Loh et al. [45], in an updated meta-analysis of 37 studies, showed that SBAE significantly reduced postprandial blood glucose (ES = –0.54 [–0.70, –0.37]), insulin (ES = –0.56 [–0.74, –0.38]), and triglycerides (ES = –0.26 [–0.44, –0.09]) in adults (both healthy and in patient with chronic disease). It is important to note that the results on triglycerides were inconsistent across individual studies, likely due to variations in the time course of the triglyceride response that was captured. It is generally accepted that exercise does not immediately (i.e., on the same day) impact postprandial lipid responses and it is more likely to impact responses the following day. This delayed response may account for the higher incidence of null findings in studies measuring triglycerides immediately after SBAE. Smith et al. [59] only focused on seven studies that included adults with T2D, and found that SBAE reduced postprandial blood glucose (ES = –0.82 [–1.26, –0.38]) compared to continuous sedentary behavior.

Taken together, these findings provide consistent evidence that SBAE improves key markers of glucose-lipid metabolism in healthy individuals and those with impaired glucose compared to continuous sedentary behavior (very low to moderate GRADE). Given that modest improvements in glycemic control are associated with a reduced risk of cardiovascular events, even in healthy adults, this benefit may have clinical significance [224,225]. Moreover, this approach offers a promising strategy for lowering blood glucose levels in individuals with impaired glucose regulation, where improved glycemic control is a key therapeutic target [226].

5.1.2 Cardiovascular Health

The main biomarkers used in research on cardiovascular function include flow-mediated dilation (FMD), peripheral vascular shear stress, blood flow, central arterial blood flow velocity, blood pressure (BP), and heart rate. Saunders et al. [42] conducted the first meta-analysis on the acute effects of SBAE on FMD during interrupted sedentary behavior (including six studies) and reported a significant effect on FMD (ES = 0.57) compared to uninterrupted sedentary behavior. Paterson et al. [16] included seven studies to quantify the pooled effects through meta-analysis, reporting a significant increase in FMD of 1.9% (ES = 0.57) following SBAE. However, Taylor et al. [49] found inconsistent results, reporting a non-significant effect of SBAE on FMD (ES = 0.13 [–0.02, 0.45]). Subsequently, Soto-Rodríguez [50] and Zheng [65] meta-analyses, which included nine and twelve studies respectively, reported significant increases in FMD of 1.7% and 1.5%, respectively, following SBAE. Both studies also found that SBAE significantly improved peripheral vascular shear stress (by 7.58 s^{-1} to 12.7 s^{-1}, respectively) and blood flow (by 12.08 mL/min). Yin et al. [62] updated the evidence with 22 studies, confirming moderate increases in FMD (ES = 0.43 [0.15, 0.72]), peripheral vascular shear stress (ES = 0.65 [0.37, 0.93]), and blood flow (ES = 0.48 [0.14, 0.82]) following SBAE. However, they found no significant effect on arterial pulse wave velocity. Notably, the populations in these studies primarily consisted of young and healthy adults.

Prolonged sitting negatively impacts cardiovascular health, with studies linking it to increased BP and heart rate. Increased sitting duration was associated with elevated systolic blood pressure (SBP, 0.42 mmHg/hour [0.18, 0.60]), diastolic blood pressure (DBP, 0.24 mmHg/hour [0.06, 0.42]), and mean arterial pressure (0.66 mmHg/hour [0.36, 0.90]) [47]. The initial systematic review on SBAE and BP was inconclusive [42]. Subsequently, Buffey et al. [46] included six studies and found SBAE had no significant effect on BP. However, Paterson et al. [44] updated review of 22 studies found SBAE significantly reduced SBP by –4.4 mmHg (ES = 0.26 [–7.4, –1.5]) and DBP by –2.4 mmHg (ES = 0.19 [–4.5, –0.3]) compared to prolonged sitting. Adams et al. [47] found SBAE during sedentary breaks reduced SBP and DBP by 0.24 mmHg/hour and 0.27 mmHg/hour, respectively, but did not affect mean arterial pressure [47].

Overall, SBAE can improve endothelial function, mainly through increased FMD, and enhance vascular shear stress and blood flow, particularly in young and healthy adults (moderate GRADE). However, the effects on pulse wave velocity remain inconclusive (very low GRADE). The acute FMD improvement could be clinically relevant, as a 1% increase in FMD has been linked to a 17% reduction in cardiovascular event risk [227]. While SBAE's effects on BP and resting heart rate are inconsistent (low GRADE), even small increases in SBP are linked to higher cardiovascular disease [228], mortality [229], and stroke mortality [230], while small reductions (~2 mmHg) lower the risks of coronary heart disease and stroke, potentially saving thousands of lives annually [231]. Further research is needed to confirm SBAE's impact on BP.

5.1.3 Brain Health

Brain health encompasses cognitive performance at the behavioral level, systemic neural (structure and function), and molecular levels, along with mental health indicators [232]. Key metrics include executive function, brain-derived neurotrophic factor (BDNF), and middle cerebral artery blood flow velocity. A systematic review by Chueh et al. [53], which included seven studies, suggested that SBAE during prolonged sitting positively impacted cognitive performance (including attention, inhibitory control, working memory, and cognitive flexibility). However, the results of the review were inconsistent, and no quantitative synthesis was performed. Feter *et al.* [60] conducted a meta-analysis that demonstrated SBAE during intermittent sitting resulted in a small but significant improvement in cognitive performance (ES = 0.20 [0.06, 0.35]), though there was no significant effect on middle cerebral artery blood flow velocity (ES = 0.15 [–0.11, 0.40]), autoregulatory function (ES = 0.13 [–0.14, 0.40]), or cerebrovascular reactivity (ES = –0.08 [–0.37, 0.21]). Other single trials have explored the acute effects of BDNF and related systemic indicators. Wheeler et al. [148] found that SBAE during intermittent sitting significantly increased the area under the curve for serum BDNF levels in older adults within an 8-hour measurement period compared to prolonged sitting. Additionally, some single trials suggested that SBAE can prevent decreases in middle cerebral artery blood flow velocity that are observed during prolonged sitting in elderly individuals with obesity or hypertension [103,147], as well as in children [139]. Conversely, no significant differences were observed in young adults [75,77,81,133].

In conclusion, SBAE shows some promise in enhancing cognitive performance and preventing declines in brain blood flow (very low to low GRADE), especially in older adults and children. However, the effects are inconsistent and may vary across age groups and health conditions. Additionally, the clinical significance of acute improvements in cognitive function remains uncertain. However, the effective prevention of declines in cerebral blood flow may be closely linked to reducing the risk of conditions such as vascular dementia and stroke [233].

5.2 Factors Influencing the Efficacy of SBAE During Interrupted Sedentary Behavior on Health Indicators (vs. Continuous Sedentary Behavior)

5.2.1 Differences in Population Characteristics

Different population characteristics can have varying impacts on the effects of SBAE during interrupted prolonged sitting. For example, Loh et al. [45] found that individuals with higher body mass index (BMI, body weight kg/height m^2) who were overweight and/or obese experienced a greater acute reduction in blood glucose and insulin during SBAE than those with normal BMI. A larger reduction was also observed among individuals with abnormal blood glucose levels (prediabetes and diagnosed diabetes) compared to normoglycemic individuals [45]. Regarding vascular function, significant improvements in cerebral middle artery blood flow velocity were observed only in older adults and children after SBAE during interrupted sedentary behavior [103,139,147]. In contrast, this benefit was not observed in healthy young adults [75,77,81,133]. In summary, the efficacy of SBAE varies across population characteristics, with factors such as BMI, blood glucose status, and age influencing its impact on metabolic and vascular responses during prolonged sitting.

5.2.2 Differences in Protocols of SBAE

Regarding SBAE protocol characteristics, Buffey et al. [46] conducted a meta-analysis of seven studies on various interruption modes for SBAE. They found that low-intensity SBAE walking was more effective than standing interruptions for reducing blood glucose (ES = –0.30 [–0.52, –0.08]) and insulin (ES = –0.54 [–0.75, –0.33]). Dempsey et al. [89] conducted a randomized crossover trial comparing low-intensity walking with bodyweight resistance exercises and found that both protocols resulted in similar reductions in postprandial blood glucose responses, 22-hour average blood glucose concentrations, insulin concentrations, and C-peptide concentrations. However, they observed a significant advantage of body weight resistance exercise in reducing postprandial triglycerides.

Regarding the frequency of SBAE, the current evidence is inconsistent; however, most studies support that higher-frequency SBAE are more effective in acutely lowering blood glucose compared to lower-frequency ones [92,112,130,142,144,150] (e.g., [30 min/session, 3 min/session] vs. [60 min/session, 6 min/session]). A three-level meta-analysis by Yin et al. [58] found that interrupting sitting at a frequency of ≤ 30 min significantly outperformed interruptions at > 30-min intervals in lowering blood glucose (ES = –0.30 [–0.57, –0.03]). However, no significant differences were observed in insulin, lipids, BP, or vascular function between different frequencies.

Quan et al. investigated the effect of exercise intensity in a network meta-analysis that included 13 studies. They found that interrupting prolonged sedentary behavior with moderate-intensity SBAE was more effective than light-intensity SBAE for reducing postprandial blood glucose (ES = –0.69 [–1.00, –0.37]) and insulin (ES = –0.47 [–0.77, –0.17]) concentrations. Collectively, existing evidence suggests that the characteristics of SBAE (including mode, frequency, and intensity) can influence its efficacy for reducing blood glucose, insulin, and lipid responses.

Further research is needed to refine these protocols and determine the optimal SBAE for metabolic health benefits.

5.3 Acute Effects of SBAE during Interrupted Sedentary Behavior (vs. Single Session or Bout of Continuous Exercise)

Several studies have compared the acute benefits of SBAE with a continuous or intermittent exercise session on glucose and lipid metabolism. A meta-analysis of 22 studies by Loh et al. [45] found that SBAE significantly outperformed single continuous exercise of equivalent energy expenditure for acutely lowering blood glucose (ES = –0.26 [–0.50, –0.02]). However, no significant differences were observed for triglyceride (ES = 0.08 [–0.22, 0.37]) or in insulin levels (ES = 0.35 [–0.37, 1.07]). Gouldrup et al. [21] included seven studies in their meta-analysis. Similarly, they found that SBAE was significantly more effective than a single bout of continuous exercise of equivalent energy expenditure for acutely lowering blood glucose (ES = –0.39 [–0.72, –0.06]). Interestingly, they noted that compared to continuous sedentary behavior, a single exercise session undertaken before sitting did not result in a significant reduction in postprandial blood glucose (ES = 0.02 [–0.32, 0.35]) [21]. However, regularly interrupting sedentary behavior with SBAE significantly reduced postprandial blood glucose (ES = –0.44 [–0.64, –0.25]) [21]. Zhang et al. [63], in a meta-analysis of 12 studies, also found that SBAE significantly improved same-day blood glucose levels compared to a single exercise session (ES = –0.36, 95% CI [–0.56, –0.17]). However, no significant differences were observed in insulin or triglyceride levels. Participants in these studies were primarily young, healthy adults, though a small number of individuals with abnormal glucose levels were also included. In summary, SBAE appears more efficacious than a single continuous or intermittent exercise session in acutely lowering blood glucose (moderate GRADE), while it shows no difference in reducing insulin or triglyceride concentrations (low GRADE).

6 CHRONIC EFFECTS OF SBAE to HEALTH PROMOTION

The chronic effects of SBAE have primarily been examined through longitudinal controlled trials aimed at understanding: 1) the health-promoting effects of SBAE (compared to a no-exercise control group) and 2) the differences in chronic effects between SBAE and single continuous or intermittent exercise sessions. These trials included interventions conducted in laboratory and real-world settings (such as workplaces), using parallel or crossover designs with fixed intervention frequencies. Outcome measures primarily included markers of cardiovascular and metabolic health, skeletal muscle health and function, body composition, perceived benefits, total PA levels, and sedentary behavior (**Table 3 and Table 4**). The study populations mainly consisted of healthy young adults and older adults. Research has involved three SBAE protocols: 1) low frequency (1–6 hours/session) with short-duration (< 1 min) vigorous-intensity exercise, 2) moderate-duration (2–5 min) moderate- to vigorous-intensity exercise, and 3) long-duration (5–10 min) moderate- to low-intensity exercise.

******Table. 3. Here******

Table. 4. Here

6.1 Health-Promoting Effects of SBAE (vs. No-Exercise Control)

6.1.1 Cardiovascular Fitness and Function

Direct measures of cardiorespiratory fitness, peak oxygen uptake ($\dot{V}O_2$peak) and maximal aerobic power, can be significantly improved by SBAE. Randomized controlled trials (RCTs) have shown that short-duration (< 1 min) vigorous-intensity exercises, such as stair climbing or cycling three times a week for sessions lasting 20 – 30 s at high to supramaximal intensity, demonstrated a $\dot{V}O_2$peak increase of 3.3 mL/kg/min (ES = 1.16 [0.65, 1.67]) after six weeks [155,164,168]. Similarly, RCTs have also shown that moderate-duration (2 – 5 min) moderate-vigorous intensity SBAE, like stair climbing five times a week for 2-min sessions, resulted in a $\dot{V}O_2$peak increase of 2.0 mL/kg/min (ES = 0.81 [0.38, 1.25]) after eight weeks [163,177,183]. A meta-analysis has shown long-duration (10 min), moderate to low- intensity exercise, consisting of walking three times a week for 10-min sessions, exhibited a $\dot{V}O_2$peak increase of 2.3 mL/kg/min (ES = 0.52 [0.24, 0.81]) after 8–12 weeks [33]. Only two RCTs consisting of short-duration (< 1 min) vigorous-intensity SBAE measured improvements in maximal aerobic power, revealing an increase of ~ 28 W (ES = 1.04 [0.47, 1.62]) after six weeks [155,168]. These studies show that different intensities of SBAE can significantly enhance $\dot{V}O_2$peak, especially in young, previously inactive, healthy adults (moderate GRADE). $\dot{V}O_2$peak as a direct measure of cardiorespiratory fitness (CRF) should be considered a clinical vital sign [234], as low CRF is associated with an increased risk of metabolic disease [235], cardiovascular disease, and cancer [236]. A $\dot{V}O_2$peak increase of just 3 mL/kg/min is associated with a 19% reduction in cardiovascular mortality and a 15% reduction in all-cause mortality [237], highlighting the clinical relevance of SBAE on $\dot{V}O_2$peak.

In addition to improved CRF, improvements in several resting cardiovascular indicators have been observed, including reductions in resting heart rate, SBP, and DBP among middle- to older-aged adults (low GRADE). A meta-analysis by Murphy et al. [33] indicated that long-duration, moderate-low intensity SBAE (primarily walking) significantly reduced resting heart rate by ~ 8 beats/min, SBP by ~3 mmHg, and DBP by ~ 5 mmHg. These long-term improvements in BP might be associated with decreased risk of coronary heart disease and stroke mortality [231].

6.1.2 Skeletal Muscle Health

Important indicators of skeletal muscle health include lower-limb muscle mass, strength, and functional performance (e.g., sit-to-stand tests). Long-duration, moderate-to-low-intensity SBAE, primarily involving body-weight resistance exercises, have shown moderate improvements in muscle strength (ES = 0.44) [157,162,166], muscle mass (ES = 0.59) [157,166], and muscle function (ES = 0.62) [158,160–162,166] (low GRADE). These findings have primarily focused on older adults, and there is a need for studies in other populations. However, given that age-related declines in skeletal muscle strength, mass, and functional capacity strongly influence morbidity, mortality, and quality of life in late life [238], the potential benefits of SBAE for skeletal muscle health in older adults warrant attention and further investigation.

6.1.3 Body Composition

Body composition indicators include body weight and BMI, body fat mass and body fat percentage, waist circumference and hip circumference, and skinfold thickness. Research by Murphy et al. [33] and Kim et al. [35] found significant small-to-large reductions in these indicators (ES = 0.33–0.96) following long-duration, moderate-to-low-intensity SBAE primarily involving walking over a median duration of 12 weeks (low GRADE). These changes have important clinical implications. For instance, reductions in body fat are frequently associated with lower risks of all-cause mortality, T2D, and heart disease [239]. A 10% reduction in waist circumference has also been linked to a decreased mortality risk [240].

6.1.4 Metabolic Health

Important metabolic health indicators include blood lipid concentrations and blood glucose control. Moderate-duration or long-duration, moderate-intensity SBAE does not significantly affect total cholesterol (ES = 0.02) [159,163,171,183] or triglyceride levels [159,163,171,178,182,183] (ES =0.19) among young to older adults including diverse health conditions (low GRADE). However, these interventions significantly increased high-density lipoprotein (ES = 0.47, increase of 0.08 mmol/L) [159,163,171,178,182,183] and decreased low-density lipoprotein (ES = 0.38, reduction of 0.22 mmol/L) [159,163,171,178,182,183]. In older adults patients with T2D, long-duration, moderate-to-low-intensity SBAE after meals reduced blood glucose iAUC by 7.5% [178], fasting blood glucose by 4–12% (0.2–1.05 mmol/L) [163,171,172,178], and glycated hemoglobin by 0.2–0.5% [172,178]. In summary, moderate-duration or long-duration, moderate-intensity SBAE improves lipid profiles by increasing high-density lipoprotein and reducing low-density lipoprotein (moderate GRADE), though the clinical significance of these changes may be limited. However, the improvements in glucose control observed with SBAE in older adults with T2D might be clinically relevant (moderate GRADE), as a reduction of 0.5% in glycated hemoglobin is often considered meaningful and is associated with significantly reduced risks of all-cause mortality, myocardial infarction, stroke, and heart failure in T2D [241].

6.1.5 Perceived Health and Physical Activity

Currently, there is limited research on the effects of SBAE for improving the quality of life [154], anxiety [154], self-efficacy, depression/anxiety, mood disorders, and, and the studies available show inconsistent findings [33]. Similarly, there is minimal evidence regarding long-term changes in PA and sedentary behavior with mixed findings [160,165], with mixed findings. Liang et al. [160] found that total PA, moderate-to-vigorous PA, and sedentary time increased at follow-up relative to baseline in older adults after 4 weeks of Tai chi-based SBAE. Stork et al. [153] reported that when participants chose to perform stair climbing based SBAE (three isolated bouts of ascending 53–60 stairs performed sporadically throughout the day), the average number of sit-to-stands performed in 24 hours was significantly increased (48.3 ± 8.7 to 52.8 ± 7.8; ES = 0.73) and moderate-to-vigorous PA tended to increase (21.9 ± 18.2 to 38.1 ± 22.1 min; ES = 0.60) compared to days without SBAE. However, Rodriguez-Hernandez et al. [165] did not observe significant changes in total PA levels or sedentary behavior after a 10-week walking SBAE intervention in office workers. In summary, the existing evidence regarding the effects of SBAE on perceived health and PA is limited and inconsistent (very low GRADE).

6.2 Differences in Health-Promoting Effects Between SBAE *vs.* Single Continuous Exercise Sessions

Studies published to date have mainly compared the health-promoting effects of two SBAE protocols (both at low frequencies) with single continuous exercise sessions: 1) long-duration, moderate-intensity SBAE (e.g., 3 sessions of 10 min, with intervals of 1–6 hours, at 65% HR_{max}) *versus* a single session of moderate-intensity continuous exercise (e.g., 30 min at 65% HR_{max}); 2) short-duration, vigorous-intensity SBAE (e.g., 3 bouts of 20–30 s, with intervals of 1–6 hours, at all-out sprints supra-maximal intensity) *versus* single continuous or intermittent bouts of exercise (e.g., 40 min at 65% HR_{max}).

Murphy et al. [33] conducted a comprehensive meta-analysis on the first comparison type (long-duration, moderate-intensity SBAE). They found no significant differences in cardiovascular, body composition, or metabolic health outcomes after long-duration, moderate-to-low-intensity SBAE (median length of 12 weeks), except for weight and blood glucose indicators. A randomized controlled trial in patients with T2D found that walking for 10 min after meals significantly improved postprandial blood glucose iAUC and fasting blood glucose, compared to a single 30-min exercise session [172,178].

Two studies by Little et al. [167] and Yin et al. [155] investigated the second comparison type (short-duration, vigorous-intensity SBAE), exploring improvements in aerobic capacity after 6 weeks (3 days per week). Little et al. [167] followed a protocol of three 20-second all-out cycling sprints per day (either performed as a single session or as single sprints throughout the day), while Yin et al. [155] implemented three all-out stair climbing sprints of 30 s each per day, compared to traditional moderate-intensity continuous exercise (40 min at 60–70% HR_{max}). Quantitative synthesis of the results ($\dot{V}O_2$peak and aerobic power) indicated no significant differences between the protocols.

