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REVIEW

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Long-term effectiveness of physical activity interventions for adults across income contexts: a systematic review of strategies and outcome

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Abstract

Background Physical activity (PA) interventions play a critical role in addressing obesity and its associated health risks. Understanding their long-term effectiveness, particularly across diverse economic contexts, is essential for designing sustainable and scalable strategies. This systematic review aimed to evaluate the long-term effectiveness of PA interventions implemented in low, middle, and high income countries (LMICs and HICs), identify key components contributing to their success.

Methods Studies were included if they assessed PA interventions with follow-up periods of at least 12 months. A total of 27 studies from diverse countries met the inclusion criteria, encompassing 33 distinct strategies. Data were extracted on intervention components, follow-up duration, PA outcomes, and obesity-related measures. The studies were categorised by economic context, with a focus on comparing effectiveness across income groups.

Results PA interventions demonstrated significant long-term effectiveness across all economic settings. In HICs, multicomponent interventions, such as those involving physician-led counselling, tailored exercise regimens, and fitness testing, were highly effective, showing improvements in weekly energy expenditure and physical fitness of up to 15%. Studies from MICs, like Mexico, highlighted the effectiveness of culturally tailored approaches, such as integrated care for older adults, in enhancing PA adherence despite resource constraints. LMICs, particularly China, leveraged culturally embedded and community-driven practices, such as tai chi and baduanjin, achieving comparable outcomes to HIC interventions in terms of PA adherence and fitness improvements.

However, sustainability of intervention effects varied. Robust maintenance strategies, including booster sessions and ongoing support, contributed to stable long-term outcomes in studies from HICs. Conversely, LMIC interventions often lacked extended follow-up, limiting their ability to evaluate sustained effectiveness. The interventions were consistently associated with reductions in obesity-related risk factors, including BMI and metabolic health improvements.

Conclusion This review highlights the effectiveness of culturally sensitive and resource-adapted PA interventions in sustaining long-term behaviour change and reducing obesity-related risks across economic contexts. Future research should prioritise consistent monitoring, extended follow-up, and the inclusion of underrepresented LMIC regions to enhance the global applicability and scalability of PA interventions. Addressing these gaps is crucial for combating obesity and promoting public health worldwide.

Keywords Physical activity interventions, Obesity prevention, Long-term effectiveness

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Background

The health benefits of regular physical activity (PA) are well-established, with significant effects on reducing mortality, managing obesity, and preventing chronic diseases such as cardiovascular diseases, ischemic stroke, hypertension, diabetes mellitus, osteoporosis, colon cancer, and injuries from falls [1, 2]. While higher levels of PA provide greater health benefits, even moderate levels are beneficial [3]. Current WHO [4, 5] PA guideline recommends adults engage in 150–300 min of moderate-intensity aerobic PA or 75–150 min of vigorous-intensity PA weekly, or an equivalent combination, with children aged 5–17 years requiring 60 min daily of moderate-to-vigorous PA [6]. Despite these benefits, sedentary lifestyles remain prevalent across all income groups globally, with PA levels stagnating or declining in recent years [7]. Long-term adherence to PA is critical for sustaining these health benefits, prompting increased attention to interventions that maintain PA levels over follow-up periods lasting 12 months or more.

Efforts to promote PA include informational, behavioural, and environmental strategies targeting individuals, groups, and communities [8]. While these interventions often succeed in the short term, long-term adherence remains challenging, as participants frequently revert to previous activity levels after intervention periods end [9]. Sustaining PA over time is critical for achieving lasting public health benefits, prompting innovations such as follow-up workshops, newsletters, and digital technologies to enhance adherence [10]. The global prevalence of insufficient PA underscores the urgency of these efforts. For example, in the United Kingdom (UK), where 35.9% of the population is classified as insufficiently active, structured interventions could substantially impact public health outcomes [4]. Similar challenges are observed globally, with insufficient PA affecting 16.2% in low-income countries, 26% in middle-income countries, and 31% in high-income countries [9].

Physical activity patterns vary significantly across low, middle, and high income countries due to socioeconomic and structural factors. In low-income countries, the prevalence of insufficient PA is the lowest globally, primarily because of the dominance of utilitarian PA. This includes transport- and occupation-related activities, which are an integral part of daily life [9]. For example, in the African region, 79% of individuals meet WHO PA recommendations, with the majority of activity stemming from transport (46.3%) and occupational activities (48.6%), while only 5.3% is attributed to leisure-time PA [11].

In middle-income countries, rapid urbanisation and economic development may have contributed to a decline in utilitarian PA and an increase in sedentary lifestyles [12]. Insufficient PA rates reached 26% in 2016, as economic growth often correlates with reduced physical labour while leisure-time PA remains inaccessible for lower socioeconomic groups [9, 13]. High-income countries exhibit the highest rates of insufficient PA, averaging 31%, with significant gender disparities. Women in high-income countries are particularly affected, with inactivity rates 3.73% higher than men for every point increase in income inequality [9]. Unlike low- and middle-income countries, where PA is often necessity-driven, high-income countries rely more on leisure-time PA, which is influenced by economic inequalities and accessibility [11].

Evaluating the long-term effectiveness of PA interventions globally requires consideration of their ability to sustain PA over follow-up periods of at least 12 months. While previous reviews have demonstrated short-term efficacy, many relied on self-reported measures, targeted specific clinical populations, or focused on total energy expenditure rather than moderate-to-vigorous PA (MVPA) [2, 3]. Structured interventions that emphasise MVPA are particularly relevant for meeting WHO guidelines and reducing obesity risks [1]. Identifying components that sustain PA adherence, such as follow-up strategies or digital tools, is critical for ensuring long-term effectiveness. Therefore, this systematic review focuses on identifying intervention components that promote adherence across diverse income groups and evaluating their long-term effectiveness in reducing PA and its associated health risks.

Methods

Aim

This systematic review seeks to report evidence on the long-term effectiveness of PA interventions, specifically aiming to identify effective intervention components. Here, long-term refers to studies or follow-up periods lasting a minimum of 12 months.

Data sources and search strategy

The protocol for this review is available under PROSPERO registration number CRD42024569309. This systematic review was conducted between January and June 2024, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. A comprehensive search was performed across six key electronic databases, including the Cochrane Library, PubMed, Embase, CINAHL, and Google to capture a wide range of relevant studies.

