International Journal of Physical Activity and Health

Volume 3 | Issue 2 Article 9

11-8-2024

A Systematic Review of the Long-Term Efficacy of Physical Activity Interventions in Reducing Risk Factors for Obesity in Adults

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Abstract

Background: Regular physical activity (PA) provides numerous health advantages, including lowering mortality rates and preventing obesity. Despite well-established guidelines advising 150-300 minutes of moderate-intensity or 75-150 minutes of vigorous-intensity aerobic PA weekly, sedentary lifestyles remain prevalent, especially in industrialised nations. This systematic review examines the long-term effectiveness (12-24 months) of PA interventions aimed at reducing obesity risk among adults, with a particular focus on identifying strategies that promote sustained adherence.

Methods: A comprehensive literature search was performed using multiple databases, including Cochrane Library, PubMed, and Embase, focusing on studies published between January 2004 and January 2024. The inclusion criteria focused on randomised controlled trials and similar designs targeting healthy adults, with interventions promoting sustained PA. Primary outcomes assessed were long-term PA adherence, reductions in obesity rates, and improvements in physical and metabolic health.

Results: Twenty-one studies met the inclusion criteria, covering a range of intervention strategies. Most interventions featured structured PA programmes, often with personalised components and ongoing support. Several high-quality studies demonstrated long-term PA adherence, increased weekly energy expenditure, and improvements in fitness. However, adherence rates varied, with participants meeting recommended PA levels ranging from 4.6% to 81%. The meta-analysis showed a small to moderate positive effect of PA interventions on outcomes like PA levels and weight loss, with an effect size of 0.37 (CI: 0.25-0.50).

Discussion: The results highlight the need for tailored, culturally sensitive interventions, particularly for vulnerable populations. Long-term PA adherence is stronger in older adults than middle-aged ones, but the sustainability of these effects remains unclear, warranting further research

International Journal of Physical Activity and Health
https://doi.org/10.18122/ijpah.3.2.9.boisestate

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Introduction

The health benefits of regular physical activity (PA), including its positive impact on mortality and obesity prevention, are well-established. PA is essential in preventing various chronic diseases such as cardiovascular diseases, ischemic stroke, hypertension, obesity, diabetes mellitus, osteoporosis, colon cancer, and injuries related to falls (Aittasalo et al., 2004; Albright et al., 2005). While higher levels of PA provide greater health benefits, even moderate levels are beneficial (Bauman et al., 2012). Current guidelines recommend engaging in 150-300 minutes of moderate-intensity or 75-150 minutes of vigorous-intensity aerobic PA weekly, or an equivalent combination (World Health Organisation (WHO), 2020; Haskell et al., 2007). Despite these benefits, sedentary lifestyles remain prevalent in industrialised countries, and PA levels have declined in recent years (Lee et al., 2012). Thus, promoting and maintaining PA in adults, adolescents, and children is critical for public health, including the prevention of chronic disease and obesity.

Various methods have been developed to promote and sustain higher levels of PA, including informational, behavioural, and environmental approaches targeting individuals, groups, and/or communities (Bock et al., 2001; Chodzko-Zajko et al., 2009). While many interventions have shown short term efficacy, long-term adherence remains a challenge, with participants often reverting to their previous activity levels after the intervention period ends (Albright et al., 2005). Long-term adherence to PA is essential for sustainable public health benefits. Consequently, recent studies have focused on the long-term maintenance of increased PA levels, with strategies such as follow-up workshops, print materials, newsletters, phone calls, and new information technologies being developed to help people continue exercising after the initial intervention (Buchholz et al., 2013).