In conclusion, current evidence suggests that low-frequency SBAE protocols, whether moderate-intensity or vigorous-intensity, provide comparable benefits to single continuous exercise sessions regarding cardiovascular, metabolic, and aerobic outcomes among young to older adults, including those with diverse health conditions (low GRADE). There were some specific advantages for body weight and blood glucose (especially elderly patients with T2D) management with long duration and moderate intensity SBAE protocols (low GRADE). Given that reductions in postprandial glucose independently contribute to improved glycemic control and reduced cardiovascular risk in patients with T2D [242,243], the advantages of SBAE might have clinical significance.

All acute and long-term health benefits are summarized in **Figure 1.**

****** Figure.1. Here******

7 APPLICATION FEASIBILITY

The design of longitudinal intervention studies can objectively assess the feasibility of long-term SBAE interventions by evaluating dropout rates, adherence and completion rates (the percentage of completed sessions compared to planned sessions, differentiated by supervision), and safety. Additionally, prospective pilot studies (i.e., some incorporating qualitative interviews) can explore participant perspectives, including facilitators and barriers to participation. A total of 37 longitudinal intervention studies [154–190] were conducted, involving 40 intervention groups categorized into short duration (12.5%), moderate duration (25%), and long duration (62.5%) SBAE. The intervention period ranged from 2 to 72 weeks, with an average of 11 weeks. Supervised interventions accounted for 25% of the studies, while unsupervised interventions constituted 75%. The settings included workplaces (20%), homes (20%), gyms or community centers (27.5%), laboratories (15%), and campuses (17.5%). The study populations consisted of healthy young adults (52.5%), middle-aged adults (30%), and older adults (17.5%).

7.1 Dropout and Adherence and Completion Rates

Ninety-five percent of the studies reported the dropout rate of SBAE, while 65% reported the adherence and completion rates. Dropout rates ranged from 0 to 50% (mean = 11.9% ± 11.7%; median = 11.8%, 25th [0%] – 75th [17.95%]). Completion rates ranged from 88.6% to 99.7% (mean = 95.8% ± 4.2%; median = 96.9%, 25th [96.0%] – 75th [98.0%]). Adherence rates ranged from 55.5 to 115.1% (mean = 85.1% ± 13.5%; median = 84.5, 25th [73.3%] – 75th [89.7%]), whereby those with an adherence rate > 100% completed more exercises than prescribed under supervised conditions. For example, Jansons et al., [161] reported that all participants were prescribed 8,640 exercises but completed 9,944 (115%). These rates may be influenced by protocol type, the presence or absence of supervision, different age groups, and application scenarios (**Figure 2**). As a comparative reference, a meta-analysis of 166 supervised vigorous-intensity interval training (HIIT) studies reported an average dropout rate of 13% and a completion rate of 89%. Likewise, a meta-analysis of 70 supervised moderate-intensity continuous training studies showed an average dropout rate of 12% and a completion rate of 93% [244]. Under unsupervised conditions, the dropout rate for SBAE was 12%, with a completion rate of 85%. A meta-analysis of 30 unsupervised

HIIT studies reported an average completion rate of 63%, while another meta-analysis of 17 MICT studies showed a completion rate of 68% [244]. These indirect comparisons suggest that SBAE is highly feasible in laboratory and real-world interventions. However, it is crucial to recognize that while investigating the potential of SBAE as a public health strategy, the observed dropout rate within the 11-week average intervention period provides insufficient evidence to assess long-term efficacy. Future research should prioritize longitudinal studies (typically spanning ≥6 months) with systematic follow-up to evaluate whether SBAE interventions can achieve sustained integration into daily routines, induce durable behavioral changes, and foster lasting health improvements.

****** Figure.2. Here******

7.2 Safety

Safety is assessed through reporting adverse events, with a reporting rate of 25% (10 reports [155,158,160–162,164,166,167,172,190]). Six studies reported no adverse events during the study period [155,161,164,166,167,190], while two studies reported two adverse events unrelated to the SBAE intervention (accidental deaths) [158,172]. Only two studies reported adverse events that may have been related to SBAE. Liang et al. [160] conducted a 4-week unsupervised home-based resistance SBAE for older adults and reported one adverse event: *"A pre-existing knee injury worsened during sit-to-stand exercises."* Fyfe et al. [162] conducted a 4-week unsupervised home-based fragmented resistance intervention for older adults. They reported that two participants experienced adverse events (one with plantar fasciitis and another with lower back/leg pain related to a spinal nerve/disc injury), allowing them to continue after adjustments. Fyfe et al. [162] also noted eight minor musculoskeletal discomforts, none of which affected participation. Overall, the adverse event rates for young adults, middle-aged adults, and older adults were 0, 0, and 0.1%, respectively, representing the ratio of occurrences to total completed sessions. Most available safety data are from low- to moderate-intensity SBAE intervention, with limited research and safety data for vigorous-intensity SBAE. Meanwhile, considering that the current adverse event reporting rate is only 25% and that reporting methods and content vary, more objective and quantitative safety data are needed to further support the application of SBAE. Therefore, these findings should be interpreted with caution.

7.3 Participant Perspectives

Six SBAE interventions [155,160–162,166,193] and three SBAPA$_{\leqslant 10min}$ projects (Snacktivity™ and VILPA) [191,192,195] explored participants' perspectives on facilitators and barriers to implementation, as well as future practice recommendations, using semi-structured interviews and surveys. Barriers and enablers may vary depending on population characteristics, culture, life stage, socioeconomic factors, and city or neighborhood design. Behavioral determinants of SBAE are broadly categorized into external and internal domains. External facilitators include flexible scheduling, seamless lifestyle integration, and time efficiency, whereas internal drivers encompass perceived health benefits, enhanced self-efficacy, and sustained positive mood. Conversely, participation barriers involve external limitations such as programmatic gaps (e.g., insufficient upper-body-focused protocols), environmental constraints, and internal challenges like motivational deficits (e.g., boredom and habitual neglect of practice). Although current evidence derives predominantly from short-term interventions, these preliminary findings establish a foundational framework for understanding behavioral determinants. Future studies may further investigate longitudinal dynamics change of SBAE behavioral determinants, examining temporal variations in determinants to optimize adaptive implementation strategies. The barriers and enablers to implementation details are summarized in **Figure 2** and **Table 5**, with future recommendations discussed in detail in **Section 8**.

****** Figure.2. Here******

******Table.5. Here******

8 EVIDENCE-BASED PRACTICE APPLICATIONS

8.1 Summary of Prescription Variables

The recommendations for all specific motion variable parameters are summarized in **Fig.3**.

****** Figure.3. Here******

8.1.1 Frequency (Daily) and Timing

The characteristic of SBAE $_{\leq 10min}$ being performed multiple times a day necessitates careful consideration of "timing" (i.e., daily frequency and density [245]) to maximize physiological benefits. Firstly, during periods of prolonged sedentary behavior (e.g., sitting, lying down), moderate- to low-intensity SBAE $_{\leq 10min}$ can intermittently break up sitting or reclining 30–60 min, mitigating the harmful effects of extended sedentary behavior [12,13,16,21,42,44–46,48–51,66]. Specifically, an approach with higher frequency and shorter bout duration per session might be more effective for acute improvements in glycemic control compared to longer bouts performed with lower frequency [92,112,130,142,144,150].

Meanwhile, one must consider the influence of meals and exercise timing throughout the day. Firstly, performing moderate-to-vigorous-intensity SBAE before meals can aid acute and long-term glycemic control. Francois et al. [95] compared a single continuous treadmill exercise (30 min at 60% HR_{max}) before dinner to SBAE before each meal (6 × 1 min at 90% HR_{max}). Only the pre-meal short bouts significantly reduced postprandial glucose levels and the 24-hour average glucose concentration, with benefits lasting into the following day. Secondly, sustained interventions can translate these acute benefits into long-term improvements in blood glucose indicators. Reynolds et al. [172] found that walking for 10 min after each meal significantly improved postprandial glucose iAUC and fasting glucose compared to a single 30-min walk at another time of day. Similar findings were also observed in fasting glucose and glucose tolerance tests [178]. Some studies have also compared the effects of exercise at pre-meal and post-meal time points. Engeroff et al. [246] included eight trials (116 participants) and found that post-meal exercise significantly reduced postprandial glucose but not pre-meal exercise. These results suggested SBAE timing around post-meal might be more beneficial to metabolic health.

Factors such as meal type (liquid *vs.* solid meals) and macronutrient composition might also affect the effect of SBAE. Bailey et al. [247] found that SBAE and lowering breakfast glycemic index each reduced postprandial glucose responses independently. However, there is currently very little evidence, and it is unclear whether SBAE combined with a glycemic index diet can have additional effects on improving metabolic health, nor is it clear whether various dietary strategies will interact with SBAE.

Finlay, SBAE for older adults has been designed for morning and evening sessions, and these interventions have been validated as both feasible and effective [157,158,160–162,166]. However, it is important to note that prolonged sedentary behavior may still occur. Therefore, incorporating "small and frequent" bouts of PA of any intensity is recommended to interrupt sedentary behavior.

8.1.2 Frequency (Weekly)

The weekly exercise frequency should be tailored to participant characteristics and the selected regimen. Firstly, it is feasible to interrupt prolonged sedentary behavior daily using small and frequent $SBAE_{\leq 10min}$ of any intensity and mode. Secondly, the feasibility and safety of performing one bodyweight $SBAE_{\leq 10min}$ in the morning and evening [157,158,160–162,166] or engaging in low-intensity walking after meals [95,172,178] have been validated in older adults and individuals with T2D. These SBAE can be implemented daily. However, for moderate- to vigorous-intensity or long-duration moderate-intensity exercises, a frequency of 3 to 5 times per week is supported by current research. Additionally, for short-duration (< 1 min), vigorous-intensity SBAE, the higher intensity requires more recovery time and motivation; evidence suggests that 3 sessions per week, with 48-hour intervals between sessions, is feasible [155,164,167,168,170]. Notably, a study comparing short-duration maximal sprint cycling interval training (2 × 20 s, maximal sprints, one session per day) found no difference in $\dot{V}O_2peak$ improvements with a training frequency of 2, 3, or 4 times/week, indicating that the frequency can be reduced to 2 days per week when intensity is maximal [248].

8.1.3 Intensity

The intensity range of SBAE is broad, spanning from low intensity to all-out efforts. Additionally, "intensity" is not well characterized (or easy to define) for all types of exercises (e.g., elastic band resistance exercises or plyometrics). Research on the effects of varying exercise intensities within the same protocol is insufficient. Interrupting prolonged sitting by walking at different intensities (low vs. moderate) shows no significant difference in acute glycemic control [91]. Although network meta-analyses have found that moderate-intensity interruptions in sedentary behavior result in a statistically significant reduction in blood glucose compared to low-intensity interruptions [51], the magnitude of difference would not be considered clinically meaningful [51]. However, increasing exercise intensity to moderate intensity is important for achieving broader long-term health benefits, including improved cardiovascular and endocrine function and favorable changes in body composition [33,34]. If the goal is to improve cardiorespiratory fitness and time is limited, vigorous-intensity exercise may be more effective, providing better improvements in cardiorespiratory fitness with shorter training durations (< 1 min) [155,164,167,168,170]. It is essential to adhere to the gradual progression principle when planning exercise intensity throughout the program. A cautious approach is necessary for individuals with chronic medical conditions, with careful medical screening and supervision before establishing specific exercise prescriptions [249].

8.1.4 Duration

A key characteristic of SBAE is their time-efficient nature, reflecting the idea that "*every minute counts*" [250]. The exercise duration complements intensity, and both must be balanced for effectiveness. The choice of exercise duration depends on the purpose of the short bouts. For counteracting sedentary behavior, low to moderate intensity SBAE for 2 to 5 min per session is supported by current evidence [16,21,42–54,58–60,62,65,66]. However, this range is broad, and large-scale meta-regression analyses are lacking to establish the minimum threshold for physiological efficacy and optimal duration. For comprehensive health benefits, evidence supports 5 to 10 min of moderate-to-vigorous-intensity exercise, performed 3 to 6 times daily (totaling 30 min daily) [33–35]. For improving $\dot{V}O_2$peak, a single duration of 20 to 30 seconds at maximum effort, performed 2 to 3 times daily [155,164,167,168], is sufficient, resembling short-duration HIIT [251–256], with an appropriate warm-up beforehand. Like intensity, exercise duration should be individualized and follow a gradual progression approach [249]. The weekly exercise duration targets be set at 150 min of moderate-intensity or 75 min of vigorous-intensity exercise to reduce the risks for chronic disease morbidity and mortality [1].

8.1.5 Mode

Due to their accessibility and integration into daily life, SBAE has demonstrated physiological efficacy and feasibility in unsupervised settings. Current evidence focuses primarily on walking, running, stair climbing, cycling, and body weight resistance exercises. While each mode generally improves key health biomarkers, there is limited evidence of the relative benefits of choosing one over another. Gao et al. [99] reported that brief walking and squatting interruptions during prolonged sitting effectively improve postprandial glucose control. They suggested that engaging large muscle groups could be a potential physiological mechanism underlying the effects of different modes of interruptions on glucose regulation. Dempsey et al. [89] found that bodyweight resistance exercises (9 × 20 seconds, alternating between half-squats, leg raises, and knee lifts) significantly reduced postprandial triglycerides compared to continuous sedentary behavior, while low-intensity walking did not.

Long-term, body-weight resistance exercises improve muscle strength and function [157,158,160–162,166]. Additionally, dynamic movements with higher ground reaction forces applied rapidly and in novel directions are more osteogenic than static, slow movements (such as jumping) [40,257]. Some types of jumping (e.g., jumping rope) may induce a significant cardiorespiratory stimulus, similar to HIIT, with the added benefit of greater neuromuscular stimulation [258], and can be performed in a reduced space and low-cost equipment (or no equipment at all [259]). Although running and cycling allow precise control of external loads through speed or power, they require specialized equipment. In contrast, all-out stair climbing achieves similar physiological intensities to maximal cycling sprints (perceived exertion, heart rate, and blood lactate) and offers long-term cardiovascular benefits (e.g., $\dot{V}O_2$peak) [260]. Additionally, body-weight resistance exercises can vary in intensity based on movement speed, quality, duration, and difficulty (e.g., Shanghai University of Sport Worker Interval Exercise Guidelines [261]), which can be made more engaging with music. Beyond planned SBAE, individuals are encouraged to explore everyday opportunities for short bouts of accumulated PA (e.g., climbing stairs quickly, using a shopping basket instead of a cart) to increase daily PA [191,196].

Additionally, we recommend incorporating varied multicomponent exercises that emphasize functional balance and strength training into SBAE. For instance, Liang et al. [194] developed a tai chi-based SBAE protocol for the elderly, which improved lower extremity strength, balance, and mobility. Given that previous studies have demonstrated the effectiveness of tai chi in enhancing cognitive [261], physical function [263], and fall prevention [264] in older adults, integrating this approach into SBAE might offer a simple and practical strategy for improving elderly health.

8.2 Current Evidence-Based Protocols Available

Figure 4 provides a visual summary of three distinct SBAE protocols identified through a comprehensive literature review, each characterized by varying intensities and durations of PA. These protocols are designed to be easily integrated into daily routines, balancing health improvement goals with practicality. Practitioners and participants can select protocols based on their specific health objectives.

For instance, participants with limited sitting time who engage in moderate- to vigorous-intensity PA but lack structured exercise time to improve cardiovascular function further can adopt a "low frequency, short duration, vigorous-intensity" protocol (**Figure 4-A**). This protocol involves short bursts of PA of ~20 to 30 s (0.5 min total) every 1-6 hours, three bouts per day, featuring maximal stair climbing or cycling sprints. These protocols are efficacious in improving cardiometabolic health, such as $\dot{V}O_2$peak [155,164,167,168], in the short term (6 weeks) and have similar benefits to the MICT as per traditional guidelines [155]. In contrast, **Figure 4-A** focuses on moderate-intensity and low-intensity exercise protocols. Moderate-intensity exercises lasting 5–10 min at 3–6 METs provide comprehensive health benefits, including cardiometabolic health and body composition across diverse populations [33–35]. For participants with persistent sedentary behavior and minimal PA, a "sitting less and moving more" strategy should be implemented [12]. This protocol involves first interrupting prolonged sedentary periods every 30–60 min with low-intensity exercise or PA, such as walking, which might be beneficial for acute glycemic control, vascular function, and cognitive performance [16,21,42–54,58–60,62,65,66], this protocol also reduces sedentary behavior and its associated health risks. These figures demonstrate the flexibility of exercise interventions, which can be tailored to different schedules and preferences while promoting overall health and reducing the risks of prolonged sitting and insufficient PA.

****** Figure.4. Here******

8.3 Recommendations of SBAE based on Populations and Scenarios

This study provides specific examples and recommendations for exercise prescriptions tailored to different populations and practical application contexts (**Figure 4-B**). **Figure 4-B** illustrates various populations and application scenarios, ranging from individuals engaged in structured exercise routines to patients undergoing treatment. The exercise prescriptions vary significantly in SBAE protocols (intensity and duration), depending on the target group.

For example, higher-intensity protocols, represented by vigorous activities such as stair climbing or cycling, are recommended for young people who do not sit for long periods every day and have accumulated a certain amount of MVPA (such as college students or workers) to enhance cardiometabolic health. These intensities and durations have been widely used in HIIT and are both effective and feasible in populations ranging from apparently healthy individuals to clinical populations [251,253–255,265–275]. In contrast, moderate- or low-intensity exercises, such as walking or simple resistance training, are prescribed for older adults or patients with chronic conditions like diabetes or cardiovascular disease [43,59,86,89,108–110,140,172,178]. These lower-intensity protocols are designed to ensure safety while still promoting recovery and physiological improvements. Finally, regular 2–5 min bouts every 30–60 min with low- to moderate-intensity SBAE are employed to interrupt prolonged sitting [16,21,42–54,58–60,62,65,66]. This strategy is suitable for all populations, as it is simple, easy to implement, and can be integrated with other SBAE protocols or traditional exercise programs. This approach helps achieve the dual objectives of reducing sedentary time and increasing overall PA. Each exercise prescription is associated with a set of expected benefits, including improvements in cardiovascular health, muscular strength, blood glucose levels, and reductions in fat mass, as represented by the color-coded bars in **Figure 4-B**.

Vigorous-intensity exercise protocols deliver a broad spectrum of benefits, particularly enhancing cardiovascular and metabolic health. In contrast, moderate- and low-intensity exercises focus more on maintaining general health, preventing deconditioning, and aiding recovery. The "Things to Note" section emphasizes the importance of exercise intensity regulation and monitoring [1,217,223], particularly in clinical or rehabilitation settings. Exercise intensity, denoted by the rating of perceived exertion (RPE) [276] and METs [277], ensures that the activity remains within a safe and effective range for the participant. In some cases, monitoring of physiological responses, such as heart rate and blood glucose levels, is necessary to avoid adverse effects and ensure that the exercise remains therapeutic rather than harmful.

Figure 5 encapsulates practical implications for health and fitness professionals, particularly those working with varied populations, including sedentary and/or insufficient physically activity individuals and patients. It highlights the need for customizable SBAE prescriptions that consider an individual's health status, physical capabilities, and goals. Moreover, the division between vigorous-, moderate-, and low-intensity exercise prescriptions underscores the importance of matching exercise intensity to an individual's fitness level and specific health objectives. This personalized approach maximizes health benefits while minimizing risks, particularly in clinical settings.

In conclusion, **Figure 4** provides comprehensive recommendations for SBAE prescriptions that adapt to the needs of diverse populations. It balances the benefits of different exercise intensities and durations while emphasizing the importance of monitoring and regulation to achieve optimal health outcomes across various application scenarios.

****** Figure.4. Here******

8.4 Impact on Policies or Guidelines

As public awareness has grown, expectations for the precision, specificity, and practicality of exercise and sedentary behavior guidelines have also increased. This consensus aims to provide a scientific basis and guidance for developing and implementing relevant public health policies and guidelines for improving population health. This consensus is also critical for formulating and updating global PA policies and guidelines, as countries and regions can integrate these recommendations into their existing frameworks. Such integration allows for a more comprehensive and scientific approach to public health strategies. When incorporating these recommendations into policies, it is essential to reflect current evidence-based practices while aligning with local realities, including cultural, social, and economic factors, to ensure effectiveness and feasibility. This consensus can serve as a foundation for constructing a comprehensive public health management framework. For example, at the national level, promoting the benefits and methods of SBAE to combat sedentary behavior and insufficient PA can help increase public health awareness and motivate behavioral change. At the same time, policies that support conducive environments, such as providing urban pathways, staircases, and office spaces designed to facilitate SBAE, are critical to the successful implementation of this consensus.