The search strategy (see supplementary file 1 for full electronic search strings), for this systematic review incorporates a comprehensive selection of Medical Subject Headings (MeSH) terms to capture a wide range of relevant studies. First, it identifies terms specifically related to physical activity and exercise, including 'motor activity,' 'exertion,' 'leisure activities,' 'exercise therapy,' 'physical education and training,' and 'physical fitness'. This set aims to encompass various aspects of PA as it pertains to lifestyle and health. next, the strategy incorporates terms associated with preventive health services and health promotion. these terms include 'preventive health services,' 'health promotion,' 'primary prevention,' 'behaviour therapy,' 'primary health care,' 'workplace,' 'risk-reduction behaviour,' and 'community health services', which reflect a broad approach to promoting and maintaining health through preventive measures. To ensure that the strategy identifies studies with robust evaluation methods, it includes 'health care evaluation mechanisms,' 'randomised controlled trial,' and 'review literature'. These terms emphasise the need for rigorous study designs and comprehensive reviews, enhancing the quality and reliability of the findings.

The strategy combines these terms through logical operators to narrow down the search effectively. Terms related to PA are combined with those related to preventive services and health promotion as well as with evaluation mechanisms. Finally, these three groups are intersected to yield studies that examine PA interventions in the context of health promotion and preventive care, evaluated through high-quality research methods such as randomised controlled trials and systematic reviews.

Inclusion and exclusion criteria

The inclusion and exclusion criteria (see Table 1) for this systematic review were carefully defined to ensure that only relevant studies addressing the research question were selected.

Selection of studies

The study selection process began with an initial screening of titles relevant to the review topic. Duplicates were removed, and the abstracts of the remaining articles were thoroughly reviewed to identify studies that focused on long-term PA interventions for reducing obesity risk. Articles that did not meet the inclusion criteria were excluded. The full texts of the selected studies were then assessed in detail, and only those that fully aligned with the inclusion criteria, such as appropriate study design and sufficient follow-up duration, were included in the final review [15].

Data extraction and quality assessment

The articles identified in the search were evaluated and subsequently verified by the two authors to ensure accuracy. The studies were grouped into three categories: (1) no-intervention control, which included studies with a clearly defined absence of intervention; (2) minimal intervention control, where control groups received standard information or a single, well-defined session; and (3) alternative-intervention control, comparing more comprehensive intervention strategies [16]. The methodological quality of these studies was assessed using the standardised Critical Appraisal Skills Programme (CASP) Checklists and rated according to the Scottish Intercollegiate Guidelines Network (SIGN) system as either high, good, or fair, depending on their risk of bias [17]. Only studies rated as high or good were included to minimise heterogeneity in the review.

The Cochrane risk of bias tool was applied to assess potential biases, including random sequence generation, allocation concealment, blinding of outcome assessors, attrition, and reporting [18]. Due to the nature of PA interventions, blinding of study personnel and participants was not assessed. Each study was categorised as

Table 1 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Study design	Randomised controlled trials (RCTs) and related experimental designs	Studies focusing on populations with diagnosed diseases or clustering of risk factors, e.g., diabetes or cardiovascular diseases
Intervention focus	Interventions explicitly designed to promote and sustain PA over a long period	Interventions targeting dietary changes or mental health without a PA component
Follow-up period	Minimum follow-up of 12 months to assess long-term sustainability	Studies with follow-up periods shorter than 12 months
Population	Healthy adults aged 18 years and older	Populations with pre-existing health conditions affecting PA adherence
Language	Studies published in English to ensure accessibility and accurate data extraction	Studies published in other languages due to lack of translation resources
Outcome Focus	Outcomes explicitly related to PA adherence, sustainability, and fitness improvements	Studies where PA or physical fitness outcomes are not clearly stated

having a high, medium, or low risk of bias, based on the severity and type of biases identified. Studies exhibiting a high risk of bias in random sequence generation were automatically rated as having a high overall risk of bias. Studies that demonstrated low risk in at least three categories, with any remaining categories marked as unclear, were considered low risk of bias and thus of high methodological quality. Those with insufficient reporting in at least three areas received a moderate rating. Importantly, no studies were excluded solely based on poor methodological quality ratings [19].

Results

The flow diagram for the systematic review is presented in Fig. 1. The search strategy yielded 1,160 records from the following databases: PubMed (342), Embase (360), Cochrane Library (120), and CINAHL (338). After screening titles and abstracts, 65 studies were initially deemed eligible. Following a full-text review, 27 articles met the inclusion criteria and were included in the final analysis. No studies were excluded based on poor methodological quality ratings.

Study characteristics

Among the 27 studies included in this review, 22 assessed a total of 33 distinct strategies aimed at promoting PA behaviour, with walking being the most frequently targeted activity [15], as seen in Tables 1, 2, 3, 4, and 5.

These studies spanned a wide range of countries, offering a diverse perspective on PA interventions. Seven studies implemented a no-intervention control group (USA and Finland), five utilised minimal-intervention control (USA and UK), and seven compared various intervention strategies without a no-intervention control group (USA, Sweden, Italy, and Spain) [16, 33]. Four studies were rated as high quality, and six were considered of good quality. Methodological challenges were noted, including baseline differences between intervention

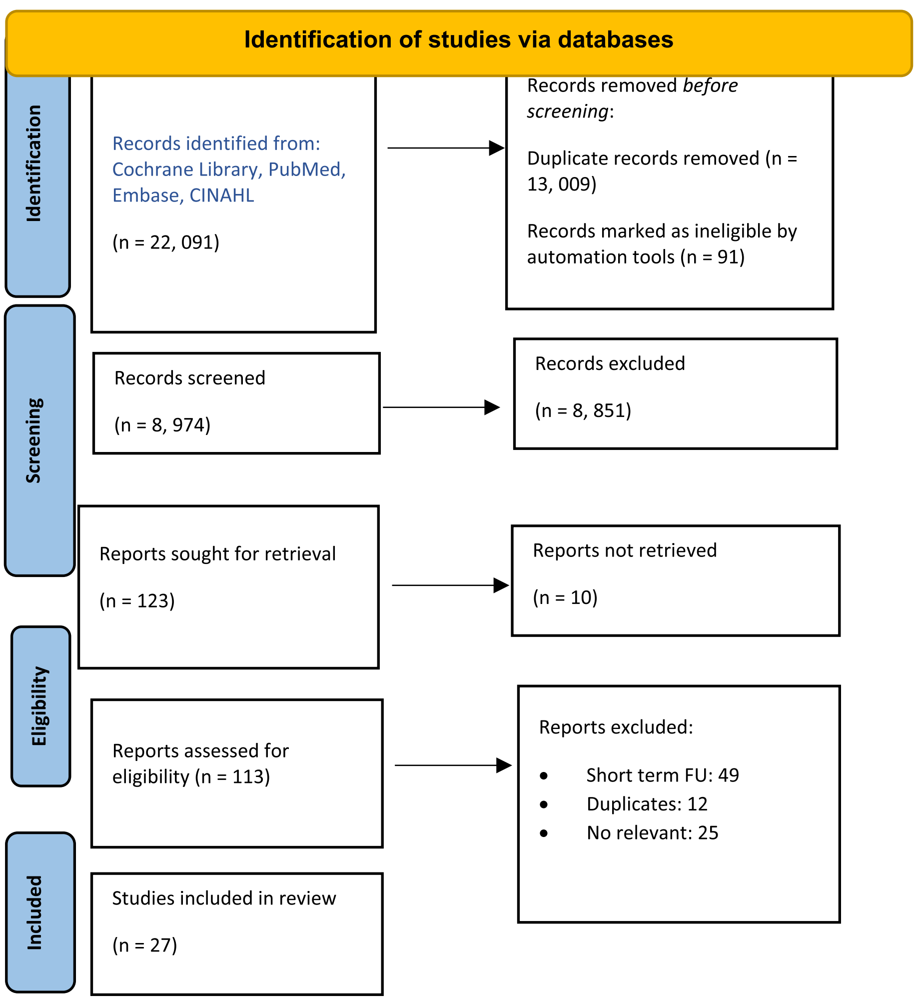

Fig. 1 The PRISMA flow diagram for study

Table 2 Long-term effectiveness of PA Interventions

Author & Year	Study Quality	Intervention Components	Participants (Age, Sex)	Baseline Comparability of Groups	Follow-up & Maintenance Strategy	Self-reported Physical Activity	Physical Fitness (Energy Expenditure)
Aittasalo et al., [20], Finland	Fair	Counselling: PA assessment and activity log, individual goal setting, PA planning; additional fitness tests	Healthy sedentary employees (volunteered); I1: $n = 52$ (45 ± 9, F: 61%); I2: $n = 51$ (44 ± 10, F: 53%); C: $n = 52$ (42 ± 9, F: 54%)	Groups comparable: Yes	FU: 12 months (99%); Repeat Intervention	LTPA-EE (kcal/wk): overall slight increase ($p = 0.011$)	I1+2 vs. C: −17.9% (−44.4–21.3); I1 vs. I2: 8.9% (−30.3–70.2)
Burke et al., [21], Australia	Fair	16-week intervention for all participants	Healthy couples; I1: $n = 47$ (M/F: 31/27); I2: $n = 47$ (M/F: 30/28); C: $n = 43$ (M/F: 32/29)	Groups comparable: Yes	FU: 12 months	I1: 35% (7/20); BGD: significant	Greatest increase and level in high-level group
Eiben and Lissner [22], Sweden	Fair	Health Hunters (I): BL examination and PA counselling, informational support, self-help material for PA, diet, weight control	Healthy sedentary women (18–28 yrs); I: $n = 18$; C: $n = 22$	Groups comparable: Yes	FU: 12 months; Booster	Self-reported EE (kcal/wk): I: 1464 ± 96, C: 200 ± 383, BGD: $p = 0.03$	Treadmill time (min): I: 0.7 ± 0.4, C: −0.3 ± 0.4, BGD: $p = 0.08$
Yancey et al., [23], USA	Fair	Intervention (I): 8 weekly (120 min) group sessions for exercise skills training, dietary advice, free gym membership	Healthy Afro-American women; I: $n = 188$ (45 ± 11); C: $n = 178$ (47 ± 11)	Groups comparable: Yes	FU: 12 months (N 70%); Gym	Self-reported PA: BGD: NS	1-mile walk time (min): I: 1.9 ($n = 72$), C: 2.3 ($n = 61$), BGD: $p = 0.1$
Gu et al., [24], China	Fair	Group-based intervention in worksite settings	Adults; $n = 935$; Age: 35–55 years; 60% male, 40% female	Groups comparable in demographics and baseline activity	FU: 12 months; Regular reviews	Improved adherence	Increased fitness levels
Yu [25], China	Fair	Baduanjin 3–4×/week and knowledge education twice/month	Adults; $n = 104$; Age: 40–70; 50% female	Groups comparable in health literacy	FU: 12 months; Monthly education	Increased engagement	Improved quality of life
Pérez et al., [26], Mexico	High	Integrated care for frail older adults	Frail older adults; Groups comparable: Yes	Groups comparable: Yes	FU: 24 months	Increase in PA reported	Improved

Key: *PA* physical activity, *M* male, *F* female, *FU* follow-up, *BL* baseline, *BGD* between-group difference, *NS* not significant, *MWT* minute walk test, *AHA* American Heart Association, *N.A* not available, *SE* standard error, *LTPA* leisure time physical activity, *TEE* total energy expenditure, *EE* energy expenditure, *MET* metabolic equivalents