9 FUTURE RESEARCH DIRECTIONS

Over the past three decades, SBAE has steadily gained scientific attention, with rapidly accumulating research evidence. This trend not only aligns with the international call for a "shift towards multidimensional forms of PA" [278] but also embodies the principle that "any movement is beneficial," as emphasized in the latest PA guidelines [1–3] and exercise prescriptions [223]. This consensus identifies several ongoing challenges in the field and summarizes participants' perspectives on "future recommendations" to provide practical insights for applying and translating research findings. However, future research must address several key areas to enhance its rigor, scope, and relevance:

- **Larger sample sizes and long-term studies:** There is an urgent need for larger sample sizes and long-term RCTs to integrate behavior change techniques, further validating the current evidence on SBAE. These studies should verify whether the acute benefits of SBAE can lead to sustained long-term physiological adaptations, particularly regarding daily physical activity and reductions in sedentary behavior. Regular follow-ups should be included for primary outcomes such as changes in daily PA and sedentary behavior. These studies are crucial for updating and refining practical guidelines.
- **Personalized, lifestyle-oriented SBAE:** Future research should focus on personalized, lifestyle-based interventions to reduce sedentary behavior and promote SBAE, especially in clinical or everyday settings. Currently, most SBAE studies primarily focus on simple, repetitive movements (e.g., walking). It is essential to explore the potential of incorporating multicomponent exercises that emphasize functional balance, resistance/muscle strength, and combined strategy (such as blood flow restriction[279]) within the SBAE framework. Meanwhile, a key part of this research field will involve identifying the best activities to replace sitting, considering factors such as frequency, duration, type, and health outcomes. It is essential to understand which activities provide the most health benefits both in the short term (1–7 days) and long term (weeks to months). Furthermore, understanding when these activities may not fully counteract the negative effects of prolonged sitting is crucial. Exploring how these interventions function in real-world environments (e.g., workplace, home) alongside controlled settings is necessary, particularly for diverse populations such as women, individuals with obesity, and those in poor health. Additionally, exploring the physiological and psychological factors that might influence adherence and effectiveness, such as motivation and stress levels, will contribute to tailoring interventions more effectively.
- **Diverse populations and contextual tailoring:** Large-scale, multicenter RCTs are needed to account for potential confounding and/or moderating factors such as ethnicity, geography, medication status, and demographics demographic variables like income and education. These studies should include diverse populations, such

as individuals with disabilities (e.g., those unable to perform lower limb exercises), patients with various conditions (e.g., diabetes, hypertension), and people across different age groups (e.g., children, adolescents, young adults, middle-aged adults, and older adults). Additionally, studies should involve women at various stages, including premenarcheal, premenopausal, and postmenopausal women. This approach would enhance the generalizability of the research and ensure that interventions are effective across diverse contexts. Additionally, research should focus on when and how individuals engage in sedentary behavior and SBAE in specific contexts (e.g., timing, meal-type/timing [280,281], stress levels, energy intake, or sleep deprivation). Finally, considering that some workers might have high occupational PA and the ongoing debate about whether higher occupational PA benefits health [282–286], it is crucial to explore if SBAE can enhance health in workers with high occupational PA. This would expand the potential applications of SBAE and offer valuable insights into its role in improving health outcomes for individuals with high occupational PA. Tailoring interventions to personalized circumstances will improve both effectiveness and outcomes is crucial.

- **Exploring non-traditional cardiometabolic risk markers and mechanisms:** Future research should aim to identify non-traditional cardiometabolic risk markers (e.g., biomarkers of inflammation, and muscle metabolism) and explore the cellular, molecular, and organ-specific mechanisms influenced by both acute and habitual sedentary behaviors. Understanding how local factors (such as muscle and fat tissue) and systemic factors (like metabolism and inflammation) interact is critical for unraveling the complex pathological consequences of sedentary lifestyles. Simultaneously, a deeper understanding of the behavioral and biological determinants or modulators of SBAE is essential. Furthermore, the acute responses and long-term beneficial adaptations of SBAE on cancer biomarkers [291] should be thoroughly explored to enhance the cancer-suppressive effects of exercise [288]. This knowledge can ultimately optimize the benefits of SBAE as part of an overall strategy to mitigate the effects of sedentary behavior.
- **Research paradigm:** A systematic research paradigm should be adopted, beginning with cross-sectional studies to reveal correlations, followed by longitudinal studies to establish causality. Mixed-methods studies will evaluate the feasibility and real-world applicability of interventions, particularly in targeted populations (e.g., patients with T2D). Longitudinal intervention studies should be conducted to assess the long-term effects of SBAE on various health markers, such as metabolic health, cardiovascular function, and quality of life.
- **Detailed reporting of intervention variables and feasibility data:** Accurate documentation of intervention variables, such as when SBAE is performed throughout the day (e.g., once every two hours), is essential. Researchers should also report dropout rates, adherence, completion rates, and any adverse events in detail to enhance the transparency and reproducibility of the research. Meanwhile, dietary conditions should be objectively monitored and quantified, especially

given their independent acute and long-term effects on markers such as metabolic health. Integrating semi-structured interviews into longitudinal SBAE interventions would yield valuable insights into behavioral determinants of adherence. Additionally, it is important to consider interviewing participants who drop out of the intervention rather than only surveying those who complete it. This approach can help evaluate the effectiveness of the intervention and identify barriers to long-term adherence.

- **Balancing methodological rigor and real-world feasibility:** Future research should prioritize a stricter methodological design while ensuring that studies maintain real-world applicability. While it is crucial to minimize bias through measures such as preregistration of trial protocols, transparent randomization, monitoring of PA and nutrition, and using triple-blind designs (for implementers, evaluators, and analysts), these efforts must be balanced with the need for more practical studies. This includes investigating the responses of individuals with lower exercise motivation and adherence to SBAE in real-world settings, especially considering the barriers individuals face in their daily routines (e.g., work schedules, and family obligations).

Fig.3 outlines urgent future research directions in five key areas: quantitative monitoring of SBAE, study populations, intervention prescriptions, application effects, and practical translation.

****** Figure.3. Here******

10 CONCLUSIONS

This summary of research on SBAE over the past three decades represents the most extensive and comprehensive integration of global evidence to date. Additionally, it marks the first international expert consensus on the operational definition, program classifications, health promotion effects, practical applications, and future research directions related to SBAE. The consensus offers insights for the public and fitness professionals while providing robust evidence for researchers and policymakers to help optimize the application of SBAE. We recommend that future research adhere to this consensus's operational definitions and protocol classifications. SBAE shows potential as an emerging strategy to address the challenges of insufficient PA and sedentary behavior while promoting improvements in national health literacy. Significantly, SBAE should complement rather than compete with traditional structured exercise; we encourage the public to engage in structured, continuous PA options when feasible, while also incorporating SBAE throughout the day. Finally, while a consensus has been reached, the scientific promotion and implementation of SBAE still require further refinement through high-quality evidence. Continued research efforts should focus on eliminating barriers to implementation, particularly in policy development, environmental support, and public health promotion. Policymakers should consider integrating SBAE into national health strategies, and further attention should be given to the tools and environments that make such interventions feasible to ensure the transition from expert consensus to public consensus.

ACKNOWLEDGEMENTS

We thank Prof Barbara E. Ainsworth for her helpful comments and thoughtful suggestions for an earlier version. We thank Dr Paddy Dempsey, Dr Ana J Pinto, and Prof Martin J Gibala for participating in this consensus survey and providing valuable insights into the clinical/ practical implications and future research directions sections. We also thank the reviewers and editor for their invaluable, constructive feedback and suggestions, which significantly contributed to improving the quality of this manuscript. Thanks to Mr.Huakun Zheng and Mr.Henghao Yan for their help in data extraction and literature quality assessment.

REFERENCES

1. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451-1462. doi:10.1136/bjsports-2020-102955
2. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. Published online 2018:9.
3. Sallis RE. Exercise is medicine and physicians need to prescribe it! *Br J Sports Med*. 2009;43(1):3-4. doi:10.1136/bjsm.2008.054825
4. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet Lond Engl*. 2012;380(9838):219-229. doi:10.1016/S0140-6736(12)61031-9
5. Strain T, Brage S, Sharp SJ, et al. Use of the prevented fraction for the population to determine deaths averted by existing prevalence of physical activity: a descriptive study. *Lancet Glob Health*. 2020;8(7):e920-e930. doi:10.1016/S2214-109X(20)30211-4
6. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *Lancet Glob Health*. 2018;6(10):e1077-e1086. doi:10.1016/S2214-109X(18)30357-7
7. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc Health*. 2020;4(1):23-35. doi:10.1016/S2352-4642(19)30323-2
8. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet Lond Engl*. 2016;388(10051):1302-1310. doi:10.1016/S0140-6736(16)30370-1
9. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi:10.1186/s12966-017-0525-8
10. Yang L, Cao C, Kantor ED, et al. Trends in Sedentary Behavior Among the US Population, 2001-2016. *JAMA*. 2019;321(16):1587-1597. doi:10.1001/jama.2019.3636
11. Chen Y, Chan S, Bennett D, et al. Device-measured movement behaviours in over 20,000 China Kadoorie Biobank participants. *Int J Behav Nutr Phys Act*. 2023;20(1):138. doi:10.1186/s12966-023-01537-8
12. Dunstan DW, Dogra S, Carter SE, Owen N. Sit less and move more for cardiovascular health: emerging insights and opportunities. *Nat Rev Cardiol*. 2021;18(9):637-648. doi:10.1038/s41569-021-00547-y
13. Pinto AJ, Bergouignan A, Dempsey PC, et al. Physiology of sedentary behavior. *Physiol Rev*. 2023;103(4):2561-2622. doi:10.1152/physrev.00022.2022
14. Chastin SFM, De Craemer M, De Cocker K, et al. How does light-intensity physical activity associate with adult cardiometabolic health and mortality? Systematic review with meta-

analysis of experimental and observational studies. *Br J Sports Med*. 2019;53(6):370-376. doi:10.1136/bjsports-2017-097563

15. Stephens BR, Granados K, Zderic TW, Hamilton MT, Braun B. Effects of 1 day of inactivity on insulin action in healthy men and women: interaction with energy intake. *Metabolism*. 2011;60(7):941-949. doi:10.1016/j.metabol.2010.08.014
16. Paterson C, Fryer S, Zieff G, et al. The Effects of Acute Exposure to Prolonged Sitting, With and Without Interruption, on Vascular Function Among Adults: A Meta-analysis. *Sports Med Auckl NZ*. 2020;50(11):1929-1942. doi:10.1007/s40279-020-01325-5
17. Raichlen DA, Aslan DH, Sayre MK, et al. Sedentary Behavior and Incident Dementia Among Older Adults. *JAMA*. 2023;330(10):934-940. doi:10.1001/jama.2023.15231
18. Du Y, Liu B, Sun Y, Snetselaar LG, Wallace RB, Bao W. Trends in Adherence to the Physical Activity Guidelines for Americans for Aerobic Activity and Time Spent on Sedentary Behavior Among US Adults, 2007 to 2016. *JAMA Netw Open*. 2019;2(7):e197597. doi:10.1001/jamanetworkopen.2019.7597
19. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc*. 2002;34(12):1996-2001. doi:10.1097/00005768-200212000-00020
20. Kimm SYS, Glynn NW, McMahon RP, Voorhees CC, Striegel-Moore RH, Daniels SR. Self-perceived barriers to activity participation among sedentary adolescent girls. *Med Sci Sports Exerc*. 2006;38(3):534-540. doi:10.1249/01.mss.0000189316.71784.dc
21. Gouldrup H, Ma T. Why are physical activity breaks more effective than a single session of isoenergetic exercise in reducing postprandial glucose? A systemic review and meta-analysis. *J Sports Sci*. 2021;39(2):212-218. doi:10.1080/02640414.2020.1812196
22. Dempsey PC, Owen N, Yates TE, Kingwell BA, Dunstan DW. Sitting Less and Moving More: Improved Glycaemic Control for Type 2 Diabetes Prevention and Management. *Curr Diab Rep*. 2016;16(11):114. doi:10.1007/s11892-016-0797-4
23. Dempsey PC, Friedenreich CM, Leitzmann MF, et al. Global Public Health Guidelines on Physical Activity and Sedentary Behavior for People Living With Chronic Conditions: A Call to Action. *J Phys Act Health*. 2021;18(1):76-85. doi:10.1123/jpah.2020-0525
24. Dempsey PC, Biddle SJH, Buman MP, et al. New global guidelines on sedentary behaviour and health for adults: broadening the behavioural targets. *Int J Behav Nutr Phys Act*. 2020;17(1):151. doi:10.1186/s12966-020-01044-0
25. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003–06. *Eur Heart J*. 2011;32(5):590-597. doi:10.1093/eurheartj/ehq451
26. M. Diaz K, J. Howard V, Hutto B, et al. Patterns of Sedentary Behavior and Mortality in U.S. Middle-Aged and Older Adults. *Ann Intern Med*. Published online September 12, 2017. Accessed January 6, 2024. https://www.acpjournals.org/doi/10.7326/M17-0212
27. Ahmadi MN, Hamer M, Gill JMR, et al. Brief bouts of device-measured intermittent lifestyle physical activity and its association with major adverse cardiovascular events and mortality in people who do not exercise: A prospective cohort study. *Lancet Public Health*. 2023;8(10):e800-e810. doi:10.1016/S2468-2667(23)00183-4

28. Stamatakis E, Johnson NA, Powell L, Hamer M, Rangul V, Holtermann A. Short and sporadic bouts in the 2018 US physical activity guidelines: is high-intensity incidental physical activity the new HIIT? *Br J Sports Med*. 2019;53(18):1137-1139. doi:10.1136/bjsports-2018-100397
29. Stamatakis E, Huang BH, Maher C, et al. Untapping the Health Enhancing Potential of Vigorous Intermittent Lifestyle Physical Activity (VILPA): Rationale, Scoping Review, and a 4-Pillar Research Framework. *Sports Med*. 2021;51(1):1-10. doi:10.1007/s40279-020-01368-8
30. Stamatakis E, Ahmadi MN, Gill JMR, et al. Association of wearable device-measured vigorous intermittent lifestyle physical activity with mortality. *Nat Med*. Published online December 8, 2022. doi:10.1038/s41591-022-02100-x
31. Stamatakis E, Ahmadi MN, Friedenreich CM, et al. Vigorous Intermittent Lifestyle Physical Activity and Cancer Incidence Among Nonexercising Adults: The UK Biobank Accelerometry Study. *JAMA Oncol*. Published online July 27, 2023:e231830. doi:10.1001/jamaoncol.2023.1830
32. Ahmadi MN, Hamer M, Gill JMR, et al. Brief bouts of device-measured intermittent lifestyle physical activity and its association with major adverse cardiovascular events and mortality in people who do not exercise: a prospective cohort study. *Lancet Public Health*. 2023;8(10):e800-e810. doi:10.1016/S2468-2667(23)00183-4
33. Murphy MH, Lahart I, Carlin A, Murtagh E. The Effects of Continuous Compared to Accumulated Exercise on Health: A Meta-Analytic Review. *Sports Med Auckl NZ*. 2019;49(10):1585-1607. doi:10.1007/s40279-019-01145-2
34. Murphy MH, Blair SN, Murtagh EM. Accumulated versus continuous exercise for health benefit: a review of empirical studies. *Sports Med Auckl NZ*. 2009;39(1):29-43. doi:10.2165/00007256-200939010-00003
35. Kim H, Reece J, Kang M. Effects of Accumulated Short Bouts of Exercise on Weight and Obesity Indices in Adults: A Meta-Analysis. *Am J Health Promot*. 2020;34(1):96-104. doi:10.1177/0890117119872863
36. Jones MD, Clifford BK, Stamatakis E, Gibbs MT. Response to Comment on “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.” *Sports Med*. Published online July 20, 2024:1-3. doi:10.1007/s40279-024-02081-6
37. Jones MD, Clifford BK, Stamatakis E, Gibbs MT. 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. *Sports Med*. Published online January 8, 2024. doi:10.1007/s40279-023-01983-1
38. Islam H, Gibala MJ, Little JP. Exercise Snacks: A Novel Strategy to Improve Cardiometabolic Health. *Exerc Sport Sci Rev*. 2022;50(1):31-37. doi:10.1249/JES.0000000000000275
39. Nuzzo JL, Pinto MD, Kirk BJC, Nosaka K. Resistance Exercise Minimal Dose Strategies for Increasing Muscle Strength in the General Population: an Overview. *Sports Med*. Published online March 20, 2024. doi:10.1007/s40279-024-02009-0
40. Jackson J. Fyfe, D. Lee Hamilton, Robin M. Daly. Minimal-Dose Resistance Training for Improving Muscle Mass, Strength, and Function: A Narrative Review of Current Evidence and

Practical Considerations. *Sports Med Auckl NZ*. 2022;52(3):463-479. doi:10.1007/s40279-021-01605-8

41. Weston KL, Little JP, Weston M, et al. Application of Exercise Snacks across Youth, Adult and Clinical Populations: A Scoping Review. *Sports Med - Open*. 2025;11(1):27. doi:10.1186/s40798-025-00829-6
42. Saunders TJ, Atkinson HF, Burr J, MacEwen B, Skeaff CM, Peddie MC. The Acute Metabolic and Vascular Impact of Interrupting Prolonged Sitting: A Systematic Review and Meta-Analysis. *Sports Med Auckl NZ*. 2018;48(10):2347-2366. doi:10.1007/s40279-018-0963-8
43. Whipple MO, Masters KS, Huebschmann AG, et al. Acute effects of sedentary breaks on vascular health in adults at risk for type 2 diabetes: A systematic review. *Vasc Med Lond Engl*. 2021;26(4):448-458. doi:10.1177/1358863X211009307
44. Paterson C, Fryer S, Stone K, Zieff G, Turner L, Stoner L. The Effects of Acute Exposure to Prolonged Sitting, with and Without Interruption, on Peripheral Blood Pressure Among Adults: A Systematic Review and Meta-Analysis. *Sports Med Auckl NZ*. 2022;52(6):1369-1383. doi:10.1007/s40279-021-01614-7
45. Loh R, Stamatakis E, Folkerts D, Allgrove JE, Moir HJ. Effects of Interrupting Prolonged Sitting with Physical Activity Breaks on Blood Glucose, Insulin and Triacylglycerol Measures: A Systematic Review and Meta-analysis. *Sports Med Auckl NZ*. 2020;50(2):295-330. doi:10.1007/s40279-019-01183-w
46. Buffey AJ, Herring MP, Langley CK, Donnelly AE, Carson BP. The Acute Effects of Interrupting Prolonged Sitting Time in Adults with Standing and Light-Intensity Walking on Biomarkers of Cardiometabolic Health in Adults: A Systematic Review and Meta-analysis. *Sports Med Auckl NZ*. 2022;52(8):1765-1787. doi:10.1007/s40279-022-01649-4
47. Adams N, Paterson C, Poles J, Higgins S, Stoner L. The Effect of Sitting Duration on Peripheral Blood Pressure Responses to Prolonged Sitting, With and Without Interruption: A Systematic Review and Meta-Analysis. *Sports Med*. Published online September 8, 2023. doi:10.1007/s40279-023-01915-z
48. Chastin SFM, Egerton T, Leask C, Stamatakis E. Meta-analysis of the relationship between breaks in sedentary behavior and cardiometabolic health. *Obes Silver Spring Md*. 2015;23(9):1800-1810. doi:10.1002/oby.21180
49. Taylor FC, Pinto AJ, Maniar N, Dunstan DW, Green DJ. The Acute Effects of Prolonged Uninterrupted Sitting on Vascular Function: A Systematic Review and Meta-analysis. *Med Sci Sports Exerc*. 2022;54(1):67-76. doi:10.1249/MSS.0000000000002763
50. Soto-Rodríguez FJ, Cabañas EI, Pérez-Mármol JM. Impact of prolonged sitting interruption strategies on shear rate, flow-mediated dilation and blood flow in adults: A systematic review and meta-analysis of randomized cross-over trials. *J Sports Sci*. 2022;40(14):1558-1567. doi:10.1080/02640414.2022.2091347
51. Quan M, Xun P, Wu H, et al. Effects of interrupting prolonged sitting on postprandial glycemia and insulin responses: A network meta-analysis. *J Sport Health Sci*. 2021;10(4):419-429. doi:10.1016/j.jshs.2020.12.006