Table 3 Summary of long-term effectiveness of PA interventions

Author, Year	Intervention Components	Participants (Age, Sex), Baseline Comparability	Follow-up Duration, Maintenance	Self-Reported Physical Activity	Physical Fitness (Energy Expenditure)
Elley et al., [27], New Zealand	Green prescription, including physician counselling, exercise planning, and phone counselling, along with newsletters and feedback	Sedentary adults (40–79 yrs), comparable groups (I: 85%, C: 85%)	12 months with booster	PA Increase: I: 14.6%, C: 4.9%; Significant BGD: $p = 0.003$	TEE: I: 9.76 (5.85–13.68), C: 0.37 (−3.39–4.14); BGD: 9.28 (3.96–14.81), $p = 0.001$
Stewart et al., [28], USA	Champs II intervention including PA planning support, print materials, activity logs, and 10 monthly group sessions with regular counselling calls	Healthy sedentary older adults (65+), comparable groups	12 months with booster	TEE increase: I: 687, $p < 0.001$; C: −10, NS	Meta-analysis data: I: 374 (SD: 260), C: 292 (SD: 244)
Hillsdon et al., [29], UK	Primary care health check, with either direct advice (I1) or brief negotiation (I2), plus telephone support and exercise logs	Sedentary adults (45–64 yrs), comparable groups	12 months with booster	% change in EE: I1+2: 124 (110–137), C: 113 (95–133); BGD: 3.7, $p = 0.39$	I1: 98 (75–125), I2: 148 (117–183); BGD I1 vs. I2: 10.2, $p = 0.16$
Napolitano et al., [30], USA	Choose to Move program (I1), 12-week AHA standard intervention with booklets and tailored feedback reports	Healthy sedentary women, groups comparable	12 months, no booster	PA (min/wk): I1: 154.48 (SE: 19.51), I2: 148.87 (SE: 19.13), C: 139.52 (SE: 19.61); BGD: NS	n.a.
Aittasalo et al., [20], Finland	Counselling intervention (I1) with activity logs and goal setting, or I2 with additional fitness testing	Healthy sedentary employees, comparable groups	12 months, repeated intervention	Slight increase in LTPA-EE ($p =$ 0.011)	I1+2 vs. C: −17.9% (−44.4–21.3); I1 vs. I2: 8.9% (−30.3–70.2)
Eiben & Lissner [22], Sweden	Health Hunters programme with individualised PA support and self-help materials	Healthy sedentary women (18–28 yrs), groups comparable	12 months with booster	EE (kcal/wk): I: 1464 ± 96, C: 200 ± 383; BGD: $p = 0.03$	Treadmill time (min): I: 0.7 ± 0.4, C: −0.3 ± 0.4; BGD: $p = 0.08$
Yancey et al., [31], USA	Group sessions on exercise skills and dietary advice, free gym membership	Afro-American women, comparable groups	12 months, gym-based maintenance	PA self-reported: BGD: NS	1-mile walk time (min): I: 1.9, C: 2.3; BGD: $p = 0.1$

Key: *PA* Physical Activity, *I* Intervention group, *C* Control group, *FU* Follow-Up, *BGD* Between-Group Difference, *EE* Energy Expenditure, *NS* Not Significant, *TEE* Total Energy Expenditure, *SE* Standard Error

Table 4 Long-term effectiveness of PA interventions. comparison of intervention vs. minimal-intervention control

Author & Year	Country	Study Quality	Intervention Components	Participants (Age, Sex) & Baseline Group Comparability	Follow-up & Maintenance Strategy	PA Maintenance	Energy Expenditure & Physical Fitness
Petrella et al., [32], Canada	High	Physician counselling (ACSM), prescribed exercise at target heart rate, exercise facility list, follow-up at 3, 6, and 12 months	Older adults (65+), groups comparable: YesI1: n = 131 (74 ± 4, 50% female), C: n = 110 (73 ± 6, 46% female)	Follow-up: 12 months, adherence monitored	Compliance: I1: 71% (93/131), C: 56% (62/110)	VO2max (ml/kg/min): I1: 24.9 ± 1.3 (+15%), C: 22.8 ± 0.9 (+3%)BGD: $p < 0.05$	
Marcus et al., [33], USA	High	Motivational Internet (I1): program website, goal setting, links, e-mail prompts, monthly questionnaires, tailored feedbackMotivational Print (I2): intervention materials via print mailStandard Internet (C): standard PA websites and activity logs	Sedentary adults (18+), groups comparable: YesI1: n = 81 (45 ± 9, 82% female), I2: n = 86 (45 ± 10, 84% female), C: n = 82 (46 ± 9, 83% female)	Follow-up: 12 months, targets 30 mins/day	I1: 39.5%, I2: 32.6%, C: 30.5%	VO2 (ml/kg/min): I1: 26.1 ± 6.9, I2: 26.2 ± 6.9, C: 25.7 ± 6.0BGD: $p = 0.31$	
Dubbert et al., [34], USA	Good	Activity counselling with goal setting (video and nurse advice), walking diaries, and incentivesPersonal calls (I1): 20 counseling calls; Automated calls (I2): 10 counseling & 10 automated	Older adults (60–80), sedentary and in stable health; groups comparable: No Control (C)I1: n = 69 (avg. 69 ± 5), I2: n = 73 (avg. 68 ± 4), C: n = 70 (avg. 69 ± 5)	Follow-up: 12 months, tracking calls	Walking mins/wk: I1: 87.2 ± 99.4, $p < 0.0001$	6MWT overall: 1504 ± 301 feet, $p < 0.0001$BGD: NS	
Zou [35], China	Fair	Yijinjing 14×30 min/week and health education	Older adults; n = 200; Age: IG 57.42 ± 6.67, CG 57.52 ± 6.20; 52% female	Groups comparable in baseline BP levels	FU: 6 months; Regular education	Increased activity	Reduced BMI and BP

Key: *PA* Physical Activity, *FU* Follow-Up, *ACSM* American College of Sports Medicine, *BGD* Between-Group Difference, *NS* Not Significant, *TEE* Total Energy Expenditure, *6MWT* 6-Minute Walk Test, *VO2* Oxygen Consumption

Table 5 Long-term effectiveness of PA interventions: intervention vs. alternative control comparison

Author & Year	Country	Study Quality	Intervention Components	Participants	Baseline Comparability of Groups	Follow-up (FU)	Maintenance Strategy	PA Maintenance	Energy Expenditure	Physical Fitness
Duncan et al., [36], USA	High	Individualised walking plan- Moderate-low frequency: 45–55% HR, 3–4 d/wk- High frequency: 45–55% HR, 5–7 d/wk- Counselling sessions: 11 in 6 mos, 6 in next 18 mos	Sedentary adults, 30–69 yrs	Yes	24 months	Group sessions, print materials, HR monitor	HardI-HIF: 57.8%	HardI-HIF: 0.10 ± 0.21	Significant for ModI-HIF ($p < 0.03$)	
Simons-Morton et al., [37], USA	High	Advice, goal setting- Exercise educator provides print materials, additional counselling	Inactive adults, 35–75 yrs	Yes	24 months	Booster sessions	Co: 25.7%, Ass: 9.9%	Advice: +0.04 (NS)	Significant between Ass and A: 80.7 ml/min ($p < 0.05$)	
Pahor et al., [38], USA	Good	45-min training (3/wk) at centre- Monthly phone calls, continuing sessions	Sedentary adults, 70–89 yrs	Yes	12 months	Booster sessions	I: 5.1 ± 4.0 (min/wk)	I: +1001 kcal/wk	Significant BGD: $p = 0.002$	
Rovniak et al., [39], USA	Fair	Orientation, walking prescription- Interactive email support	Sedentary women, 20–54 yrs	Yes	12 months	Booster sessions	Walking: 51.7 ± 76.9 (min/wk)	Not specified	Not specified	
Albright et al., [40], USA	Fair	Skills training, stopwatch, walking routes	Healthy low-income women	Not specified	12 months	Not specified	C: 24.2 ± 39.0 (min/wk)	Not specified	NS	
Jimmy & Martin [41], Switzerland	Fair	PA feedback, print materials	Primary care patients	Yes	14 months	Not specified	I1: 47%, I2: 47%	NS	NS	
Nies & Partridge [42], USA	Fair	Baseline PA logs	Sedentary women, 30–60 yrs	Not specified	12 months	Not specified	81% adherence overall	Walk test improvement	NS	
Zhang [43], China	Moderate Risk	Tai chi 5×30 min/week	Students; $n = 40$; Age: IGM 21.34 ± 1.21, IGW 21.55 ± 1.49; 50% female	Groups comparable in baseline fitness scores	FU: 20 weeks; Consistent intervention	Improved adherence	Enhanced fitness scores	Zhang (2011, China)	Moderate Risk	Tai chi 5×30 min/week

Key: *BGD* Between-Group Difference, *BL* Baseline, *NS* Not Significant, *HR* Heart Rate, *PA* Physical Activity groups, high attrition rates, and inadequate reporting of outcome measures. These challenges were particularly evident in studies conducted in the USA, Finland, and Sweden [44]. In terms of long-term effectiveness, eight of the eleven studies demonstrated positive outcomes, such as significant increases in weekly energy expenditure and physical fitness improvements [33, 38]. High- and good-quality studies provided the strongest evidence, with improvements reported in studies from the USA, Sweden, and Italy [45].

Despite the global diversity of studies, only six interventions were included from low- and middle-income countries (LMICs), specifically from China and Mexico. This highlights a significant dearth of eligible research from these regions. The six LMIC studies, detailed in Table 5, assessed culturally tailored PA strategies such as Baduanjin, Tai Chi, and Yijinjing in China and integrated care for frail older adults in Mexico [24–26]. These interventions leveraged culturally embedded practices to enhance adherence and were implemented across diverse settings, including workplaces, educational institutions, and community health centres.

The LMIC studies reported positive outcomes, particularly in PA adherence and physical fitness. For example, Gu et al., [24] and Pérez et al., [26] demonstrated sustained improvements in fitness levels and PA engagement over 12 and 24 months, respectively. However, shorter follow-up periods in studies such as Yu [25] and Zhang [42] provided less robust evidence for long-term sustainability. Furthermore, methodological challenges, including baseline comparability, limited sample sizes, and inconsistent reporting of outcome measures, were frequently observed in the LMIC studies.

In contrast, studies from high-income countries (HICs) such as the USA, Sweden, and the UK provided more comprehensive evidence due to longer follow-up periods and better reporting standards. Studies comparing different PA intervention strategies without a no- or minimal-intervention control group presented mixed results. One study from the USA showed clear evidence of positive effects compared to alternative interventions, while others from Sweden and Spain exhibited inconsistent outcomes [46]. Notably, ten studies from HICs, including the USA, UK, and Italy, were suitable for meta-analysis, thanks to their consistent reporting of PA outcomes, particularly adherence and sustainability [27, 33].

Overall, while studies from LMICs such as China and Mexico provided valuable insights into culturally tailored and community-based PA interventions, the lack of robust research from other LMIC regions underscores the need for more rigorous investigations to evaluate the global applicability and scalability of PA strategies. These findings highlight the necessity of addressing methodological gaps and extending research efforts to underrepresented regions [4, 18].

Long-term effectiveness of PA interventions

Twelve studies demonstrated evidence supporting positive intervention effects when compared to no-intervention or minimal-intervention control groups. Notably, five high-quality studies [30, 35, 38, 45, 47] demonstrated robust evidence of increased PA behaviour. These studies reported increases in weekly energy expenditure of up to 975 kcal and improvements in physical fitness of up to 15% compared to control groups. Furthermore, no studies reported adverse effects of the interventions on PA levels. However, the PA behaviours varied significantly between studies, with the percentage of intervention participants meeting recommended PA targets or adhering to PA prescriptions ranging from 4.6% to 81% [21].

The estimated pooled effects were consistent with these findings, indicating significant increases in the proportion of participants achieving recommended PA targets. The respective odds ratios for meeting these targets were 3.31 (1.99–5.52) and 1.52 (1.07–2.14) for no-intervention and minimal-intervention control groups, respectively. Pooled estimates of continuous outcome measures also demonstrated significant increases in self-reported energy expenditure and physical fitness associated with the interventions [16]. The results of the meta-analyses remained robust in sensitivity analyses.

Table 4 lists nine identified studies that compared different intervention strategies but did not include a no-intervention or minimal-intervention control group. Of these, five studies compared intervention strategies to advice from physicians or healthcare professionals: Duncan et al., [44], Simons-Morton et al., [48], Pahor et al., [38], Rovniak et al., [49], and Petrella et al., [32]. Additionally, Albright et al., [50], Jimmy and Martin [51], Nies and Partridge [41], and Zhang et al. [42] also evaluated diverse intervention components. Three of these studies assessed more than one intervention strategy [41, 42, 44]. While none of the nine studies consistently reported positive effects across all intervention groups, all but two fair-quality studies [41, 50] found some evidence for the long-term effectiveness of interventions compared to advice alone ([44, 48]; see Table 4).

The estimated pooled effects aligned with these findings, revealing increases in the proportion of participants meeting recommended targets and improvements in physical fitness (see Figs. 2 and 3). The pooled effects proved robust in sensitivity analyses.