52. Dong Y, Pan Y, Zhang X, et al. Impact of Prolonged Sitting Interruption on Blood Glucose, Insulin and Triacylglycerol in Adults: A Systematic Review and Meta-Analysis. *Appl Sci*. 2024;14(8):3201. doi:10.3390/app14083201
53. Chueh TY, Chen YC, Hung TM. Acute effect of breaking up prolonged sitting on cognition: a systematic review. *BMJ Open*. 2022;12(3):e050458. doi:10.1136/bmjopen-2021-050458
54. Bates LC, Alansare A, Gibbs BB, Hanson ED, Stoner L. Effects of Acute Prolonged Sitting and Interrupting Prolonged Sitting on Heart Rate Variability and Heart Rate in Adults: A Meta-Analysis. *Front Physiol*. 2021;12:664628. doi:10.3389/fphys.2021.664628
55. Yin M, Li H, Zhang B, Li Y. Comment on “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.” *Sports Med*. Published online July 22, 2024. doi:10.1007/s40279-024-02080-7
56. 《中国人群身体活动指南》编写委员会. 中国人群身体活动指南（2021）. 中华流行病学杂志. 20220126;43(1):5-6. doi:10.3760/cma.j.cn112338-20211119-00903
57. 顾东风, 翁建平, 鲁向锋. 中国健康生活方式预防心血管代谢疾病指南. 中国循环杂志. 2020;35(3):209-230.
58. Yin M, Xu K, Deng J, et al. Optimal Frequency of Interrupting Prolonged Sitting for Cardiometabolic Health: A Systematic Review and Meta-analysis of Randomized Cross-Over Trials. *Scand J Med Sci Sports*. Published online Revised 2024.
59. Smith S, Salmani B, LeSarge J, Dillon-Rossiter K, Morava A, Prapavessis H. Interventions to reduce sedentary behaviour in adults with type 2 diabetes: A systematic review and meta-analysis. *PloS One*. 2024;19(7):e0306439. doi:10.1371/journal.pone.0306439
60. Feter N, Ligeza TS, Bashir N, et al. Effects of reducing sedentary behaviour by increasing physical activity, on cognitive function, brain function and structure across the lifespan: a systematic review and meta-analysis. *Br J Sports Med*. Published online August 28, 2024:bjsports-2024-108444. doi:10.1136/bjsports-2024-108444
61. 殷明越, 刘骞, 李汉森, et al. 运动间断久坐对糖、脂代谢与血管功能的急性影响、科学机理与应用建议：系统综述. 中国运动医学杂志. Published online 2024:1-21. doi:10.16038/j.1000-6710.20240809.001
62. Yin M, Deng S, Jianfeng D, Li Y. 久坐间断对成年人血管功能的急性影响与调节因素：荟萃分析. 中国组织工程研究. Published online August 19, 2024. doi:10.12307/2025.627
63. Zhang X, Zheng C, Ho RST, Miyashita M, Wong SHS. The Effects of Accumulated Versus Continuous Exercise on Postprandial Glycemia, Insulin, and Triglycerides in Adults with or Without Diabetes: A Systematic Review and Meta-Analysis. *Sports Med - Open*. 2022;8(1):14. doi:10.1186/s40798-021-00401-y
64. Tuckwell GA, Vincent GE, Gupta CC, Ferguson SA. Does breaking up sitting in office-based settings result in cognitive performance improvements which last throughout the day? A review of the evidence. *Ind Health*. Published online January 28, 2022. doi:10.2486/indhealth.2021-0174
65. Zheng C, Zhang X, Sheridan S, et al. Effect of sedentary behavior interventions on vascular function in adults: A systematic review and meta-analysis. *Scand J Med Sci Sports*. 2021;31(7):1395-1410. doi:10.1111/sms.13947

66. 马生霞, 曹振波. 久坐行为间断干预对血糖、胰岛素和血脂影响的系统综述与 Meta 分析. 中国体育科技. 2018;54(4):75-91. doi:10.16470/j.csst.201804010
67. Altenburg TM, Rotteveel J, Dunstan DW, Salmon J, Chinapaw MJM. The effect of interrupting prolonged sitting time with short, hourly, moderate-intensity cycling bouts on cardiometabolic risk factors in healthy, young adults. *J Appl Physiol Bethesda Md 1985*. 2013;115(12):1751-1756. doi:10.1152/japplphysiol.00662.2013
68. Bailey DP, Locke CD. Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not. *J Sci Med Sport*. 2015;18(3):294-298. doi:10.1016/j.jsams.2014.03.008
69. Bailey DP, Orton CJ, Maylor BD, Zakrzewski-Fruer JK. Cardiometabolic Response to a Single High-intensity Interval Exercise Session Versus Breaking up Sedentary Time with Fragmented High-intensity Interval Exercise. *Int J Sports Med*. 2019;40(3):165-170. doi:10.1055/a-0828-8217
70. Bailey DP, Withers TM, Goosey-Tolfrey VL, et al. Acute effects of breaking up prolonged sedentary time on cardiovascular disease risk markers in adults with paraplegia. *Scand J Med Sci Sports*. 2020;30(8):1398-1408. doi:10.1111/sms.13671
71. Barone Gibbs B, Kowalsky RJ, Perdomo SJ, Taormina JM, Balzer JR, Jakicic JM. Effect of alternating standing and sitting on blood pressure and pulse wave velocity during a simulated workday in adults with overweight/obesity. *J Hypertens*. 2017;35(12):2411-2418. doi:10.1097/hjh.0000000000001463
72. Bhammar DM, Sawyer BJ, Tucker WJ, Gaesser GA. Breaks in Sitting Time: Effects on Continuously Monitored Glucose and Blood Pressure. *Med Sci Sports Exerc*. 2017;49(10):2119-2130. doi:10.1249/MSS.0000000000001315
73. Blankenship JM, Granados K, Braun B. Effects of subtracting sitting versus adding exercise on glycemic control and variability in sedentary office workers. *Appl Physiol Nutr Metab Physiol Appl Nutr Metab*. 2014;39(11):1286-1293. doi:10.1139/apnm-2014-0157
74. Brocklebank LA, Andrews RC, Page A, Falconer CL, Leary S, Cooper A. The Acute Effects of Breaking Up Seated Office Work With Standing or Light-Intensity Walking on Interstitial Glucose Concentration: A Randomized Crossover Trial. *J Phys Act Health*. 2017;14(8):617-625. doi:10.1123/jpah.2016-0366
75. Caldwell HG, Coombs GB, Rafiei H, Ainslie PN, Little JP. Hourly staircase sprinting exercise “snacks” improve femoral artery shear patterns but not flow-mediated dilation or cerebrovascular regulation: a pilot study. *Appl Physiol Nutr Metab Physiol Appl Nutr Metab*. 2021;46(5):521-529. doi:10.1139/apnm-2020-0562
76. Campbell MD, Alobaid AM, Hopkins M, et al. Interrupting prolonged sitting with frequent short bouts of light-intensity activity in people with type 1 diabetes improves glycaemic control without increasing hypoglycaemia: The SIT-LESS randomised controlled trial. *Diabetes Obes Metab*. 2023;25(12):3589-3598. doi:10.1111/dom.15254
77. Carter SE, Draijer R, Holder SM, Brown L, Thijssen DHJ, Hopkins ND. Regular walking breaks prevent the decline in cerebral blood flow associated with prolonged sitting. *J Appl Physiol*. 2018;125(3):790-798. doi:10.1152/japplphysiol.00310.2018

78. Carter SE, Draijer R, Holder SM, Brown L, Thijssen DHJ, Hopkins ND. Effect of different walking break strategies on superficial femoral artery endothelial function. *Physiol Rep*. 2019;7(16). doi:10.14814/phy2.14190
79. Carter SE, Gladwell VF. Effect of breaking up sedentary time with callisthenics on endothelial function. *J Sports Sci*. 2017;35(15):1508-1514. doi:10.1080/02640414.2016.1223331
80. Champion RB, Smith LR, Smith J, et al. Reducing prolonged sedentary time using a treadmill desk acutely improves cardiometabolic risk markers in male and female adults. *J Sports Sci*. 2018;36(21):2484-2491. doi:10.1080/02640414.2018.1464744
81. Chandran O, Shruthi P, Sukumar S, et al. Effects of physical activity breaks during prolonged sitting on vascular and executive function-A randomised cross-over trial. *J Taibah Univ Med Sci*. 2023;18(5):1065-1075. doi:10.1016/j.jtumed.2023.03.004
82. Chen YC, Betts JA, Walhin JP, Thompson D. Adipose Tissue Responses to Breaking Sitting in Men and Women with Central Adiposity. *Med Sci Sports Exerc*. 2018;50(10):2049-2057. doi:10.1249/MSS.0000000000001654
83. Cho MJ, Bunsawat K, Kim HJ, Yoon ES, Jae SY. The acute effects of interrupting prolonged sitting with stair climbing on vascular and metabolic function after a high-fat meal. *Eur J Appl Physiol*. 2020;120(4):829-839. doi:10.1007/s00421-020-04321-9
84. Climie RE, Grace MS, Larsen RL, et al. Regular brief interruptions to sitting after a high-energy evening meal attenuate glycemic excursions in overweight/obese adults. *Nutr Metab Cardiovasc Dis*. 2018;28(9):909-916. doi:10.1016/j.numecd.2018.05.009
85. Climie RE, Wheeler MJ, Grace M, et al. SIMPLE INTERMITTENT RESISTANCE ACTIVITY MITIGATES THE DETRIMENTAL EFFECT OF PROLONGED UNBROKEN SITTING ON ARTERIAL FUNCTION IN OVERWEIGHT AND OBESE ADULTS. *J Appl Physiol Bethesda Md 1985*. Published online 2018. doi:10.1152/japplphysiol.00544.2018
86. Dempsey PC, Blankenship JM, Larsen RN, et al. Interrupting prolonged sitting in type 2 diabetes: nocturnal persistence of improved glycaemic control. *Diabetologia*. 2017;60(3):499-507. doi:10.1007/s00125-016-4169-z
87. Dempsey PC, Larsen RN, Winkler EAH, Owen N, Kingwell BA, Dunstan DW. Prolonged uninterrupted sitting elevates postprandial hyperglycaemia proportional to degree of insulin resistance. *Diabetes Obes Metab*. 2018;20(6):1526-1530. doi:10.1111/dom.13254
88. Dempsey PC, Sacre JW, Larsen RN, et al. Interrupting prolonged sitting with brief bouts of light walking or simple resistance activities reduces resting blood pressure and plasma noradrenaline in type 2 diabetes. *J Hypertens*. 2016;34(12):2376-2382. doi:10.1097/hjh.0000000000001101
89. Dempsey PC, Larsen RN, Sethi P, et al. Benefits for Type 2 Diabetes of Interrupting Prolonged Sitting With Brief Bouts of Light Walking or Simple Resistance Activities. *Diabetes Care*. 2016;39(6):964-972. doi:10.2337/dc15-2336
90. Dey KC, Zakrzewski-Fruer JK, Smith LR, Jones RL, Bailey DP. Interrupting sitting acutely attenuates cardiometabolic risk markers in South Asian adults living with overweight and obesity. *Eur J Appl Physiol*. 2024;124(4):1163-1174. doi:10.1007/s00421-023-05345-7

91. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking Up Prolonged Sitting Reduces Postprandial Glucose and Insulin Responses. *Diabetes Care*. 2012;35(5):976-983. doi:10.2337/dc11-1931
92. Duran AT, Friel CP, Serafini MA, Ensari I, Cheung YK, Diaz KM. Breaking Up Prolonged Sitting to Improve Cardiometabolic Risk: Dose–Response Analysis of a Randomized Crossover Trial. *Med Sci Sports Exerc*. 2023;55(5):847-855. doi:10.1249/MSS.0000000000003109
93. English C, Janssen H, Crowfoot G, et al. Frequent, short bouts of light-intensity exercises while standing decreases systolic blood pressure: breaking Up Sitting Time after Stroke (BUST-Stroke) trial. *Int J Stroke*. 2018;13(9):932-940. doi:10.1177/1747493018798535
94. Evans WS, Stoner L, Willey Q, Kelsch E, Credeur DP, Hanson ED. Local exercise does not prevent the aortic stiffening response to acute prolonged sitting: a randomized crossover trial. *J Appl Physiol Bethesda Md 1985*. 2019;127(3):781-787. doi:10.1152/japplphysiol.00318.2019
95. Francois ME, Baldi JC, Manning PJ, et al. “Exercise snacks” before meals: a novel strategy to improve glycaemic control in individuals with insulin resistance. *Diabetologia*. 2014;57(7):1437-1445. doi:10.1007/s00125-014-3244-6
96. Freire YA, Macêdo G de AD de, Browne RAV, et al. Effect of Breaks in Prolonged Sitting or Low-Volume High-Intensity Interval Exercise on Markers of Metabolic Syndrome in Adults With Excess Body Fat: A Crossover Trial. *J Phys Act Health*. 2019;16(9):727-735. doi:10.1123/jpah.2018-0492
97. Gale JT, Haszard JJ, Peddie MC. Improved glycaemic control induced by evening activity breaks does not persist overnight amongst healthy adults: A randomized crossover trial. *Diabetes Obes Metab*. 2024;26(7):2732-2740. doi:10.1111/dom.15589
98. Gale JT, Wei DL, Haszard JJ, Brown RC, Taylor RW, Peddie MC. Breaking Up Evening Sitting with Resistance Activity Improves Postprandial Glycemic Response: A Randomized Crossover Study. *Med Sci Sports Exerc*. 2023;55(8):1471-1480. doi:10.1249/MSS.0000000000003166
99. Gao Y, Li QY, Finni T, Pesola AJ. Enhanced muscle activity during interrupted sitting improves glycemic control in overweight and obese men. *Scand J Med Sci Sports*. 2024;34(4):e14628. doi:10.1111/sms.14628
100. Gillen JB, Estafanos S, Williamson E, et al. Interrupting prolonged sitting with repeated chair stands or short walks reduces postprandial insulinemia in healthy adults. *J Appl Physiol 1985*. 2021;130(1):104-113. doi:10.1152/japplphysiol.00796.2020
101. Han H, Lim J, Viskochil R, Aguiar EJ, Tudor-Locke C, Chipkin SR. Pilot Study of Impact of a Pedal Desk on Postprandial Responses in Sedentary Workers. *Med Sci Sports Exerc*. 2018;50(10):2156-2163. doi:10.1249/mss.0000000000001679
102. Hansen RK, Andersen JB, Vinther AS, Pielmeier U, Larsen RG. Breaking up Prolonged Sitting does not Alter Postprandial Glycemia in Young, Normal-Weight Men and Women. *Int J Sports Med*. 2016;37(14):1097-1102. doi:10.1055/s-0042-113466

103. Hartman YAW, Tillmans LCM, Benschop DL, et al. Long-Term and Acute Benefits of Reduced Sitting on Vascular Flow and Function. *Med Sci Sports Exerc*. 2021;53(2):341-350. doi:10.1249/MSS.0000000000002462
104. Hawari NS, Al-Shayji I, Wilson J, Gill JM. Frequency of Breaks in Sedentary Time and Postprandial Metabolic Responses. *Med Sci Sports Exerc*. 2016;48(12):2495-2502. doi:10.1249/mss.0000000000001034
105. Hawari NSA, Wilson J, Gill JMR. Effects of breaking up sedentary time with “chair squats” on postprandial metabolism. *J Sports Sci*. 2019;37(3):331-338. doi:10.1080/02640414.2018.1500856
106. Henson J, Davies MJ, Bodicoat DH, et al. Breaking Up Prolonged Sitting With Standing or Walking Attenuates the Postprandial Metabolic Response in Postmenopausal Women: A Randomized Acute Study. *Diabetes Care*. 2016;39(1):130-138. doi:10.2337/dc15-1240
107. Holmstrup M, Fairchild T, Keslacy S, Weinstock R, Kanaley J. Multiple short bouts of exercise over 12-h period reduce glucose excursions more than an energy-matched single bout of exercise. *Metabolism*. 2014;63(4):510-519. doi:10.1016/j.metabol.2013.12.006
108. Homer AR, Taylor FC, Dempsey PC, et al. Frequency of Interruptions to Sitting Time: Benefits for Postprandial Metabolism in Type 2 Diabetes. *Diabetes Care*. 2021;44(6):1254-1263. doi:10.2337/dc20-1410
109. Homer AR, Taylor FC, Dempsey PC, et al. Different frequencies of active interruptions to sitting have distinct effects on 22 h glycemic control in type 2 diabetes. *Nutr Metab Cardiovasc Dis NMCD*. 2021;31(10):2969-2978. doi:10.1016/j.numecd.2021.07.001
110. Honda H, Igaki M, Hatanaka Y, et al. Stair climbing/descending exercise for a short time decreases blood glucose levels after a meal in people with type 2 diabetes. *Bmj Open Diabetes Res Care*. 2016;4(1). doi:10.1136/bmjdrc-2016-000232
111. Kashiwabara K, Kidokoro T, Yanaoka T, Burns SF, Stensel DJ, Miyashita M. Different Patterns of Walking and Postprandial Triglycerides in Older Women. *Med Sci Sports Exerc*. 2018;50(1):79-87. doi:10.1249/MSS.0000000000001413
112. Kerr J, Crist K, Vital DG, et al. Acute glucoregulatory and vascular outcomes of three strategies for interrupting prolonged sitting time in postmenopausal women: A pilot, laboratory-based, randomized, controlled, 4-condition, 4-period crossover trial. Samocha-Bonet D, ed. *PLOS ONE*. 2017;12(11):e0188544. doi:10.1371/journal.pone.0188544
113. Kowalsky RJ, Jakicic JM, Hergenroeder A, Rogers RJ, Gibbs BB. Acute cardiometabolic effects of interrupting sitting with resistance exercise breaks. *Appl Physiol Nutr Metab*. 2019;44(10):1025-1032. doi:10.1139/apnm-2018-0633
114. Kruse NT, Hughes WE, Benzo RM, Carr LJ, Casey DP. Workplace Strategies to Prevent Sitting-induced Endothelial Dysfunction. *Med Sci Sports Exerc*. 2018;50(4):801-808. doi:10.1249/MSS.0000000000001484
115. Larsen RN, Kingwell BA, Robinson C, et al. Breaking up of prolonged sitting over three days sustains, but does not enhance, lowering of postprandial plasma glucose and insulin in overweight and obese adults. *Clin Sci*. 2015;129(2):117-127. doi:10.1042/cs20140790

116. Larsen R, Ali H, Dempsey PC, et al. Interrupting Sitting Time with Simple Resistance Activities Lowers Postprandial Insulinemia in Adults with Overweight or Obesity. *Obes Silver Spring Md*. 2019;27(9):1428-1433. doi:10.1002/oby.22554

117. Ma SX, Zhu Z, Cao ZB. Effects of interrupting sitting with different activity bouts on postprandial lipemia: A randomized crossover trial. *Scand J Med Sci Sports*. 2021;31(3):633-642. doi:10.1111/sms.13886

118. Ma SX, Zhu Z, Zhang L, Liu XM, Lin YY, Cao ZB. Metabolic Effects of Three Different Activity Bouts during Sitting in Inactive Adults. *Med Sci Sports Exerc*. 2020;52(4):851-858. doi:10.1249/MSS.0000000000002212

119. Masahiro Horiuchi, Lee Stoner. Macrovascular and microvascular responses to prolonged sitting with and without bodyweight exercise interruptions: A randomized cross-over trial. *Vasc Med Lond Engl*. 2022;27(2):127-135. doi:10.1177/1358863X211053381

120. Maylor BD, Zakrzewski-Fruer JK, Orton CJ, Bailey DP. Beneficial postprandial lipaemic effects of interrupting sedentary time with high-intensity physical activity versus a continuous moderate-intensity physical activity bout: A randomised crossover trial. *J Sci Med Sport*. 2018;21(12):1250-1255. doi:10.1016/j.jsams.2018.05.022

121. McCarthy M, Edwardson CL, Davies MJ, et al. Fitness Moderates Glycemic Responses to Sitting and Light Activity Breaks. *Med Sci Sports Exerc*. 2017;49(11):2216-2222. doi:10.1249/MSS.0000000000001338

122. McCarthy M, Edwardson CL, Davies MJ, et al. Breaking up sedentary time with seated upper body activity can regulate metabolic health in obese high-risk adults: A randomized crossover trial. *Diabetes Obes Metab*. 2017;19(12):1732-1739. doi:10.1111/dom.13016