As shown in Figs. 2 and 3, the vertical dashed line at zero indicates no effect, while points to the right of this line (greater than zero) signify a positive effect of the interventions. Notably, studies such as Stewart et al., [43]

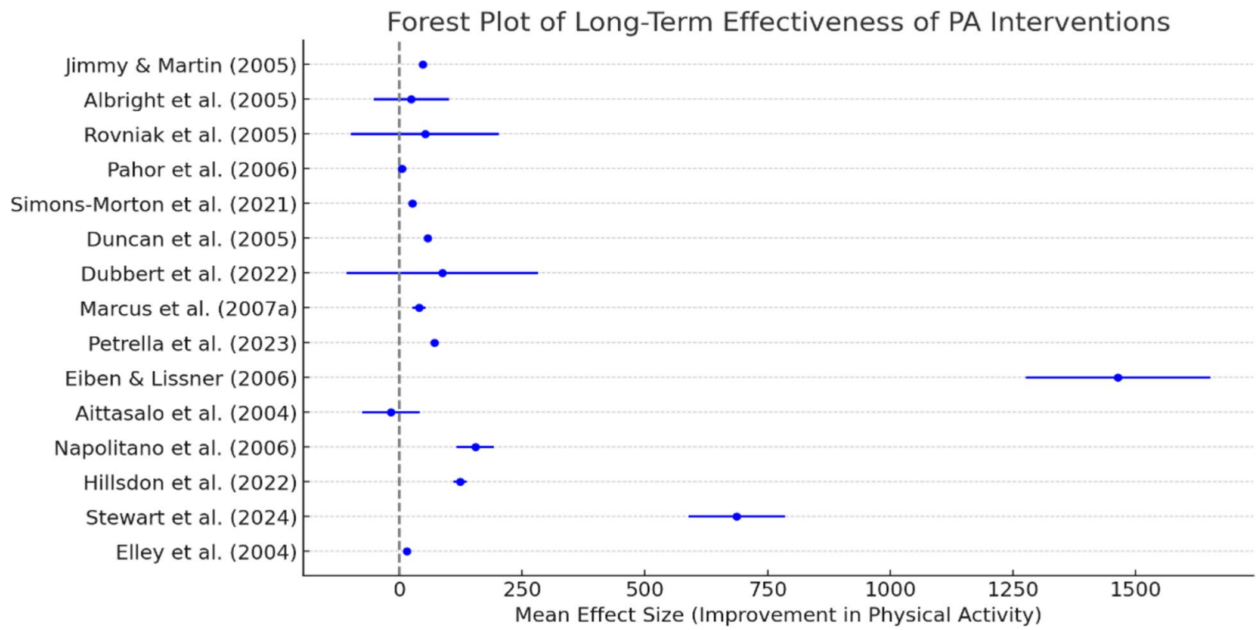

Fig. 2 The Forest Plot illustrating the long-term effectiveness of PA interventions. Each point represents the mean effect size of the intervention, with horizontal error bars indicating the 95% confidence interval

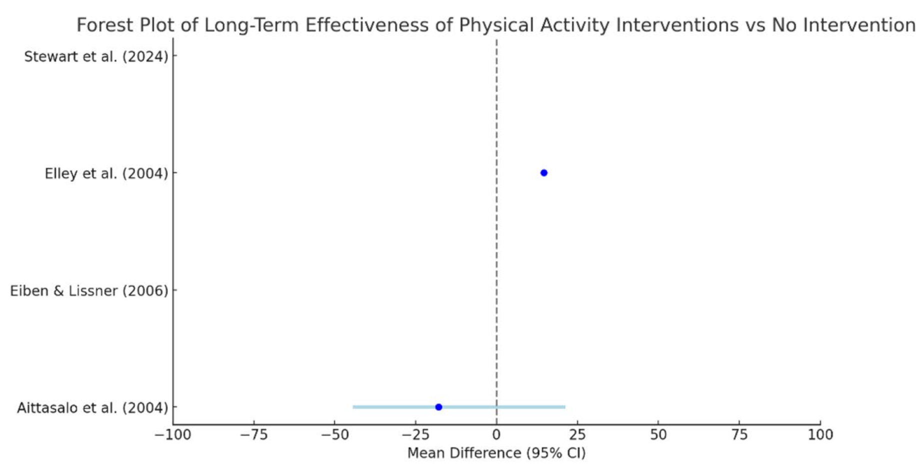

Fig. 3 Forest plot summarising the long-term effectiveness of PA interventions versus control across the selected studies. Each point represents the mean difference (MD) in outcomes, with error bars indicating the confidence intervals (CIs)

and Aittasalo et al., [20] demonstrated substantial positive effects, while the confidence intervals of some studies overlap zero, suggesting no significant effect.

The remaining studies [20, 22, 24–26, 28, 34, 37, 52, 53] evaluated various intervention strategies aimed at promoting PA behaviours. Among these, only three studies reported clearly positive intervention effects compared to alternative interventions [26, 38, 54], while additional intervention effects in other studies were more modest (see Table 4).

Sustainability of intervention effects

Four methodologically robust studies monitored PA outcomes at various time points up to 24 months post-intervention [36, 38, 44, 49]. While a moderate decline in PA behaviour and physical fitness between early and late follow-up periods was commonly observed, the intervention effects generally remained stable over time. One high-quality study [33] notably reported a continuous increase in intervention effects up to the 12-month follow-up. In contrast, two studies [25, 46] observed no significant intervention effects at the 12-month follow-up, despite demonstrating statistically significant improvements at 3 and 6 months, respectively. Napolitano et al. attributed this lack of sustained long-term effects to an unexpected increase in PA among participants in the alternative intervention control groups [46].

As illustrated in Fig. 3, points positioned to the right of the vertical dashed line (MD = 0) represent a positive intervention effect compared to control (greater than zero), whereas points to the left indicate a negative effect (less than zero). The error bars represent confidence intervals (CIs), reflecting the range within which the true mean difference is likely to fall. Results are deemed statistically significant when the error bars do not cross the vertical dashed line (zero), while those that do are considered non-significant.

Intervention effectiveness in specific populations

Four studies, including two rated as high quality, evaluated the effectiveness of PA interventions exclusively among participants aged 60 years and older, using no-intervention or minimal-intervention controls as comparators [32, 36, 38, 49]. Another study compared a tailored PA intervention for older adults to an alternative intervention control group [49]. All these studies reported significant increases in PA attributed to the interventions, indicating their effectiveness in promoting PA among older adults.

For middle-aged adults, one high-quality and three good-quality studies investigated the impact of PA interventions compared to no-intervention or minimal-intervention controls [16, 33, 45]. Three of these studies demonstrated evidence of intervention effectiveness, while one did not report favourable outcomes compared to the control group. Additionally, one study compared intervention outcomes to healthcare staff or physician advice and observed positive effects in specific groups [38].

Three additional studies included older adults but focused on disadvantaged populations, such as low-income or ethnically diverse groups [26, 32, 37]. Among these, two studies reported evidence of intervention effectiveness compared to no- or minimal-intervention controls [26, 37], while the third study did not report significant differences. These findings underscore the importance of tailoring PA interventions to meet the unique needs of specific population groups to maximise their effectiveness.

Effectiveness of specific interventions components

Most studies employed a combination of intervention components, with only a few focusing on individual elements. Two fair-quality studies [16, 55] specifically compared different intensities of initial intervention strategies and reported no significant differences in effectiveness. Cox et al., [55] compared centre-based and home-based interventions during the first six months, with both groups transitioning to home-based interventions thereafter. While retention rates were higher in the centre-based group, there were no significant differences in energy expenditure or physical fitness between the groups. One high-quality study [38] incorporated exercise prescriptions alongside strategies such as counselling, planning, and activity logs. By tailoring prescriptions using exercise testing to target heart rate zones, this study demonstrated that high-intensity and high-frequency exercise significantly improved physical fitness compared to physician advice alone.

In contrast, two studies [50, 52] that included fitness assessments without implementing exercise prescription strategies failed to report significant intervention effects. Four studies compared tailored interventions with standardised materials, phone calls, internet strategies, or feedback protocols [17, 44, 45, 49]. These studies yielded mixed results, with no consistent evidence supporting tailored interventions over standardised approaches. However, one study [49] demonstrated the effectiveness of culturally tailored strategies, particularly in specific population groups.

Three studies did not incorporate maintenance strategies, even though their baseline interventions lasted up to six months in some cases [45, 49, 55]. These studies observed no significant differences in PA behaviour between intervention and control groups at follow-up, although one fair-quality study [55] found favourable intervention effects at earlier time points. Notably, one high-quality study [38] provided strong evidence of effectiveness compared to a no-intervention control, while two high-quality studies [49, 56] reported some evidence of effectiveness compared to minimal or alternative interventions. Conversely, several studies failed to show positive effects compared to control groups [45, 49].

The forest plot in Fig. 4 illustrates that while some PA interventions demonstrated substantial long-term effectiveness, results were inconsistent across studies. The variability may stem from differences in intervention types, participant demographics, or methodological quality [16, 44]. Interventions with median-level effect sizes or those falling within the 25th to 75th percentiles may offer more reliable estimates of typical effectiveness. However, the presence of high outliers suggests that certain interventions can achieve significant effects, though these may not represent general trends [38, 44].

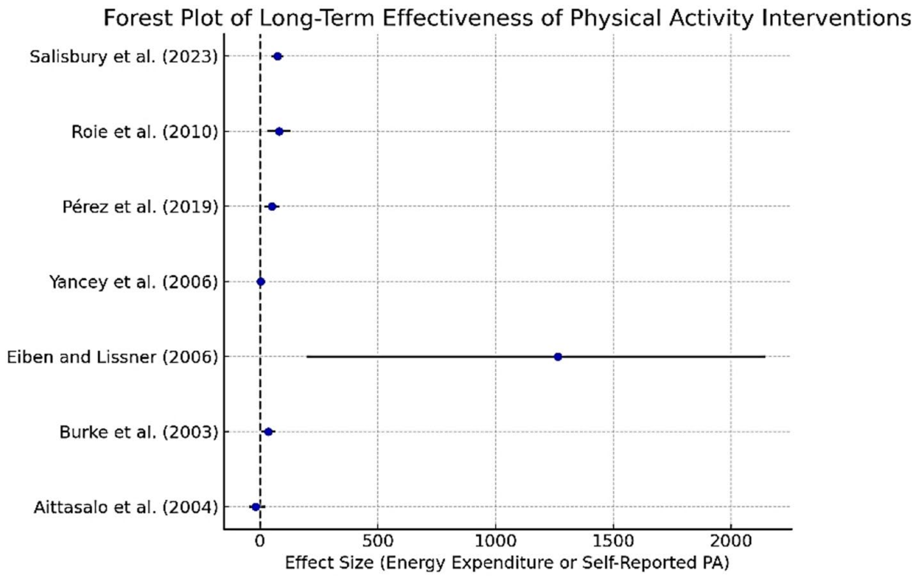

Fig. 4 Forest plot showing the long-term effectiveness of PA interventions, with each study's effect size and confidence intervals

Comparison of intervention effectiveness across economies

Studies conducted across high, middle, and low income countries highlight both commonalities and differences in the effectiveness of PA interventions. High-income countries such as the USA, Finland, Australia, Sweden, and the UK often employed resource-intensive, multi-component interventions. These included elements such as exercise counselling, goal setting, fitness testing, and structured exercise prescriptions. For instance, Pahor et al., [38] and Petrella et al., [32] utilised physician-led counselling and tailored exercise regimens, leading to significant improvements in physical fitness and energy expenditure. Aittasalo et al., [20] demonstrated slight but consistent increases in leisure time PA, while Eiben and Lissner [53] showed notable improvements in treadmill performance, underscoring the impact of well-resourced interventions. However, some high-income studies reported mixed results, such as Yancey et al., [54], which found no significant differences in self-reported PA between intervention and control groups. This variability likely reflects differences in population characteristics, adherence rates, and maintenance strategies.

In middle-income countries like Mexico, interventions often focused on specific populations with heightened vulnerabilities, such as frail older adults. Pérez et al., [23] highlighted the potential of integrated care models, which led to significant increases in PA and physical fitness. These interventions, though resource-constrained compared to those in high-income settings, demonstrated comparable effectiveness when tailored to the cultural and socioeconomic needs of the population. The outcomes in these studies emphasise the importance of context-sensitive approaches that address the unique barriers and facilitators faced by middle-income populations.

Low-income countries, primarily represented in this review by studies from China, leveraged culturally embedded and community-driven strategies. Interventions such as tai chi, baduanjin, and group-based exercises were particularly prominent. Gu et al., [24] reported improved adherence and fitness levels in a worksite intervention, while Zhang [42] demonstrated significant fitness improvements through tai chi among students. These low-cost, culturally relevant interventions achieved outcomes comparable to those observed in high-income settings, showcasing the adaptability and scalability of such approaches in resource-limited contexts.

Discussion

This systematic review evaluates the long-term effectiveness of PA interventions across low, middle, and high income countries, focusing on identifying effective intervention components. By considering studies with a minimum follow-up period of 12 months, the review provides a comprehensive understanding of how structured and tailored strategies can sustain PA behaviours and contribute to addressing obesity-related challenges. These findings align with contemporary evidence supporting scalable and sustainable PA programmes [31, 57].

Interventions in HICs, such as the USA, Finland, and Sweden, frequently involved resource-intensive, multicomponent approaches, including physician-led counselling, exercise prescriptions, and fitness testing. Studies such as Pahor et al., [38] and Petrella et al., [30] demonstrated significant increases in energy expenditure and physical fitness, reflecting the efficacy of these strategies. These findings are corroborated by Brown et al., [58], who highlighted the importance of tailored counselling and goal setting in enhancing PA adherence. However, variability in outcomes, as observed in Yancey et al., [37], highlights the need for interventions that account for diverse population characteristics and adherence levels.