123. Miyashita M. Effects of continuous versus accumulated activity patterns on postprandial triacylglycerol concentrations in obese men. *Int J Obes 2005*. 2008;32(8):1271-1278. doi:10.1038/ijo.2008.73

124. Miyashita M, Edamoto K, Kidokoro T, et al. Interrupting Sitting Time with Regular Walks Attenuates Postprandial Triglycerides. *Int J Sports Med*. 2016;37(2):97-103. doi:10.1055/s-0035-1559791

125. Miyashita M, Burns SF, Stensel DJ. Exercise and postprandial lipemia: effect of continuous compared with intermittent activity patterns. *Am J Clin Nutr*. 2006;83(1):24-29. doi:10.1093/ajcn/83.1.24

126. Miyashita M, Burns SF, Stensel DJ. Accumulating short bouts of brisk walking reduces postprandial plasma triacylglycerol concentrations and resting blood pressure in healthy young men. *Am J Clin Nutr*. 2008;88(5):1225-1231. doi:10.3945/ajcn.2008.26493

127. Miyashita M, Burns SF, Stensel DJ. Acute effects of accumulating exercise on postprandial lipemia and C-reactive protein concentrations in young men. *Int J Sport Nutr Exerc Metab*. 2009;19(6):569-582. doi:10.1123/ijsnem.19.6.569

128. Morishima T, Restaino RM, Walsh LK, Kanaley JA, Fadel PJ, Padilla J. Prolonged sitting-induced leg endothelial dysfunction is prevented by fidgeting. *Am J Physiol Heart Circ Physiol*. 2016;311(1):H177-182. doi:10.1152/ajpheart.00297.2016

129. Murphy MH, Nevill AM, Hardman AE. Different patterns of brisk walking are equally effective in decreasing postprandial lipaemia. *Int J Obes Relat Metab Disord J Int Assoc Study Obes*. 2000;24(10):1303-1309. doi:10.1038/sj.ijo.0801399
130. Paing AC, McMillan KA, Kirk AF, Collier A, Hewitt A, Chastin SFM. Dose-response between frequency of breaks in sedentary time and glucose control in type 2 diabetes: A proof of concept study. *J Sci Med Sport*. 2019;22(7):808-813. doi:10.1016/j.jsams.2019.01.017
131. Park SY, Wooden TK, Pekas EJ, et al. Effects of passive and active leg movements to interrupt sitting in mild hypercapnia on cardiovascular function in healthy adults. *J Appl Physiol*. 2022;132(3):874-887. doi:10.1152/japplphysiol.00799.2021
132. Peddie MC, Kessell C, Bergen T, et al. The effects of prolonged sitting, prolonged standing, and activity breaks on vascular function, and postprandial glucose and insulin responses: A randomised crossover trial. *PloS One*. 2021;16(1):e0244841. doi:10.1371/journal.pone.0244841
133. Perdomo SJ, Gibbs BB, Kowalsky RJ, Taormina JM, Balzer JR. Effects of alternating standing and sitting compared to prolonged sitting on cerebrovascular hemodynamics. *Sport Sci Health*. 2019;15(2):375-383. doi:10.1007/s11332-019-00526-4
134. Pulsford RM, Blackwell J, Hillsdon M, Kos K. Intermittent walking, but not standing, improves postprandial insulin and glucose relative to sustained sitting: A randomised cross-over study in inactive middle-aged men. *J Sci Med Sport*. 2017;20(3):278-283. doi:10.1016/j.jsams.3016.08.012
135. Rafiei H, Omidian K, Myette-Côté É, Little JP. Metabolic Effect of Breaking Up Prolonged Sitting with Stair Climbing Exercise Snacks. *Med Sci Sports Exerc*. 2021;53(1):150-158. doi:10.1249/MSS.0000000000002431
136. Rodriguez-Hernandez M, Martin JS, Pascoe DD, Roberts MD, Wadsworth DW. Multiple Short Bouts of Walking Activity Attenuate Glucose Response in Obese Women. *J Phys Act Health*. 2018;15(4):279-286. doi:10.1123/jpah.2017-0251
137. Shambrook P, Kingsley MI, Taylor NF, Wundersitz DW, Wundersitz CE, Gordon BA. Multiple short bouts of exercise are better than a single continuous bout for cardiometabolic health: a randomised crossover trial. *Eur J Appl Physiol*. 2020;120(11):2361-2369. doi:10.1007/s00421-020-04461-y
138. Silva GO, Carvalho JF, Kanegusuku H, Farah BQ, Correia MA, Ritti-Dias RM. Acute effects of breaking up sitting time with isometric exercise on cardiovascular health: Randomized crossover trial. *Scand J Med Sci Sports*. 2021;31(11):2044-2054. doi:10.1111/sms.14024
139. Tallon CM, Nowak-Flück D, Reiger MG, et al. Exercise breaks prevent attenuation in cerebrovascular function following an acute bout of uninterrupted sitting in healthy children. *Exp Physiol*. 2023;108(11):1386-1399. doi:10.1113/EP091314
140. Taylor FC, Dunstan DW, Homer AR, et al. Acute effects of interrupting prolonged sitting on vascular function in type 2 diabetes. *Am J Physiol Heart Circ Physiol*. 2021;320(1):H393-h403. doi:10.1152/ajpheart.00422.2020
141. Taylor FC, Dunstan DW, Fletcher E, et al. Interrupting Prolonged Sitting and Endothelial Function in Polycystic Ovary Syndrome. *Med Sci Sports Exerc*. 2021;53(3):479-486. doi:10.1249/MSS.0000000000002513

142. Thorsen IK, Johansen MY, Pilmark NS, et al. The effect of frequency of activity interruptions in prolonged sitting on postprandial glucose metabolism: A randomized crossover trial. *Metabolism*. 2019;96:1-7. doi:10.1016/j.metabol.2019.04.003
143. Thosar SS, Bielko SL, Mather KJ, Johnston JD, Wallace JP. Effect of prolonged sitting and breaks in sitting time on endothelial function. *Med Sci Sports Exerc*. 2015;47(4):843-849. doi:10.1249/MSS.0000000000000479
144. Toledo MJL, Ainsworth BE, Gaesser GA, Hooker SP, Pereira MA, Buman MP. Does frequency or duration of standing breaks drive changes in glycemic response? A randomized crossover trial. *Scand J Med Sci Sports*. 2023;33(7):1135-1145. doi:10.1111/sms.14344
145. Wanders L, Cuijpers I, Kessels RPC, van de Rest O, Hopman MTE, Thijssen DHJ. Impact of prolonged sitting and physical activity breaks on cognitive performance, perceivable benefits, and cardiometabolic health in overweight/obese adults: The role of meal composition. *Clin Nutr*. 2021;40(4):2259-2269. doi:10.1016/j.clnu.2020.10.006
146. Wennberg P, Boraxbekk CJ, Wheeler M, et al. Acute effects of breaking up prolonged sitting on fatigue and cognition: a pilot study. *BMJ Open*. 2016;6(2):e009630. doi:10.1136/bmjopen-2015-009630
147. Wheeler MJ, Dunstan DW, Smith B, et al. Morning exercise mitigates the impact of prolonged sitting on cerebral blood flow in older adults. *J Appl Physiol*. 2019;126(4):1049-1055. doi:10.1152/japplphysiol.00001.2019
148. Wheeler MJ, Green DJ, Ellis KA, et al. Distinct effects of acute exercise and breaks in sitting on working memory and executive function in older adults: a three-arm, randomised cross-over trial to evaluate the effects of exercise with and without breaks in sitting on cognition. *Br J Sports Med*. 2020;54(13):776-781. doi:10.1136/bjsports-2018-100168
149. Wongpipit W, Zhang X, Miyashita M, Wong SH. Interrupting Prolonged Sitting Reduces Postprandial Glucose Concentration in Young Men With Central Obesity. *J Clin Endocrinol Metab*. 2021;106(2):e791-e802. doi:10.1210/clinem/dgaa834
150. Wongpipit W, Huang WY, Miyashita M, Tian XY, Wong SHS. Frequency of interruptions to prolonged sitting and postprandial metabolic responses in young, obese, Chinese men. *J Sports Sci*. 2021;39(12):1376-1385. doi:10.1080/02640414.2021.1874170
151. Yap MC, Balasekaran G, Burns SF. Acute effect of 30 min of accumulated versus continuous brisk walking on insulin sensitivity in young Asian adults. *Eur J Appl Physiol*. 2015;115(9):1867-1875. doi:10.1007/s00421-015-3174-0
152. Yates T, Edwardson CL, Celis-Morales C, et al. Metabolic Effects of Breaking Prolonged Sitting With Standing or Light Walking in Older South Asians and White Europeans: a Randomized Acute Study. *J Gerontol A Biol Sci Med Sci*. 2020;75(1):139-146. doi:10.1093/gerona/gly252
153. Stork MJ, Marcotte-Chénard A, Jung ME, Little JP. Exercise in the workplace: Examining the receptivity of practical and time-efficient stair climbing "exercise snacks." *Appl Physiol Nutr Metab*. Published online September 25, 2023:apnm-2023-0128. doi:10.1139/apnm-2023-0128
154. Yn MY, Liitle J, Li Y. Effects of Integrating Stair Climbing-based Exercise Snacks into the Campus on Feasibility, Perceived Efficacy, and Participation Perspectives in Inactive Young

Adult: A Randomized Mixed-Methods Pilot Study. *Scand J Med Sci Sports*. Published online 2024.

155. Yin M, Deng S, Chen Z, et al. Exercise snacks are a time-efficient alternative to moderate-intensity continuous training for improving cardiorespiratory fitness but not maximal fat oxidation in inactive adults: a randomized controlled trial. *Appl Physiol Nutr Metab Physiol Appl Nutr Metab*. Published online April 3, 2024. doi:10.1139/apnm-2023-0593
156. Liang IJ, Perkin OJ, Williams S, McGuigan PM, Thompson D, Wester MJ. The efficacy of 12-week progressive home-based strength and tai-chi exercise snacking in older adults: A mixed-method exploratory randomised control trial. *J Frailty Aging*. Published online 2024. doi:10.14283/jfa.2024.32
157. Brandt T, Schwandner CTL, Schmidt A. Resistance exercise snacks improve muscle mass in female university employees: a prospective, controlled, intervention pilot-study. *Front Public Health*. 2024;12. Accessed February 25, 2024. https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1347825
158. Western MJ, Welsh T, Keen K, Bishop V, Perkin OJ. Exercise snacking to improve physical function in pre-frail older adult memory clinic patients: a 28-day pilot study. *BMC Geriatr*. Published online 2023.
159. 刘朝辉, 庞亚俊, 孟慧丽, 焦洁. 久坐间断干预对肥胖女大学生身体成分和血脂代谢的影响. 中国学校卫生. 2023;44(8):1140-1144. doi:10.16835/j.cnki.1000-9817.2023.08.005
160. Liang IJ, Perkin OJ, McGuigan PM, Thompson D, Western MJ. Feasibility and Acceptability of Home-Based Exercise Snacking and Tai Chi Snacking Delivered Remotely to Self-Isolating Older Adults During COVID-19. *J Aging Phys Act*. 2022;30(1):33-43. doi:10.1123/japa.2020-0391
161. Jansons P, Dalla Via J, Daly RM, Fyfe JJ, Gvozdenko E, Scott D. Delivery of Home-Based Exercise Interventions in Older Adults Facilitated by Amazon Alexa: A 12-week Feasibility Trial. *J Nutr Health Aging*. 2022;26(1):96-102. doi:10.1007/s12603-021-1717-0
162. Fyfe JJ, Dalla Via J, Jansons P, Scott D, Daly RM. Feasibility and acceptability of a remotely delivered, home-based, pragmatic resistance ‘exercise snacking’ intervention in community-dwelling older adults: a pilot randomised controlled trial. *BMC Geriatr*. 2022;22(1):521. doi:10.1186/s12877-022-03207-z
163. Michael E, White MJ, Eves FF. Home-Based Stair Climbing as an Intervention for Disease Risk in Adult Females; A Controlled Study. *Int J Environ Res Public Health*. 2021;18(2):603. doi:10.3390/ijerph18020603
164. Wun CH, Zhang MJ, Ho BH, McGeough K, Tan F, Aziz AR. Efficacy of a Six-Week Dispersed Wingate-Cycle Training Protocol on Peak Aerobic Power, Leg Strength, Insulin Sensitivity, Blood Lipids and Quality of Life in Healthy Adults. *Int J Environ Res Public Health*. 2020;17(13):4860. doi:10.3390/ijerph17134860
165. Rodriguez-Hernandez MG, Wadsworth DW. The effect of 2 walking programs on aerobic fitness, body composition, and physical activity in sedentary office employees. *PloS One*. 2019;14(1):e0210447. doi:10.1371/journal.pone.0210447

166. Perkin OJ, McGuigan PM, Stokes KA. Exercise Snacking to Improve Muscle Function in Healthy Older Adults: A Pilot Study. *J Aging Res*. 2019;2019:7516939. doi:10.1155/2019/7516939
167. Little JP. Sprint exercise snacks: a novel approach to increase aerobic fitness. *Eur J Appl Physiol*. Published online 2019:10.
168. Jenkins EM, Nairn LN, Skelly LE, Little JP, Gibala MJ. Do stair climbing exercise "snacks" improve cardiorespiratory fitness? *Appl Physiol Nutr Metab*. 2019;44(6):681-684. doi:10.1139/apnm-2018-0675
169.Hasan R, Perez-Santiago D, Churilla JR, et al. Can Short Bouts of Exercise ("Exercise Snacks") Improve Body Composition in Adolescents with Type 1 Diabetes? A Feasibility Study. *Horm Res Paediatr*. 2019;92(4):245-253. doi:10.1159/000505328
170. Ho BH, Lim I, Tian R, Tan F, Aziz AR. Effects of a novel exercise training protocol of Wingate-based sprint bouts dispersed over a day on selected cardiometabolic health markers in sedentary females: a pilot study. *BMJ OPEN SPORT Exerc Med*. 2018;4(1):e000349. doi:10.1136/bmjsem-2018-000349
171. Chung J, Kim K, Hong J, Kong HJ. Effects of prolonged exercise versus multiple short exercise sessions on risk for metabolic syndrome and the atherogenic index in middle-aged obese women: a randomised controlled trial. *BMC Womens Health*. 2017;17(1):65. doi:10.1186/s12905-017-0421-z
172. Reynolds AN, Mann JI, Williams S, Venn BJ. Advice to walk after meals is more effective for lowering postprandial glycaemia in type 2 diabetes mellitus than advice that does not specify timing: a randomised crossover study. *Diabetologia*. 2016;59(12):2572-2578. doi:10.1007/s00125-016-4085-2
173. Lim ST, Min SK, Kwon YC, Park SK, Park H. Effects of intermittent exercise on biomarkers of cardiovascular risk in night shift workers. *Atherosclerosis*. 2015;242(1):186-190. doi:10.1016/j.atherosclerosis.2015.06.017
174. Mair JL, Boreham CA, Ditroilo M, et al. Benefits of a worksite or home-based bench stepping intervention for sedentary middle-aged adults - a pilot study. *Clin Physiol Funct Imaging*. 2014;34(1):10-17. doi:10.1111/cpf.12056
175. Eguchi M, Ohta M, Yamato H. The Effects of Single Long and Accumulated Short Bouts of Exercise on Cardiovascular Risks in Male Japanese Workers: A Randomized Controlled Study. *Ind Health*. 2013;51(6):563-571. doi:10.2486/indhealth.2013-0023
176. Serwe KM, Swartz AM, Hart TL, Strath SJ. Effectiveness of Long and Short Bout Walking on Increasing Physical Activity in Women. *J Womens Health*. 2011;20(2):247-253. doi:10.1089/jwh.2010.2019
177. Kennedy RA, Boreham CAG, Murphy MH, Young IS, Mutrie N. Evaluating the effects of a low volume stairclimbing programme on measures of health-related fitness in sedentary office workers. *J Sports Sci Med*. Published online 2007:7.
178. Eriksen L, Dahl-Petersen I, Haugaard SB, Dela F. Comparison of the effect of multiple short-duration with single long-duration exercise sessions on glucose homeostasis in type 2 diabetes mellitus. *Diabetologia*. 2007;50(11):2245-2253. doi:10.1007/s00125-007-0783-0

179. Macfarlane DJ, Taylor LH, Cuddihy TF. Very short intermittent vs continuous bouts of activity in sedentary adults. *Prev Med*. 2006;43(4):332-336. doi:10.1016/j.ypmed.2006.06.002
180. Altena TS, Michaelson JL, Ball SD, Guilford BL, Thomas TR. Lipoprotein subfraction changes after continuous or intermittent exercise training. *Med Sci Sports Exerc*. 2006;38(2):367-372. doi:10.1249/01.mss.0000185088.33669.fd
181. Osei-Tutu KB, Campagna PD. The effects of short- vs. long-bout exercise on mood, VO2max., and percent body fat. *Prev Med*. 2005;40(1):92-98. doi:10.1016/j.ypmed.2004.05.005
182. Murtagh EM, Boreham CAG, Nevill A, Hare LG, Murphy MH. The effects of 60 minutes of brisk walking per week, accumulated in two different patterns, on cardiovascular risk. *Prev Med*. 2005;41(1):92-97. doi:10.1016/j.ypmed.2004.10.008
183. Boreham C a. G, Kennedy RA, Murphy MH, Tully M, Wallace WFM, Young I. Training effects of short bouts of stair climbing on cardiorespiratory fitness, blood lipids, and homocysteine in sedentary young women. *Br J Sports Med*. 2005;39(9):590-593. doi:10.1136/bjsm.2002.001131
184. Murphy M, Nevill A, Neville C, Biddle S, Hardman A. Accumulating brisk walking for fitness, cardiovascular risk, and psychological health: *Med Sci Sports Exerc*. 2002;34(9):1468-1474. doi:10.1097/00005768-200209000-00011
185. Schmidt WD, Biwer CJ, Kalscheuer LK. Effects of Long *versus* Short Bout Exercise on Fitness and Weight Loss in Overweight Females. *J Am Coll Nutr*. 2001;20(5):494-501. doi:10.1080/07315724.2001.10719058
186. Boreham CA, Wallace WF, Nevill A. Training effects of accumulated daily stair-climbing exercise in previously sedentary young women. *Prev Med*. 2000;30(4):277-281. doi:10.1006/pmed.2000.0634
187. Jakicic JM, Winters C, Lang W, Wing RR. Effects of Intermittent Exercise and Use of Home Exercise Equipment on Adherence, Weight Loss, and Fitness in Overweight Women: A Randomized Trial. *JAMA*. 1999;282(16):1554. doi:10.1001/jama.282.16.1554
188. Coleman KJ, Raynor HR, Mueller DM, Cerny FJ, Dorn JM, Epstein LH. Providing Sedentary Adults with Choices for Meeting Their Walking Goals. *Prev Med*. 1999;28(5):510-519. doi:10.1006/pmed.1998.0471
189. Murphy MH, Hardman AE. Training effects of short and long bouts of brisk walking in sedentary women. *Med Sci Sports Exerc*. 1998;30(1):152-157. doi:10.1097/00005768-199801000-00021
190. DeBusk RF, Stenestrand U, Sheehan M, Haskell WL. Training effects of long versus short bouts of exercise in healthy subjects. *Am J Cardiol*. 1990;65(15):1010-1013. doi:10.1016/0002-9149(90)91005-Q
191. Tyldesley-Marshall N, Greenfield SM, Parretti HM, et al. Snacktivity™ to Promote Physical Activity: a Qualitative Study. *Int J Behav Med*. 2022;29(5):553-564. doi:10.1007/s12529-021-10040-y
192. Thøgersen-Ntoumani C, Kritz M, Grunseit A, et al. Barriers and enablers of vigorous intermittent lifestyle physical activity (VILPA) in physically inactive adults: a focus group study. *Int J Behav Nutr Phys Act*. 2023;20(1):78. doi:10.1186/s12966-023-01480-8