Middle-income countries, exemplified by Mexico, showcased culturally and contextually adapted strategies. For instance, Pérez et al., [23] highlighted the effectiveness of integrated care models in increasing PA engagement among frail older adults. These findings align with García-Hermoso et al., [59], who demonstrated that culturally embedded interventions improve adherence despite limited resources. The adaptability of such models in addressing obesity-related risk factors reinforces their scalability and relevance in middle-income settings.

Low and middle income countries primarily represented by studies from China, highlighted the success of culturally embedded and community-driven interventions. Practices such as tai chi and baduanjin were associated with improved PA adherence and physical fitness, as reported by Gu et al., [24] and Yu [25]. These findings resonate with evidence from Zhang et al., [42], which emphasise the role of culturally rooted practices in sustaining PA behaviours in resource-constrained environments. Interventions in LMICs demonstrated effectiveness in reducing body mass index (BMI) and improving fitness outcomes, echoing findings by Raza et al., [60] on the potential of tailored approaches to mitigate obesity-related health disparities.

While interventions across economies were generally effective in reducing obesity-related risk factors, disparities in follow-up durations and reporting standards influenced the comparability of outcomes. HIC studies often featured longer follow-up periods and robust evaluation frameworks, enabling more comprehensive assessments of long-term effectiveness. Conversely, shorter follow-up durations in LMIC studies, such as Yu [25], limited the ability to assess sustainability, a concern echoed by Liu et al., [61]. Such variability underscores the importance of consistent monitoring and reporting practices to strengthen the evidence base for PA interventions.

Sustaining the long-term effects of PA interventions remains a challenge. Studies such as Pahor et al., [38] and Marcus et al., [33, 62] reported moderate declines in PA behaviours over time, though intervention effects remained stable overall. This finding aligns with Kim et al., [63], who emphasised the need for booster sessions and robust maintenance strategies to support sustained behaviour change. Interventions with limited maintenance, such as Yu [25] and Napolitano et al., [46], showed diminished long-term effects, highlighting the critical role of continued support in maintaining PA behaviours [31]. Emerging evidence supports the integration of digital health tools and community-based support systems as promising strategies to enhance engagement and sustain PA outcomes over extended periods [64, 65].

This review also highlights the importance of aligning interventions with cultural and socioeconomic contexts to enhance effectiveness and scalability. While HICs benefited from advanced resources, LMICs demonstrated the adaptability of culturally embedded approaches in achieving comparable outcomes despite resource constraints. These findings align with the World Health Organisation's [4] recommendations for implementing culturally appropriate PA programmes to address global obesity challenges.

Strengths and weaknesses

A significant strength of this systematic review lies in its comprehensive inclusion of studies from diverse economic contexts, encompassing high, middle, and low income countries. This approach provides valuable insights into the adaptability and scalability of PA interventions across varying resource settings. The review's consideration of culturally tailored and context-sensitive interventions further highlights the importance of addressing the unique needs of different populations, particularly in low-resource settings. In addition, the focus on long-term effectiveness and sustainability of intervention outcomes adds to the growing evidence base on strategies for combating obesity. However, the representation of studies from LMICs was limited, with only six eligible studies from these regions. This imbalance underscores the need for increased research efforts in LMICs to address global health disparities. Methodological inconsistencies, such as baseline differences, high attrition rates, and variable reporting standards, presented challenges in comparing findings across studies. The reliance on self-reported PA outcomes in many studies also raises concerns about potential biases. Finally, shorter follow-up periods in some LMIC studies hinder the ability to assess the long-term sustainability of intervention effects, highlighting the need for extended evaluations.

Conclusions

This review emphasises the efficacy of tailored PA interventions in promoting sustained PA behaviours across diverse settings. High-income countries demonstrated the benefits of resource-intensive, multicomponent interventions, while LMICs showcased the potential of culturally embedded, cost-effective strategies. These findings affirm the importance of aligning intervention designs with cultural, socioeconomic, and resource-specific contexts to enhance adherence and effectiveness.

Future research should prioritise underrepresented populations, particularly in LMICs, to address global health inequities. Longer follow-up periods are crucial for evaluating the sustainability of intervention effects and identifying factors that influence long-term adherence. Incorporating robust maintenance strategies, such as booster sessions, digital health tools, and community-based support, could improve outcomes. Standardising evaluation frameworks and reporting practices would enhance comparability across studies and strengthen the evidence base.

The integration of technology, such as mobile apps and wearable devices, offers promising avenues for scaling interventions and tailoring strategies to individual needs. Collaborative, cross-sectoral approaches that involve healthcare systems, community organisations, and policymakers are essential for designing holistic PA programmes. By addressing these gaps, future efforts can contribute to more effective, equitable, and sustainable solutions for reducing obesity globally.

Abbreviations

AHA	American Heart Association
ACSM	American college of sports medicine
BGD	Between-group difference
BL	Baseline
C	Control group
CASP	Critical Appraisal Skills Programme
CI	Confidence Interval
Co	Comparison (used in group comparisons)
COM-B	Capability, Opportunity, and Motivation model for Behaviour change
EE	Energy Expenditure
EPI	Epidemiology
FHEQ	Framework for higher education qualifications
FU	Follow-up
GPAQ	Global Physical Activity Questionnaire
HR	Heart rate
I	Intervention group
I1	Intervention group 1 (used when comparing multiple intervention groups)
I2	Intervention group 2 (used when comparing multiple intervention groups)
IMPACT	Increasing motivation for physical activity project
LIFE	Lifestyle interventions and independence for elders study
LTPA-EE	Leisure-time physical activity energy expenditure
MET	Metabolic equivalent of task
MVPA	Moderate to vigorous physical activity
NS	Not significant
NHS	National health service
PA	Physical activity
RCT	Randomised controlled trial
SD	Standard deviation
SE	Standard error
SIGN	Scottish intercollegiate guidelines network
STEP	Standardised testing and evaluation programme
TEE	Total energy expenditure
VO2max	Maximal oxygen uptake (measure of cardiovascular fitness)

Supplementary Information

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Supplementary Material 1.

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Declarations

Ethics approval and consent to participate
Being a scoping review, this research was exempt from human subjects IRB review.

Consent for publication
Not applicable.

Competing interests
The authors declare no conflicts of interest.

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