193. Stawarz K, Liang IJ, Alexander L, Carlin A, Wijekoon A, Western MJ. Exploring the Potential of Technology to Promote Exercise Snacking for Older Adults Who Are Prefrail in the Home Setting: User-Centered Design Study. Published online 2023.
194. Liang IJ, Francombe-Webb J, McGuigan PM, Perkin OJ, Thompson D, Western MJ. The acceptability of homebased exercise snacking and Tai-chi snacking amongst high and low function UK and Taiwanese older adults. *Front Aging*. 2023;4:1180939. doi:10.3389/fragi.2023.1180939
195. Krouwel M, Greenfield SM, Chalkley A, et al. Promoting participation in physical activity through Snacktivity: A qualitative mixed methods study. Kwaghe AV, ed. *PLOS ONE*. 2023;18(9):e0291040. doi:10.1371/journal.pone.0291040
196. K. Gokal, R. Amos-Hirst, C. A. Moakes, et al. Views of the public about Snacktivity^{TM}: a small changes approach to promoting physical activity and reducing sedentary behaviour. *BMC Public Health*. 2022;22(1):618. doi:10.1186/s12889-022-13050-x
197. Jansons P, Fyfe JJ, Dalla Via J, Daly RM, Scott D. Barriers and enablers associated with participation in a home-based pragmatic exercise snacking program in older adults delivered and monitored by Amazon Alexa: a qualitative study. *Aging Clin Exp Res*. Published online January 17, 2023. doi:10.1007/s40520-022-02327-1
198. Daley AJ, Griffin RA, Moakes CA, et al. Snacktivity^{TM} to promote physical activity and reduce future risk of disease in the population: protocol for a feasibility randomised controlled trial and nested qualitative study. *Pilot Feasibility Stud*. 2023;9(1):45. doi:10.1186/s40814-023-01272-8
199. 祝莉, 王正珍, 朱为模. 健康中国视域中的运动处方库构建. 体育科学. 2020;40(1):4-15. doi:10.16469/j.css.202001001
200. 卢文云, 陈佩杰. 全民健身与全民健康深度融合的内涵、路径与体制机制研究. 体育科学. 2018;38(5):25-39+55. doi:10.16469/j.css.201805003
201. 健康中国行动(2019—2030 年):总体要求、重大行动及主要指标. 中国循环杂志. 2019;34(9):846-858.
202. Leavitt MO. 2008 Physical Activity Guidelines for Americans.
203. Coates AM, Joyner MJ, Little JP, Jones AM, Gibala MJ. A Perspective on High-Intensity Interval Training for Performance and Health. *Sports Med*. Published online October 7, 2023. doi:10.1007/s40279-023-01938-6
204. Drevon D, Fursa SR, Malcolm AL. Intercoder Reliability and Validity of WebPlotDigitizer in Extracting Graphed Data. *Behav Modif*. 2017;41(2):323-339. doi:10.1177/0145445516673998
205. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017;358:j4008. doi:10.1136/bmj.j4008
206. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:l4898. doi:10.1136/bmj.l4898
207. Büttner F, Winters M, Delahunt E, et al. Identifying the 'incredible'! Part 2: Spot the difference - a rigorous risk of bias assessment can alter the main findings of a systematic review. *Br J Sports Med*. 2020;54(13):801-808. doi:10.1136/bjsports-2019-101675

208. Büttner F, Winters M, Delahunt E, et al. Identifying the ‘incredible’! Part 1: assessing the risk of bias in outcomes included in systematic reviews. *Br J Sports Med*. 2020;54(13):798-800. doi:10.1136/bjsports-2019-100806
209. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Aust J Physiother*. 2009;55(2):129-133. doi:10.1016/s0004-9514(09)70043-1
210. Smart NA, Waldron M, Ismail H, et al. Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. *Int J Evid Based Healthc*. 2015;13(1):9-18. doi:10.1097/XEB.0000000000000020
211. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials*. 1986;7(3):177-188. doi:10.1016/0197-2456(86)90046-2
212. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Routledge; 1988. doi:10.4324/9780203771587
213. Quintana DS. A Guide for Calculating Study-Level Statistical Power for Meta-Analyses. *Adv Methods Pract Psychol Sci*. 2023;6(1):25152459221147260. doi:10.1177/25152459221147260
214. Schünemann HJ, Higgins JP, Vist GE, et al. Completing ‘Summary of findings’ tables and grading the certainty of the evidence. In: *Cochrane Handbook for Systematic Reviews of Interventions*. John Wiley & Sons, Ltd; 2019:375-402. doi:10.1002/9781119536604.ch14
215. Guyatt GH, Oxman AD, Kunz R, et al. GRADE guidelines 6. Rating the quality of evidence--imprecision. *J Clin Epidemiol*. 2011;64(12):1283-1293. doi:10.1016/j.jclinepi.2011.01.012
216. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep Wash DC 1974*. 1985;100(2):126-131.
217. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA*. 2018;320(19):2020-2028. doi:10.1001/jama.2018.14854
218. Rey-Lopez JP, Stamatakis E, Mackey M, Sesso HD, Lee IM. Associations of self-reported stair climbing with all-cause and cardiovascular mortality: The Harvard Alumni Health Study. *Prev Med Rep*. 2019;15:100938. doi:10.1016/j.pmedr.2019.100938
219. Riebe D, Ehrman J, Liguori G, Magal M. *ACSM’s Guidelines for Exercise Testing and Prescription*.; 2018:363.
220. Rogers EM, Banks NF, Trachta ER, Barone Gibbs B, Carr LJ, Jenkins NDM. Acceptability of Performing Resistance Exercise Breaks in the Workplace to Break Up Prolonged Sedentary Time: A Randomized Control Trial in U.S. Office Workers and Students. *Workplace Health Saf*. Published online February 5, 2024:21650799231215814. doi:10.1177/21650799231215814
221. Hawley JA, Hargreaves M, Joyner MJ, Zierath JR. Integrative Biology of Exercise. *Cell*. 2014;159(4):738-749. doi:10.1016/j.cell.2014.10.029
222. 黎涌明. 高强度间歇训练对不同训练人群的应用效果. 体育科学. 2015;35(8):59-75+96. doi:10.16469/j.css.201508009

223. Kanaley JA, Colberg SR, Corcoran MH, et al. Exercise/Physical Activity in Individuals with Type 2 Diabetes: A Consensus Statement from the American College of Sports Medicine. *Med Sci Sports Exerc*. 2022;54(2):353-368. doi:10.1249/MSS.0000000000002800

224. Coutinho M, Gerstein HC, Wang Y, Yusuf S. The relationship between glucose and incident cardiovascular events. A metaregression analysis of published data from 20 studies of 95,783 individuals followed for 12.4 years. *Diabetes Care*. 1999;22(2):233-240. doi:10.2337/diacare.22.2.233

225. Levitan EB, Song Y, Ford ES, Liu S. Is nondiabetic hyperglycemia a risk factor for cardiovascular disease? A meta-analysis of prospective studies. *Arch Intern Med*. 2004;164(19):2147-2155. doi:10.1001/archinte.164.19.2147

226. Davies MJ, Aroda VR, Collins BS, et al. Management of Hyperglycemia in Type 2 Diabetes, 2022. A Consensus Report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetes Care*. 2022;45(11):2753-2786. doi:10.2337/dci22-0034

227. Green DJ, Jones H, Thijssen D, Cable NT, Atkinson G. Flow-mediated dilation and cardiovascular event prediction: does nitric oxide matter? *Hypertens Dallas Tex 1979*. 2011;57(3):363-369. doi:10.1161/HYPERTENSIONAHA.110.167015

228. Wei YC, George NI, Chang CW, Hicks KA. Assessing sex differences in the risk of cardiovascular disease and mortality per increment in systolic blood pressure: A systematic review and meta-analysis of follow-up studies in the united states. *PloS One*. 2017;12(1):e0170218. doi:10.1371/journal.pone.0170218

229. van den Hoogen PC, Feskens EJ, Nagelkerke NJ, Menotti A, Nissinen A, Kromhout D. The relation between blood pressure and mortality due to coronary heart disease among men in different parts of the world. Seven countries study research group. *N Engl J Med*. 2000;342(1):1-8. doi:10.1056/NEJM200001063420101

230.Palmer AJ, Bulpitt CJ, Fletcher AE, et al. Relation between blood pressure and stroke mortality. *Hypertens Dallas Tex 1979*. 1992;20(5):601-605. doi:10.1161/01.hyp.20.5.601

231. Stamler R. Implications of the INTERSALT study. *Hypertens Dallas Tex 1979*. 1991;17(1 Suppl):I16-20. doi:10.1161/01.hyp.17.1_suppl.i16

232. Zou L, Herold F, Cheval B, et al. Sedentary behavior and lifespan brain health. *Trends Cogn Sci*. Published online March 2024:S1364661324000305. doi:10.1016/j.tics.2024.02.003

233. Keage HAD, Churches OF, Kohler M, et al. Cerebrovascular function in aging and dementia: a systematic review of transcranial Doppler studies. *Dement Geriatr Cogn Disord Extra*. 2012;2(1):258-270. doi:10.1159/000339234

234. Ross R, Blair SN, Arena R, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation*. 2016;134(24):e653-e699. doi:10.1161/CIR.0000000000000461

235. Haapala EA, Tompuri T, Lintu N, et al. Is low cardiorespiratory fitness a feature of metabolic syndrome in children and adults? *J Sci Med Sport*. 2022;25(11):923-929. doi:10.1016/j.jsams.2022.08.002

236. Laukkanen JA, Kurl S, Salonen R, Rauramaa R, Salonen JT. The predictive value of cardiorespiratory fitness for cardiovascular events in men with various risk profiles: a prospective population-based cohort study. *Eur Heart J*. 2004;25(16):1428-1437. doi:10.1016/j.ehj.2004.06.013
237. Dc L, X S, Eg A, et al. Long-term effects of changes in cardiorespiratory fitness and body mass index on all-cause and cardiovascular disease mortality in men: the Aerobics Center Longitudinal Study. *Circulation*. 2011;124(23). doi:10.1161/CIRCULATIONAHA.111.038422
238. Maestroni L, Read P, Bishop C, et al. The benefits of strength training on musculoskeletal system health: Practical applications for interdisciplinary care. *Sports Med Auckl NZ*. 2020;50(8):1431-1450. doi:10.1007/s40279-020-01309-5
239. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: A systematic analysis for the global burden of disease study 2019. *Lancet Lond Engl*. 2020;396(10258):1204-1222. doi:10.1016/S0140-6736(20)30925-9
240. Ross R, Neeland IJ, Yamashita S, et al. Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. *Nat Rev Endocrinol*. 2020;16(3):177-189. doi:10.1038/s41574-019-0310-7
241. Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): Prospective observational study. *BMJ*. 2000;321(7258):405-412. doi:10.1136/bmj.321.7258.405
242. Monnier L, Lapinski H, Colette C. Contributions of fasting and postprandial plasma glucose increments to the overall diurnal hyperglycemia of type 2 diabetic patients: Variations with increasing levels of HbA(1c). *Diabetes Care*. 2003;26(3):881-885. doi:10.2337/diacare.26.3.881
243. Bonora E, Muggeo M. Postprandial blood glucose as a risk factor for cardiovascular disease in type II diabetes: The epidemiological evidence. *Diabetologia*. 2001;44(12):2107-2114. doi:10.1007/s001250100020
244. Santos A, Braaten K, MacPherson M, et al. Rates of compliance and adherence to high-intensity interval training: a systematic review and Meta-analyses. *Int J Behav Nutr Phys Act*. 2023;20(1):134. doi:10.1186/s12966-023-01535-w
245. Herold F, Zou L, Theobald P, et al. *Beyond FITT: How Density Can Improve the Understanding of the Dose-Response Relationship Between Physical Activity and Brain Health.*; 2024. doi:10.51224/SRXIV.411
246. Engeroff T, Groneberg DA, Wilke J. After Dinner Rest a While, After Supper Walk a Mile? A Systematic Review with Meta-analysis on the Acute Postprandial Glycemic Response to Exercise Before and After Meal Ingestion in Healthy Subjects and Patients with Impaired Glucose Tolerance. *Sports Med*. 2023;53(4):849-869. doi:10.1007/s40279-022-01808-7
247. Bailey DP, Maylor BD, Orton CJ, Zakrzewski-Fruer JK. Effects of breaking up prolonged sitting following low and high glycaemic index breakfast consumption on glucose and insulin concentrations. *Eur J Appl Physiol*. 2017;117(7):1299-1307. doi:10.1007/s00421-017-3610-4

248. Thomas G, Songsorn P, Gorman A, et al. Reducing training frequency from 3 or 4 sessions/week to 2 sessions/week does not attenuate improvements in maximal aerobic capacity with reduced-exertion high-intensity interval training (REHIT). *Appl Physiol Nutr Metab*. 2020;45(6):683-685. doi:10.1139/apnm-2019-0750

249. 运动处方中国专家共识（2023）. 中国运动医学杂志. 2023;42(1):3-13. doi:10.16038/j.1000-6710.2023.01.012

250. Katzmarzyk, P, Jakicic J. Physical Activity for Health—Every Minute Counts. *JAMA*. Published online 2023.

251. Yin M, Li H, Bai M, et al. Is low-volume high-intensity interval training a time-efficient strategy to improve cardiometabolic health and body composition? A meta-analysis. *Appl Physiol Nutr Metab*. Published online November 8, 2023. doi:10.1139/apnm-2023-0329

252. Metcalfe R. Reduced-Exertion High-Intensity Interval Training (REHIT): A Feasible Approach for Improving Health and Fitness? *Appl Physiol Nutr Metab*. Published online April 30, 2024. doi:10.1139/apnm-2024-0024

253. Niels B. J. Vollaard, Metcalfe RS, Williams S. Effect of Number of Sprints in an SIT Session on Change in V˙O2max: A Meta-analysis. *Med Sci Sports Exerc*. 2017;49(6):1147-1156. doi:10.1249/MSS.0000000000001204

254. Vollaard NBJ, Metcalfe RS. Research into the Health Benefits of Sprint Interval Training Should Focus on Protocols with Fewer and Shorter Sprints. *Sports Med*. 2017;47(12):2443-2451. doi:10.1007/s40279-017-0727-x

255. Sabag A, Little JP, Johnson NA. Low-volume high-intensity interval training for cardiometabolic health. *J Physiol*. 2022;600(5):1013-1026. doi:10.1113/JP281210

256. Gibala MJ, Little JP. Physiological basis of brief vigorous exercise to improve health. *J Physiol*. 2020;598(1):61-69. doi:10.1113/JP276849

257. Beck BR, Daly RM, Singh MAF, Taaffe DR. Exercise and Sports Science Australia (ESSA) position statement on exercise prescription for the prevention and management of osteoporosis. *J Sci Med Sport*. 2017;20(5):438-445. doi:10.1016/j.jsams.2016.10.001

258. Ducrocq GP, Hureau TJ, Meste O, Blain GM. Similar Cardioventilatory but Greater Neuromuscular Stimuli With Interval Drop Jump Than With Interval Running. *Int J Sports Physiol Perform*. 2020;15(3):330-339. doi:10.1123/ijspp.2019-0031

259. Ramirez-Campillo R, Moran J, Chaabene H, et al. Methodological characteristics and future directions for plyometric jump training research: A scoping review update. *Scand J Med Sci Sports*. 2020;30(6):983-997. doi:10.1111/sms.13633

260. Allison MK, Baglole JH, Martin BJ, Macinnis MJ, Gurd BJ, Gibala MJ. Brief Intense Stair Climbing Improves Cardiorespiratory Fitness. *Med Sci Sports Exerc*. 2017;49(2):298-307. doi:10.1249/MSS.0000000000001188

261. 久坐族做“绿瓦工间操.” Accessed August 3, 2024. https://www.lifetimes.cn/article/4GIgzxMnp7V

262. Li F, Harmer P, Eckstrom E, Fitzgerald K, Winters-Stone K. Clinical Effectiveness of Cognitively Enhanced Tai Ji Quan Training on Global Cognition and Dual-Task Performance During Walking in Older Adults With Mild Cognitive Impairment or Self-Reported Memory

Concerns: A Randomized Controlled Trial. *Ann Intern Med*. 2023;176(11):1498-1507. doi:10.7326/M23-1603

263. Li F, Harmer P, Eckstrom E, Fitzgerald K, Chou LS, Liu Y. Effectiveness of Tai Ji Quan vs Multimodal and Stretching Exercise Interventions for Reducing Injurious Falls in Older Adults at High Risk of Falling: Follow-up Analysis of a Randomized Clinical Trial. *JAMA Netw Open*. 2019;2(2):e188280. doi:10.1001/jamanetworkopen.2018.8280
264. Li F, Harmer P, Fitzgerald K, et al. Effectiveness of a Therapeutic Tai Ji Quan Intervention vs a Multimodal Exercise Intervention to Prevent Falls Among Older Adults at High Risk of Falling: A Randomized Clinical Trial. *JAMA Intern Med*. 2018;178(10):1301-1310. doi:10.1001/jamainternmed.2018.3915
265. Gibala MJ, Gillen JB, Percival ME. Physiological and health-related adaptations to low-volume interval training: influences of nutrition and sex. *Sports Med Auckl NZ*. 2014;44 Suppl 2(Suppl 2):S127-137. doi:10.1007/s40279-014-0259-6
266. Gist NH, Fedewa MV, Dishman RK, Cureton KJ. Sprint interval training effects on aerobic capacity: a systematic review and meta-analysis. *Sports Med Auckl NZ*. 2014;44(2):269-279. doi:10.1007/s40279-013-0115-0
267. Weston M, Taylor KL, Batterham AM, Hopkins WG. Effects of low-volume high-intensity interval training (HIT) on fitness in adults: a meta-analysis of controlled and non-controlled trials. *Sports Med Auckl NZ*. 2014;44(7):1005-1017. doi:10.1007/s40279-014-0180-z
268. Milanović Z, Sporiš G, Weston M. Effectiveness of High-Intensity Interval Training (HIT) and Continuous Endurance Training for VO2max Improvements: A Systematic Review and Meta-Analysis of Controlled Trials. *Sports Med*. 2015;45(10):1469-1481. doi:10.1007/s40279-015-0365-0
269. Costigan SA, Eather N, Plotnikoff RC, Taaffe DR, Lubans DR. High-intensity interval training for improving health-related fitness in adolescents: a systematic review and meta-analysis. *Br J Sports Med*. 2015;49(19):1253-1261. doi:10.1136/bjsports-2014-094490
270. Ramos JS, Dalleck LC, Tjonna AE, Beetham KS, Coombes JS. The Impact of High-Intensity Interval Training Versus Moderate-Intensity Continuous Training on Vascular Function: a Systematic Review and Meta-Analysis. *Sports Med*. 2015;45(5):679-692. doi:10.1007/s40279-015-0321-z
271. Batacan RB, Duncan MJ, Dalbo VJ, Tucker PS, Fenning AS. Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies. *Br J Sports Med*. 2017;51(6):494-503. doi:10.1136/bjsports-2015-095841
272. Keating SE, Johnson NA, Mielke GI, Coombes JS. A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity. *Obes Rev Off J Int Assoc Study Obes*. 2017;18(8):943-964. doi:10.1111/obr.12536
273. Wewege M, van den Berg R, Ward RE, Keech A. The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis. *Obes Rev Off J Int Assoc Study Obes*. 2017;18(6):635-646. doi:10.1111/obr.12532
274. Sultana RN, Sabag A, Keating SE, Johnson NA. The Effect of Low-Volume High-Intensity Interval Training on Body Composition and Cardiorespiratory Fitness: A Systematic Review

and Meta-Analysis. *Sports Med Auckl NZ*. 2019;49(11):1687-1721. doi:10.1007/s40279-019-01167-w

275. Edwards JJ, Griffiths M, Deenmamode AHP, O'Driscoll JM. High-Intensity Interval Training and Cardiometabolic Health in the General Population: A Systematic Review and Meta-Analysis of Randomised Controlled Trials. *Sports Med*. Published online May 19, 2023. doi:10.1007/s40279-023-01863-8
276. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377-381.
277. Herrmann SD, Willis EA, Ainsworth BE, et al. 2024 Adult Compendium of Physical Activities: A third update of the energy costs of human activities. *J Sport Health Sci*. 2024;13(1):6-12. doi:10.1016/j.jshs.2023.10.010
278. Thompson D, Peacock O, Western M, Batterham AM. Multidimensional physical activity: an opportunity, not a problem. *Exerc Sport Sci Rev*. 2015;43(2):67-74. doi:10.1249/JES.0000000000000039
279. Yin M, Deng S, Deng J, et al. Physiological adaptations and performance enhancement with combined blood flow restricted and interval training: A systematic review with meta-analysis. *J Sport Health Sci*. Published online February 2025:101030. doi:10.1016/j.jshs.2025.101030
280. Parr EB, Heilbronn LK, Hawley JA. A Time to Eat and a Time to Exercise. *Exerc Sport Sci Rev*. 2020;48(1):4. doi:10.1249/JES.0000000000000207
281. Rynders CA, Broussard JL. Running the clock: new insights into exercise and circadian rhythms for optimal metabolic health. *J Physiol*. 2024;602(23):6367-6371. doi:10.1113/JP287024
282. Holtermann A. Physical activity health paradox: reflections on physical activity guidelines and how to fill research gap. *Occup Environ Med*. 2022;79(3):145-146. doi:10.1136/oemed-2021-108050
283. Holtermann A, Hansen JV, Burr H, Søgaard K, Sjøgaard G. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med*. 2012;46(4):291-295. doi:10.1136/bjsm.2010.079582
284. Pearce M, Strain T, Wijndaele K, Sharp SJ, Mok A, Brage S. Is occupational physical activity associated with mortality in UK Biobank? *Int J Behav Nutr Phys Act*. 2021;18(1):102. doi:10.1186/s12966-021-01154-3
285. Jordakieva G, Hasenoehrl T, Steiner M, Jensen-Jarolim E, Crevenna R. Occupational physical activity: the good, the bad, and the proinflammatory. *Front Med*. 2023;10:1253951. doi:10.3389/fmed.2023.1253951
286. Cillekens B, Lang M, van Mechelen W, et al. How does occupational physical activity influence health? An umbrella review of 23 health outcomes across 158 observational studies. *Br J Sports Med*. 2020;54(24):1474-1481. doi:10.1136/bjsports-2020-102587
287. Jenkins DG, Devin JL, Weston KL, Jenkins JG, Skinner TL. Benefits beyond cardiometabolic health: the potential of frequent high intensity 'exercise snacks' to improve outcomes for those living with and beyond cancer. *J Physiol*. Published online September 21, 2023:JP284985. doi:10.1113/JP284985

288. Bettariga F, Taaffe DR, Galvão DA, Newton RU. Effects of short- and long-term exercise training on cancer cells in vitro: Insights into the mechanistic associations. *J Sport Health Sci*. 2025;14:100994. doi:10.1016/j.jshs.2024.100994

Table 1 Summary of the Intervention Protocols

	Frequency of Bouts (h)	Duration (min)	Intensity (RPE 0–10)
Low frequency, short duration, low intensity [a]	Every 1~6	≤ 1	2–3
Low frequency, short duration, moderate intensity [a]	Every 1~6	≤ 1	4–6
Low frequency, short duration, vigorous intensity [b]	Every 1~6	≤ 1	≥ 6
Low frequency, moderate duration, low intensity [b]	Every 1~6	2~5	2–3
Low frequency, moderate duration, moderate intensity [a]	Every 1~6	2~5	4–6
Low frequency, moderate duration, vigorous intensity [a]	Every 1~6	2~5	≥ 6
Low frequency, long duration, low intensity [b]	Every 1~6	5~10	2–3
Low frequency, long duration, moderate intensity [b]	Every 1~6	5~10	4–6
High frequency, short duration, low intensity [a]	Every 0.5~1	≤ 1	2–3
High frequency, short duration, moderate intensity [a]	Every 0.5~1	≤ 1	4-6
High frequency, short duration, vigorous intensity [b]	Every 0.5~1	≤ 1	≥ 6
High frequency, moderate duration, low intensity [b]	Every 0.5~1	2~5	2–3
High frequency, moderate duration, moderate intensity [b]	Every 0.5~1	2~5	4–6
High frequency, moderate duration, vigorous intensity [a]	Every 0.5~1	2~5	≥ 6
High frequency, long duration, moderate intensity [a]	Every 0.5~1	5~10	4–6

Note: ***Frequency of Bouts,*** this represents the interval between each exercise, for example, 1~6 h means SBAE every 1–6 hours**;** ***RPE*****,** rating of perceived exertion, is a scale ranging from 0 to 10, where 0 indicates rest, 1 represents very light activity, 2–3 corresponds to light activity that can be maintained for hours, 4–5 refers to moderate activity with heavier breathing but still manageable conversation, 6–7 indicates vigorous-intensity physical activity with difficulty holding a conversation, 8–9 reflects very hard activity near maximum effort, and 10 signifies maximal exertion where continuing feels impossible [276]; [a] Refers to protocols of SBAE with no current research evidence; [b] Refers to protocols of SBAE with current research support.

Table.2 Summary of the evidence on SBAE to break sedentary behavior

Outcome	Type of evidence	Number of studies [references]	Quality of the evidence	SMD	MD	GRADE	Recommended level
Interrupted with SBAE vs. Uninterrupted prolonged sitting							
Metabolic Health							
- Glucose iAUC	SR and Meta-Analysis	9[21,42,45,46,48,51,52,59,66]	Very Low to Moderate	0.54	n/a	⊕⊕⊕○	Strong recommendation
- Postprandial C-Peptide	RCTs	4[108,110,142,149]	Moderate	0.50	n/a	⊕⊕○○	Weak recommendation
- Insulin iAUC	SR and Meta-Analysis	6[42,45,46,48,51,66]	Very Low to Moderate	0.56	n/a	⊕⊕⊕○	Strong recommendation
- Triglyceride iAUC	SR and Meta-Analysis	4[42,45,48,66]	Very Low to Moderate	0.26	n/a	⊕○○○	Weak recommendation
Cardiovascular Health							
- SBP	SR and Meta-Analysis	5[42–44,46,47]	Low to Moderate	0.26	4.4 mmHg	⊕⊕○○	Weak recommendation
- DBP	SR and Meta-Analysis	5[42–44,46,47]	Low to Moderate	0.19	2.4 mmHg	⊕⊕○○	Weak non-recommendation
- MAP	SR and Meta-Analysis	3[43,44,47]	Low to Moderate	n/a	n/a	⊕○○○	Strong recommendation
- HR/HR variability	Meta-Analysis	1[54]	Moderate	n/a	4 beats/min	⊕○○○	Strong recommendation
- Pulse wave velocity	RCTs	5[71,94,113,119,131]	Moderate	n/a	n/a	⊕○○○	Strong recommendation
- Vascular blood flow	Meta-Analysis	2[50,62]	Moderate	0.48	12.08 mL/min	⊕⊕⊕○	Weak recommendation
- Vascular shear stress	Meta-Analysis	3[50,62,65]	Moderate	0.65	7.58～12.7 s^{-1}	⊕⊕⊕○	Weak non-recommendation

- FMD	Meta-Analysis	5[42,49,50,62,65]	Moderate	0.51	1.5%–1.91%	⊕⊕⊕◯	Weak non-recommendation
			Brain Health				
- Cognitive performance	SR and Meta-Analysis	2[53,60]	Moderate	0.20	n/a	⊕⊕◯◯	Weak non-recommendation
- *MCABFv*	Meta-Analysis	1[60]	Moderate	0.15	n/a	⊕◯◯◯	Weak recommendation
- Cerebral autoregulation	Meta-Analysis	1[60]	Moderate	0.13	n/a	⊕◯◯◯	Weak recommendation
- Cerebrovascular reactivity	Meta-Analysis	1[60]	Moderate	0.08	n/a	⊕◯◯◯	Weak recommendation
- BDNF	RCTs	1[148]	Moderate	n/a	514 ng/mL/h	⊕⊕◯◯	Weak recommendation
			Interrupted with SBAE vs. Single bout continuous exercise				
			Metabolic Health				
- Glucose iAUC	Meta-Analysis	3[21,45,63]	Moderate	0.26–0.39	n/a	⊕⊕⊕◯	Weak recommendation
- Insulin iAUC	Meta-Analysis	2[45,63]	Moderate	n/a	n/a	⊕⊕◯◯	Weak recommendation
- Triglyceride iAUC	Meta-Analysis	2[45,63]	Moderate	n/a	n/a	⊕⊕◯◯	Weak recommendation

Note: ↑ / ↓ indicates a significant increase/decrease in outcome with SBAE compared to uninterrupted prolonged sitting, while → indicates no statistically significant difference***,*** ***SR:*** systematic review***,*** ***SMD:*** standardized mean difference, represents the effect size in meta-analyses. ***MD:*** Mean Difference, Represents the raw difference between means, where applicable***,*** ***GRADE:*** Grading of Recommendations Assessment, Development, and Evaluation, A system for evaluating the quality of evidence and strength of recommendations, ⊕◯◯◯: very low level of evidence***,*** ⊕⊕◯◯: low level of evidence***,*** ⊕⊕⊕◯: moderate level of evidence***,*** ⊕⊕⊕⊕: high level of evidence***,*** ***iAUC:*** incremental area under the curve***,*** ***RCTs:*** randomized cross-over trials***,*** ***SBP:*** systolic blood pressure***,*** ***DBP:*** diastolic blood pressure***,*** ***MAP:*** mean arterial pressure***,*** ***HR:*** heart rate***,*** ***FMD:*** flow-mediated dilation, ***MCABFv:*** middle cerebral artery blood flow velocity***,*** ***BDNF:*** brain-derived neurotrophic factor.

Table.3 Summary of the evidence on long-term (>7 days) health benefits of SBAE

Outcome	Type of evidence	Number of studies [references]	Quality of the evidence	SMD	MD	GRADE	Recommended level
SBAE vs. No exercise control							
Cardiovascular Fitness and Function							
- Short-duration, vigorous-intensity effect on $\dot{V}O_2peak$	RCTs	3 [155,164,168]	Moderate	1.16	3.30 mL/kg/min	⊕⊕⊕◯	Strong recommendation
- Short-duration, vigorous-intensity effect on peak aerobic power	RCTs	2 [155,168]	Moderate	1.04	28.25 W	⊕⊕⊕◯	Strong recommendation
- Moderate-duration, moderate-vigorous intensity effect on $\dot{V}O_2peak$	RCTs	3 [163,177,183]	Moderate	0.84	2.00 mL/kg/min	⊕⊕⊕◯	Strong recommendation
- Long-duration, moderate-low intensity effect on $\dot{V}O_2peak$	Meta-Analysis	1 [33]	Moderate	0.52	2.32 mL/kg/min	⊕⊕⊕◯	Strong recommendation
- Resting heart rate	Meta-Analysis	1 [33]	Moderate	n/a	8.10 beats/min	⊕⊕◯◯	Weak recommendation
- Resting SBP	Meta-Analysis	1 [33]	Moderate	n/a	2.97 mmHg	⊕⊕◯◯	Weak recommendation
- Resting DBP	Meta-Analysis	1 [33]	Moderate	n/a	4.83 mmHg	⊕⊕◯◯	Weak recommendation
Skeletal Muscle Health							

- Muscle mass	Controlled Trial	2 [157,166]	Low to Moderate	0.59	0.58 kg	⊕⊕◯◯	Weak recommendation
- Muscle strength	Controlled Trial	3 [157,162,166]	Low to Moderate	0.44	n/a	⊕⊕◯◯	Weak recommendation
- Function (Sit-to-Stand Test)	Controlled Trial	5 [158,160–162,166]	Low to Moderate	0.62	3 repetitions	⊕⊕◯◯	Weak recommendation
			Body Composition				
- Body weight	Meta-Analysis	2 [33,35]	Moderate	0.51	1.94 kg	⊕⊕◯◯	Weak recommendation
- BMI	Meta-Analysis	2 [33,35]	Moderate	0.61	0.97 kg/m^2	⊕⊕◯◯	Weak recommendation
- Fat mass	Meta-Analysis	1 [33]	Moderate	0.55	n/a	⊕⊕◯◯	Weak recommendation
- Body fat (%)	Meta-Analysis	2 [33,35]	Moderate	0.33	0.92 %	⊕⊕◯◯	Weak recommendation
- Waist circumference	Meta-Analysis	2 [33,35]	Moderate	0.44	2.62 cm	⊕⊕◯◯	Weak recommendation
- Hip circumference	Meta-Analysis	1 [33]	Moderate	n/a	2.32 cm	⊕⊕◯◯	Weak recommendation
- Skinfold thickness	Meta-Analysis	2 [33,35]	Moderate	0.96	6.39 mm	⊕⊕◯◯	Weak recommendation
			Metabolic Health				
- Total cholesterol	RCTs	4 [159,163,171,183]	Moderate	0.02	n/a	⊕⊕◯◯	Weak recommendation
- HDL-C	RCTs	6 [159,163,171,178,182,183]	Moderate	0.47	0.08 mmol/L	⊕⊕⊕◯	Weak recommendation
- LDL-C	RCTs	6 [159,163,171,178,182,183]	Moderate	0.38	0.22 mmol/L	⊕⊕⊕◯	Weak recommendation
- Triglycerides	RCTs	6 [159,163,171,178,182,183]	Moderate	0.19	0.08 mmol/L	⊕⊕◯◯	Weak recommendation
- Glucose iAUC	RCTs	1 [178]	Moderate	n/a	7.5 %	⊕⊕⊕◯	Weak recommendation

- Fasting blood glucose	RCTs	4 [163,171,172,178]	Moderate	4–12%	0.2–1.05 mmol/L	⊕⊕⊕○	Weak recommendation
- HbA1c	RCTs	2 [172,178]	Moderate	n/a	0.2–0.5 %	⊕⊕⊕○	Weak recommendation
Perceived Benefits							
- Self-efficacy	Meta-Analysis	1 [33]	Moderate	n/a	14%	⊕○○○	Weak recommendation
- Depression/Anxiety	Meta-Analysis	1 [33]	Moderate	0.93	n/a	⊕⊕○○	Weak recommendation
- Mood disorders	Meta-Analysis	1 [33]	Moderate	n/a	n/a	⊕○○○	Weak non-recommendation
- Vitality	Meta-Analysis	1 [33]	Moderate	n/a	n/a	⊕○○○	Weak non-recommendation
Physical Activity and Sedentary Behavior							
- Daily steps (steps/day)	RCTs	1 [176]	Moderate	1.25	2039 steps	⊕⊕○○	Weak recommendation
- MVPA (min/day)	RCTs	2 [160,165]	Low to Moderate	0.01	0.59 min/day	⊕○○○	Weak non-recommendation
- Sedentary time (min/day)	RCTs	2 [160,165]	Low to Moderate	0.02	2.5 min/day	⊕○○○	Weak non-recommendation

Note: ↑ / ↓ indicates a significant increase/decrease in outcome with SBAE compared to no exercise, while → indicates no statistically significant difference. ***SMD:*** standardized mean difference, represents the effect size in meta-analyses. ***MD:*** Mean Difference, Represents the raw difference between means, where applicable. ***GRADE:*** Grading of Recommendations Assessment, Development, and Evaluation, A system for evaluating the quality of evidence and strength of recommendations. ⊕○○○: very low level of evidence**,** ⊕⊕○○: low level of evidence**,** ⊕⊕⊕○: moderate level of evidence**,** ⊕⊕⊕⊕: high level of evidence. ***iAUC:*** incremental area under the curve***, RCTs:*** randomized controlled trials, ***SBP:*** systolic blood pressure, ***DBP:*** diastolic blood pressure, ***BMI:*** body mass index, ***HDL-C:*** high-density lipoprotein cholesterol, ***LDL-C:*** low-density lipoprotein cholesterol, ***HbA1c:*** glycated hemoglobin, ***MVPA:*** moderate-to-vigorous physical activity.

Table.4 Summary of the differences in effects between SBAE and single bout continuous exercise

Outcome	Type of evidence	Number of studies [references]	Quality of the evidence	SMD	MD	GRADE	Recommended level
Moderate-intensity SBAE vs. No exercise control							
Cardiovascular Fitness and Function							
- $\dot{V}O_2$peak	Meta-Analysis	1 [33]	Moderate	0.00	0.50 mL/kg/min	⊕⊕◯◯	Weak recommendation
- SBP	Meta-Analysis	1 [33]	Moderate	n/a	1.28 mmHg	⊕⊕◯◯	Weak recommendation
- DBP	Meta-Analysis	1 [33]	Moderate	n/a	1.27 mmHg	⊕⊕◯◯	Weak recommendation
Body Composition							
- Body weight	Meta-Analysis	1 [33]	Moderate	n/a	0.92 kg	⊕⊕⊕◯	Weak recommendation
- Body fat (%)	Meta-Analysis	1 [33]	Moderate	n/a	0.46 %	⊕⊕◯◯	Weak recommendation
- Waist circumference	Meta-Analysis	1 [33]	Moderate	n/a	1.43 cm	⊕⊕◯◯	Weak recommendation
- Hip circumference	Meta-Analysis	1 [33]	Moderate	n/a	2.32 cm	⊕⊕◯◯	Weak recommendation
Metabolic Health							
- Total cholesterol	Meta-Analysis	1 [33]	Moderate	n/a	0.22 mmol/L	⊕⊕◯◯	Weak recommendation
- LDL-C	Meta-Analysis	1 [33]	Moderate	n/a	0.50 mmol/L	⊕⊕◯◯	Weak recommendation
- HDL-C	Meta-Analysis	1 [33]	Moderate	n/a	0.06 mmol/L	⊕⊕◯◯	Weak recommendation

- Triglycerides	Meta-Analysis	1 [33]	Moderate	n/a	0.07 mmol/L	⊕⊕○○	Weak recommendation
- Fasting blood glucose	RCTs	1 [178]	Moderate	n/a	0.05 mmol/L	⊕⊕⊕○	Weak recommendation
- Glucose iAUC	RCTs	1 [172]	Moderate	n/a	n/a	⊕⊕⊕○	Weak recommendation
- Fasting insulin	Meta-Analysis	1 [33]	Moderate	n/a	0.37 mmol/L	⊕⊕○○	Weak recommendation
Vigorous-intensity exercise SBAE vs. Single bout continuous exercise							
- $\dot{V}O_2$peak	RCTs	2 [155,167]	Moderate	0.17	0.51 mL/kg/min	⊕⊕○○	Weak recommendation
- aerobic power	RCTs	2 [155,167]	Moderate	0.44	15.34 W	⊕⊕○○	Weak recommendation

Note: ↑ / ↓ indicates a significant increase/decrease in outcome with SBAE compared to single bout continuous exercise, while → indicates no statistically significant difference. ***SMD:*** standardized mean difference, represents the effect size in meta-analyses. ***MD:*** Mean Difference, Represents the raw difference between means, where applicable. ***GRADE:*** Grading of Recommendations Assessment, Development, and Evaluation, A system for evaluating the quality of evidence and strength of recommendations. ⊕○○○: very low level of evidence, ⊕⊕○○: low level of evidence, ⊕⊕⊕○: moderate level of evidence, ⊕⊕⊕⊕: high level of evidence, ***iAUC:*** incremental area under the curve, ***RCTs:*** randomized controlled trials, ***SBP:*** systolic blood pressure, ***DBP:*** diastolic blood pressure, ***BMI:*** body mass index, ***HDL-C:*** high-density lipoprotein cholesterol, ***LDL-C:*** low-density lipoprotein cholesterol, ***HbA1c:*** glycated hemoglobin, ***MVPA:*** moderate-to-vigorous physical activity.

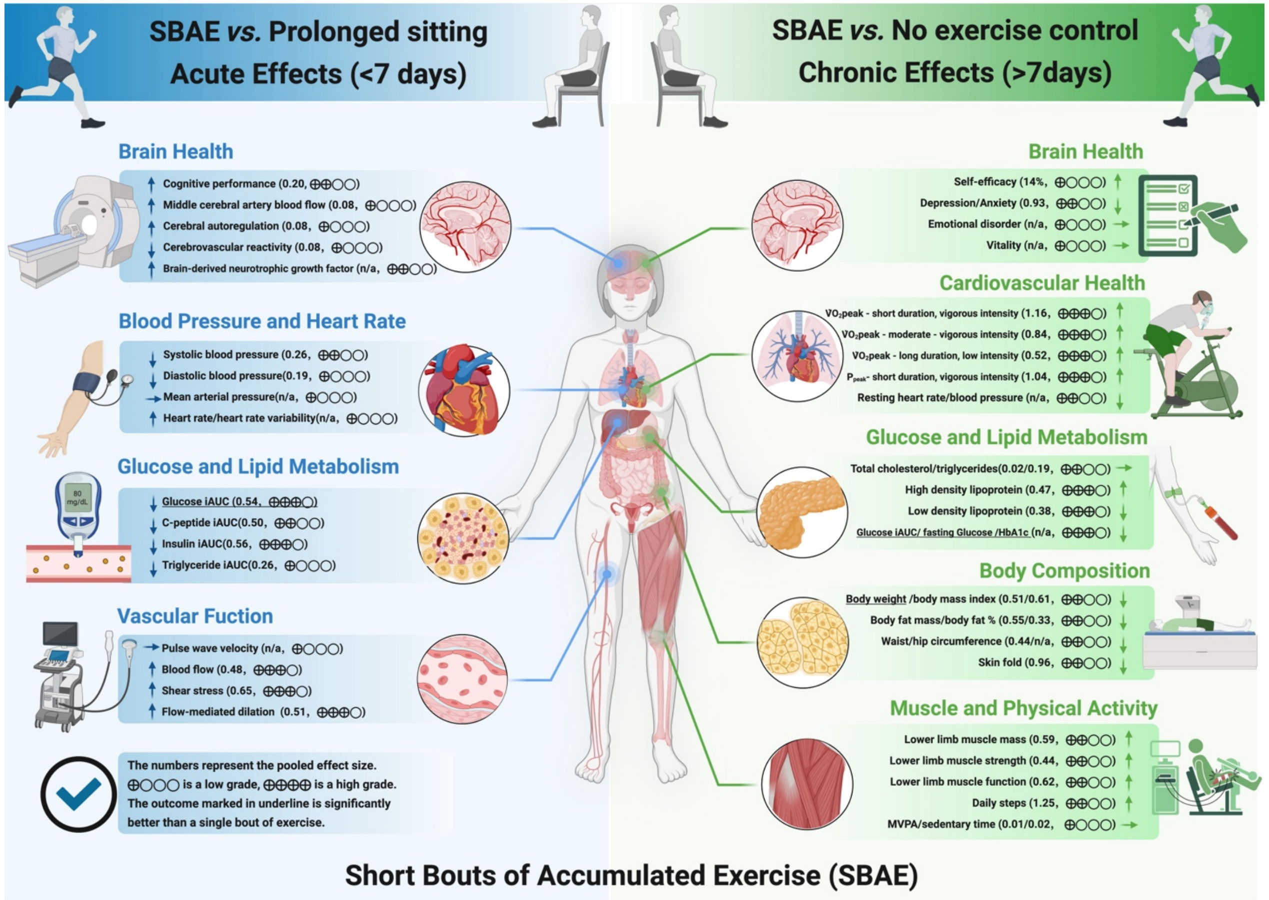


Fig 1. Summary of the effects of SBAE to break in sedentary behavior, promote health, and prevent disease

Note: This figure aims to show the acute (blue part, left) and chronic effects (green, right) of SBAE on various systems of humans. No exercise refers to the control group in long-term intervention studies, which usually does not receive exercise intervention and maintains previous habitual behavior. Among them, the number after each outcome indicator indicates the effect size, and the GRADE of this effect follows the number, the outcome marked in red is significantly better than a single bout of exercise.

Table.5 Perspectives from participants of SBAE based on semi-structured interviews

Study	Population	Intervention Protocol	Participants Perspectives				
			External Facilitators	Internal Facilitators	External Barriers	Internal Barriers	Future Recommendations
SBAE							
Fyfe et al., 2022 [162] (ACTRN12621001538831)	38 older adults Age: 69.8 ± 3.8 years 63% female	Home-based Long-duration, moderate-to-low-intensity bodyweight resistance exercises	Flexible scheduling Time-efficient Low equipment requirements Integration into daily life	Enhanced self-efficacy Perceived health benefits	Lack of upper body exercise options Lack of upper body exercise equipment	n/a	More personalized exercise programs More varied exercise options
Liang et al., 2022 [160]	63 older adults Age: 72.2 ± 4.7 years 54% female	Home-based Long-duration, moderate-to-low-intensity bodyweight resistance/Tai Chi	Easy to perform Easy to track	n/a	Difficulty with fragmented Tai Chi techniques	Boredom	Focus on both upper and lower limb exercises Provide mirror demonstrations for practice
Jansons et al., 2023 [161] (HREC 2020-166)	15 older adults with chronic conditions Age: 70.3 years 60% female	Home-based Long-duration, moderate-to-low-intensity	Flexible scheduling Time-efficient Integration into daily life	Enhanced self-efficacy Perceived health benefits	Lack of time to complete 3 sessions Lack of upper body exercise options	Lack of motivation to complete 3 sessions per day	n/a

		bodyweight resistance exercises			Lack of upper body exercise equipment		
Stawarz et al., 2023 [193] (COMSC/Ethics/2020/071)	15 older adults with chronic conditions Age: 70.3 years 60% female	Home-based Long-duration, moderate-to-low- intensity bodyweight resistance exercises	Flexible scheduling Integration into daily life	n/a	n/a	n/a	Provide personalized feedback through technology Simple visual cues required Technology should integrate into daily life
Liang et al., 2023 [194]	63 older adults Age: 72.7 ± 4.8 years 68% female	Home-based Long-duration, moderate-to-low- intensity bodyweight resistance/Tai Chi	Easy to perform Easy to track	Perceived health benefits	Difficulty with fragmented Tai Chi techniques	Boredom	Focus on both upper and lower limb exercises Provide more personalized feedback and guidance More diverse and varied exercise options
Yin et al., 2023 [154] (ChiCTR2300076975)	42 young adults Age: 22 years 57% female	Home-based Short-duration, vigorous-intensity Stair climbing	Integration into daily life Easy to perform Flexible scheduling Time-efficient Real-time data feedback Peer support/external supervision	Perceived health benefits Enhanced self-efficacy Positive emotional state Can reduce sedentary behavior	Lack of time to complete 3 sessions Difficult to recover due to vigorous intensity Stress from exercising in public spaces Environmental constraints	Boredom Perceived insufficient exercise duration leading to inefficacy	Group-based completion of tasks Integration with wearable devices for reminders and tracking Avoid strict daily completion targets Track total sessions on a weekly basis Provide long-term, progressive, and personalized plans

SBPA (VILPA and Snacktivity™)							
Tyldesley-Marshall et al., 2022 (19/EM/0370) [191]	31 participants (young to older adults) Age: n/a 65% female	Daily life Moderate-to-low-intensity Various physical activities Snacktivity™	Integration into daily life Easy to perform Easy to manage Flexible scheduling Low equipment requirements External encouragement and goals	Perceived health benefits Enhanced self-efficacy Curiosity towards a novel concept Keeping the mind active Focus on physical activity Can reduce sedentary behavior	n/a	Forgetting or overlooking the activity Health conditions or illness Perceived insufficient exercise duration leading to inefficacy Dislike of the term "snacking" Boredom	Integration with wearable devices for reminders and tracking Provide clearer guidance on intensity levels Develop programs combining multiple activities Provide both short- and long-duration specific plans
Krouwel et al., 2023 [195] (REF:20/PR/0589)	11 older adults Age: 62.3 ± 9.5 years 73% female	Daily life Long-duration, moderate-to-low-intensity Various physical activities Snacktivity™	Flexible scheduling Integration into daily life Time-efficient Varied modalities	Perceived health benefits Positive emotional state Enhanced self-efficacy Habit formation	Stress from exercising in public spaces Difficulty recognizing Snacktivity™ activities	n/a	n/a
Thøgersen-Ntoumani et al., 2023 (HRE2020-0670) [192]	78 participants (young to older adults) Age: n/a 75% female	Daily life Short-duration, moderate-to-vigorous-intensity Various physical	Flexible scheduling Integration into daily life Integration with electronic reminders	Perceived health benefits Enhanced self-efficacy	Health conditions limiting activity Environmental constraints	Concern about unsuitability of exercise due to aging Uncertainty about how to implement VILPA	Provide personalized plans for different populations Emphasize relative intensity rather than absolute intensity Develop practical guidelines for

	activities VILPA	Negative emotions towards vigorous-intensity activity	VILPA implementation Combine environmental opportunities to encourage VILPA Provide more public education on VILPA Integrate gamification with technology to support VILPA Help individuals gain a sense of achievement from VILPA Encourage external goals or rewards to support adherence

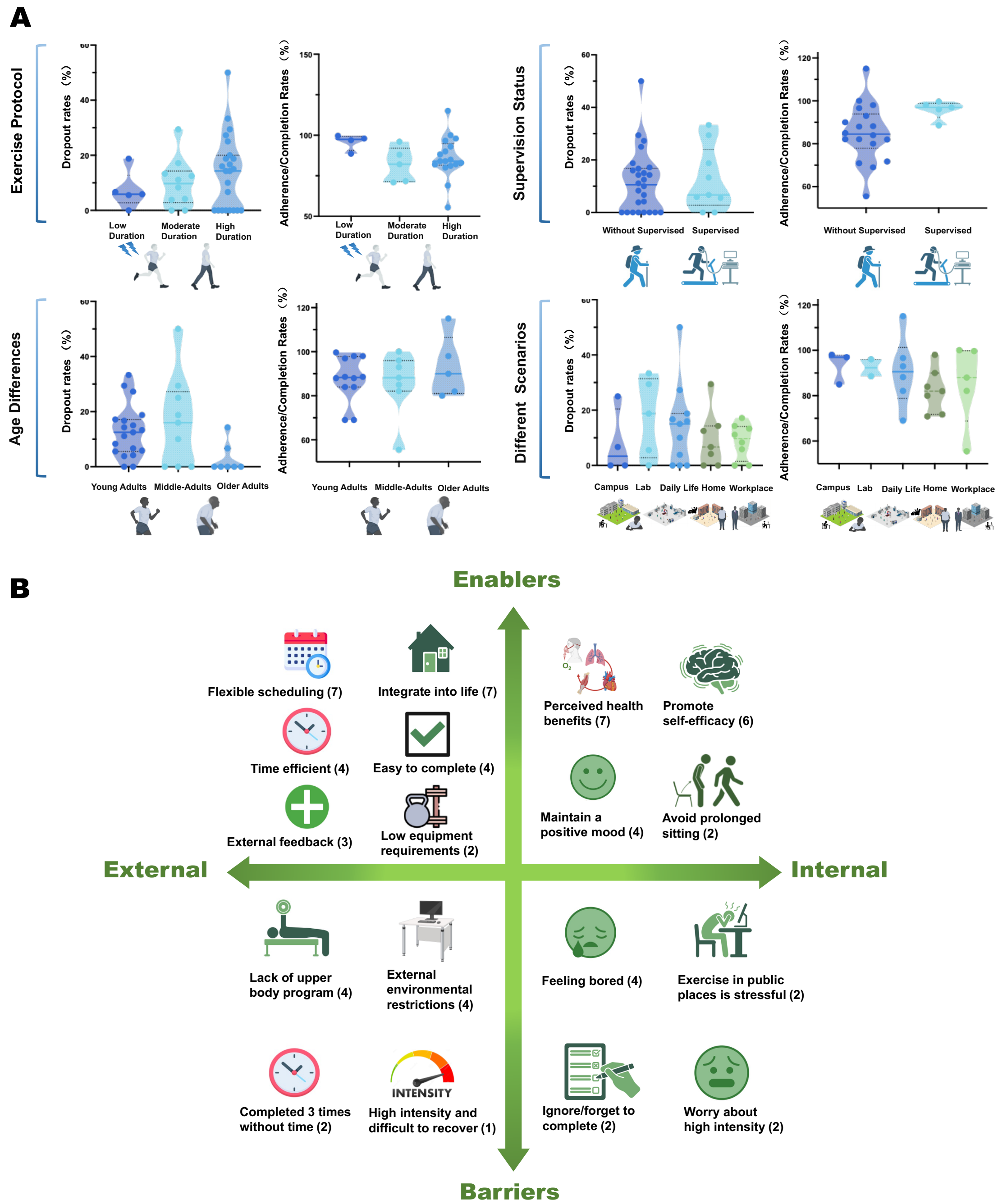


Figure 2. Potential Factors Influencing Dropout and Adherence/Completion Rates of SBAE Interventions, and Summary of Barriers and Enablers

Note: (A) This panel presents the distribution of dropout and adherence/completion rates of SBAE interventions under different influencing factors. It does not (and cannot easily) include statistical tests. Age categories: young adults (18–44 years), middle-aged adults (45–64 years), and older adults (≥65 years). **(B)** This panel summarizes the internal and external barriers and enablers influencing participation in SBAE interventions. The number (x) following each factor indicates the frequency with which it was reported across included studies. For example, "flexible scheduling (7)" under external enablers means that this factor was identified as an enabler in seven studies—the most frequently mentioned in that category.

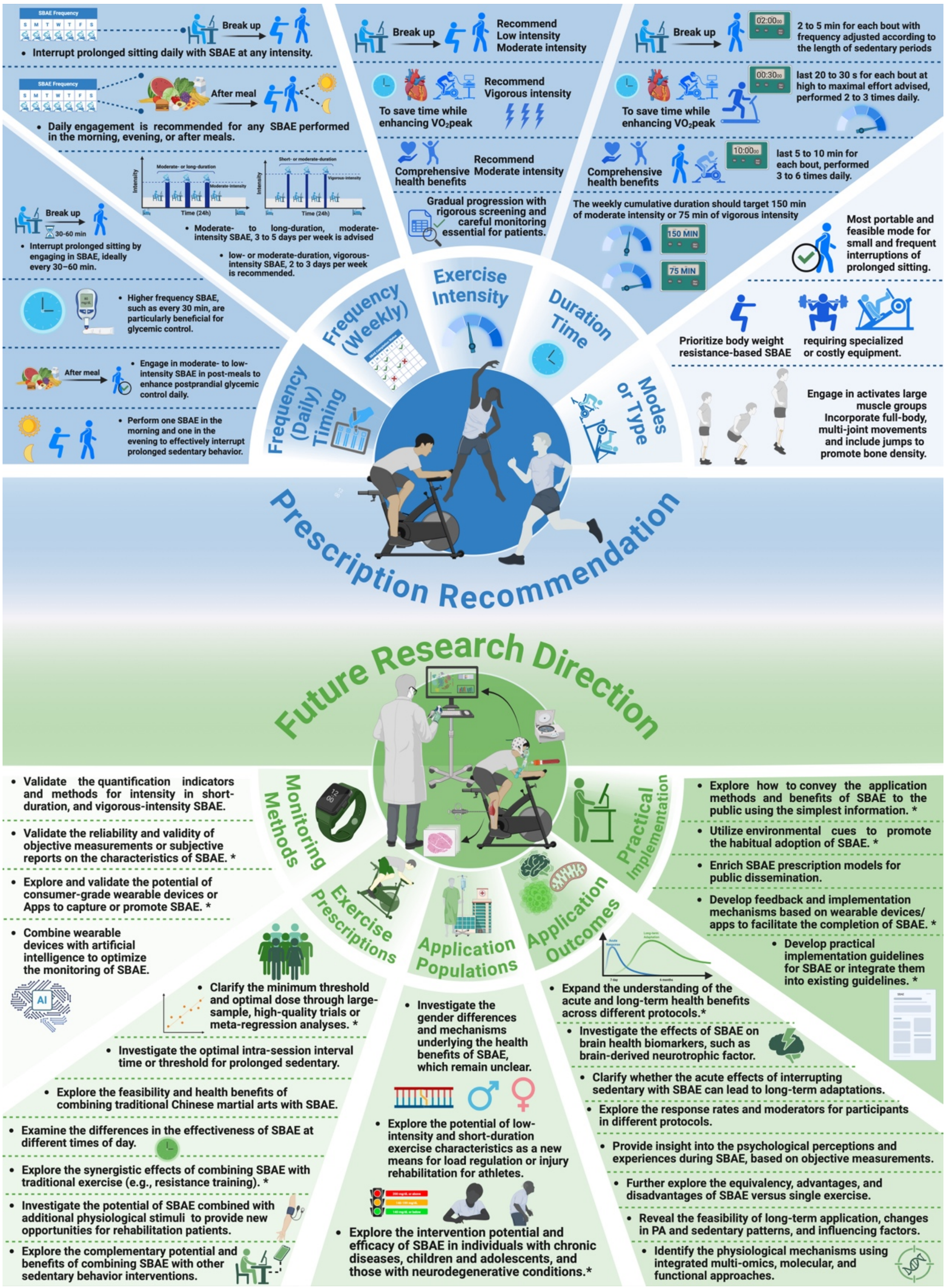


Figure 3. Summary of SBAE Prescription Variables Recommendation and Future Research Directions

Note: The Top panel summarizes recommendations for each prescription variable of SBAE. Bottom panel outlines proposed future research directions for SBAE. More detailed recommendation levels and scoring for each item can be found in **Supplementary File 8**.

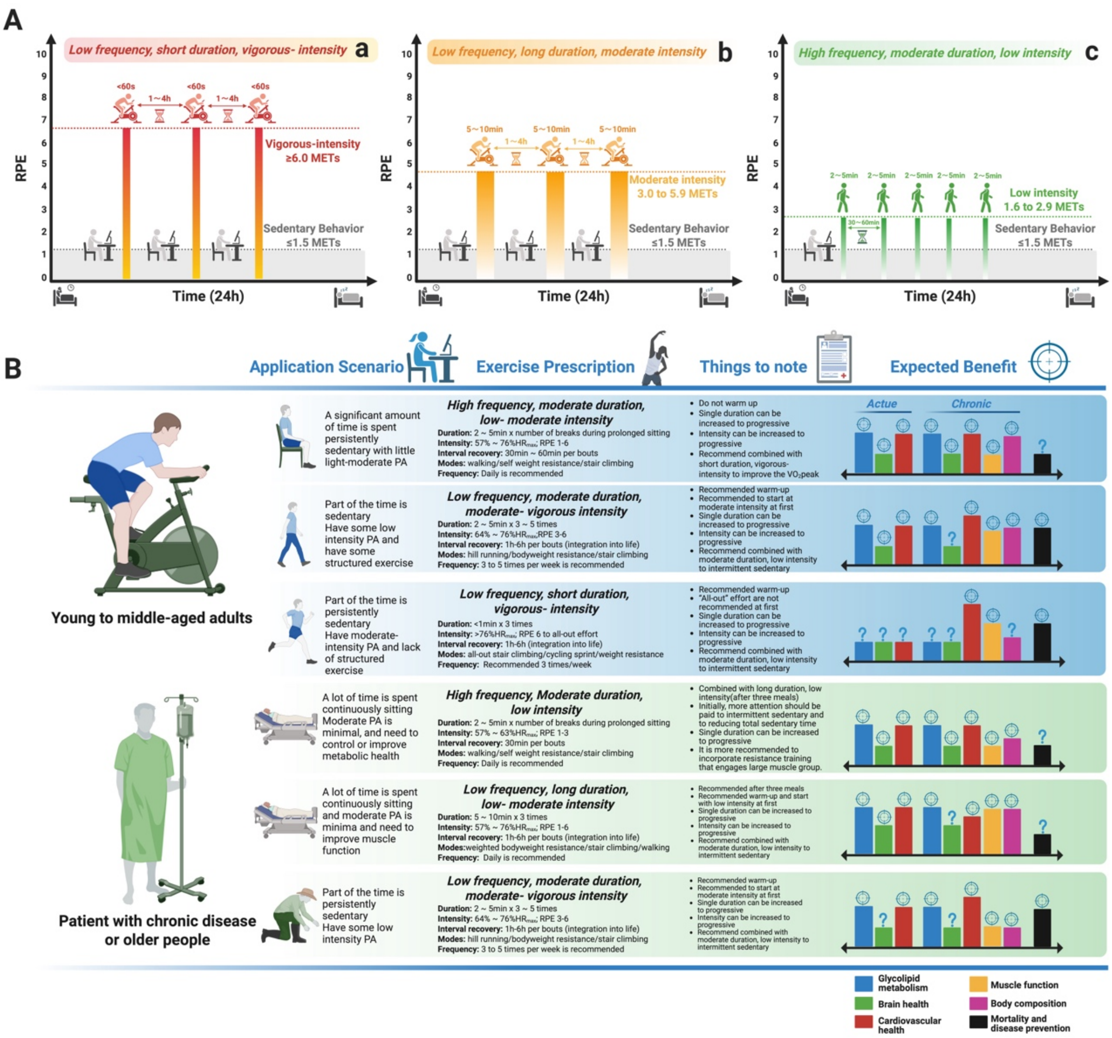


Figure 4. Evidence-based SBAE protocols and recommendations with expected health benefits based on populations and scenarios.

Note: (**A**), a=vigorous intensity; b = moderate intensity; c = low intensity. The grey columns in the above figure represent sedentary behavior, the green columns represent low-intensity activity/exercise, the yellow columns represent moderate-intensity activity/exercise, and the red columns represent vigorous-intensity exercise. ***RPE*****,** rating of perceived exertion, is a scale ranging from 0 to 10, where 0 indicates rest, 1 represents very light activity, 2–3 corresponds to light activity that can be maintained for hours, 4–5 refers to moderate activity with heavier breathing but still manageable conversation, 6–7 indicates vigorous activity with difficulty holding a conversation, 8–9 reflects very hard activity near maximum effort, and 10 signifies maximal exertion where continuing feels impossible [276]. (**B**) The rating of perceived exertion (RPE) is based on the Borg category-ratio 10-point scale (CR-10). The target icon refers to the magnitude and focus of the expected health benefits based on previous evidence.