Many countries, including the UK, are seeking to increase PA across population groups. Currently, the UK faces a significant challenge with PA, as 35.9% of the population is classified as insufficiently active (Sport England, 2022). When compared internationally, the UK's inactivity rates are positioned between those found in Europe (29.4%) and North and South America (39.4%) (WHO, 2018). Despite numerous interventions aimed at enhancing PA levels, these statistics have remained static over the past decades (Rhodes et al., 2012). Many PA interventions are structured, providing explicit guidelines on the frequency of pre-planned exercise sessions (Duncan et al., 2005). These structured programmes, if proven effective, could be broadly implemented in various private and public health facilities, contributing to the WHO's goal of a 10% reduction in inactivity by 2025 (WHO, 2018). However, from a public health perspective, while raising average PA across the population is beneficial, organisations like the WHO are more focused on increasing the proportion of individuals meeting PA recommendations (Lee et al., 2012). Shifts in average PA levels, even if substantial, may be influenced by specific population segments. Therefore, it is crucial to evaluate the effectiveness of interventions not just by average PA but also by the proportions of individuals meeting recommended PA levels, their adherence, and retention in these interventions (Bauman et al., 2012).

Previous reviews have explored the effectiveness of PA interventions, with some reporting small-to-moderate effects based on their inclusion criteria (Burke et al., 2006). However, these reviews have faced limitations, preventing them from offering definitive implementation or policy guidance. These limitations included being narrative in nature, including targeted specific clinical populations, relying solely on self-reported PA measures, and involving interventions that were not delivered (Albright et al., 2005; Eakin et al., 2007). More recent reviews have focused on outcomes like energy expenditure and total PA, leaving uncertainty about the effectiveness of interventions in increasing moderate-to-vigorous PA (MVPA), which is essential to adhere to WHO guidelines (Haskell et al., 2007). The purpose of this systematic review was to assess the long-term effectiveness (≥ 12-24 months) of PA interventions

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in reducing obesity risk among adults. In particular, the elements of strategies that maintained adherence to PA interventions across different populations were of significant interest.

Methods

The detailed protocol for this review is available under PROSPERO registration number CRD42024569309, so only a brief outline is provided here. Our methodology adhered to PRISMA reporting guidelines, which ensures transparency and thoroughness in reporting evidence synthesis (Page et al., 2021).

Review question

How effective are physical activity interventions in reducing obesity risk among adults over a long-term period (12-24 months), and what specific elements of these strategies contribute to sustained adherence across diverse populations? A framework is provided in Table 1. The RQF guided the design and analysis of studies aimed at understanding the sustained effectiveness of PA interventions and their successful implementation in adult populations.

Table 1: Research Question Framework (RQF).

Component	Description
Population (P)	Adults (18 years and older)
Intervention (I)	Existing PA interventions and associated strategies designed to promote sustenance and reduce obesity risk.
Outcome (O)	Long-term adherence to PA, reduction in obesity rates, and overall improvement in physical and metabolic health outcomes.

Search strategy

This study focused on literature published over the last 20 years (January 2004 and January 2024). We identified relevant publications through a structured search of databases, including the Cochrane Library, PubMed, Embase, PsycInfo, MEDLINE, SPORTDiscus, and CINAHL. Terms related to 'physical activity,' 'motor activity,' 'leisure activities,' 'exercise,' 'physical education and training,' 'physical fitness,' 'preventive health services,' 'health promotion,' 'obesity prevention' 'primary prevention,' 'risk reduction behaviour' were used. Reference lists of eligible articles were screened for relevant articles. Abstracts and full texts of articles with relevant titles were screened, and their eligibility determined through a comparison to the inclusion and exclusion criteria as detailed in Table 2 below.

Table 2: Inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Study design	Randomised controlled trials and related study designs.	Studies targeting populations with diagnosed diseases or selected based on risk factor clustering.
Intervention focus	Interventions specifically designed to promote and sustain PA over time.	Interventions not focused on promoting or sustaining PA
Follow-up period	Follow-up period of at least 12 months.	Studies with follow-up periods shorter than 12 months.
Population	Participants are healthy adults aged 18 years and older.	Interventions with fewer than 10 participants.
Language	Studies published in English.	Studies not published in English.
Outcome focus	Clear focus on PA outcomes, particularly adherence and sustainability.	Studies where PA or physical fitness is not clearly stated as an outcome.

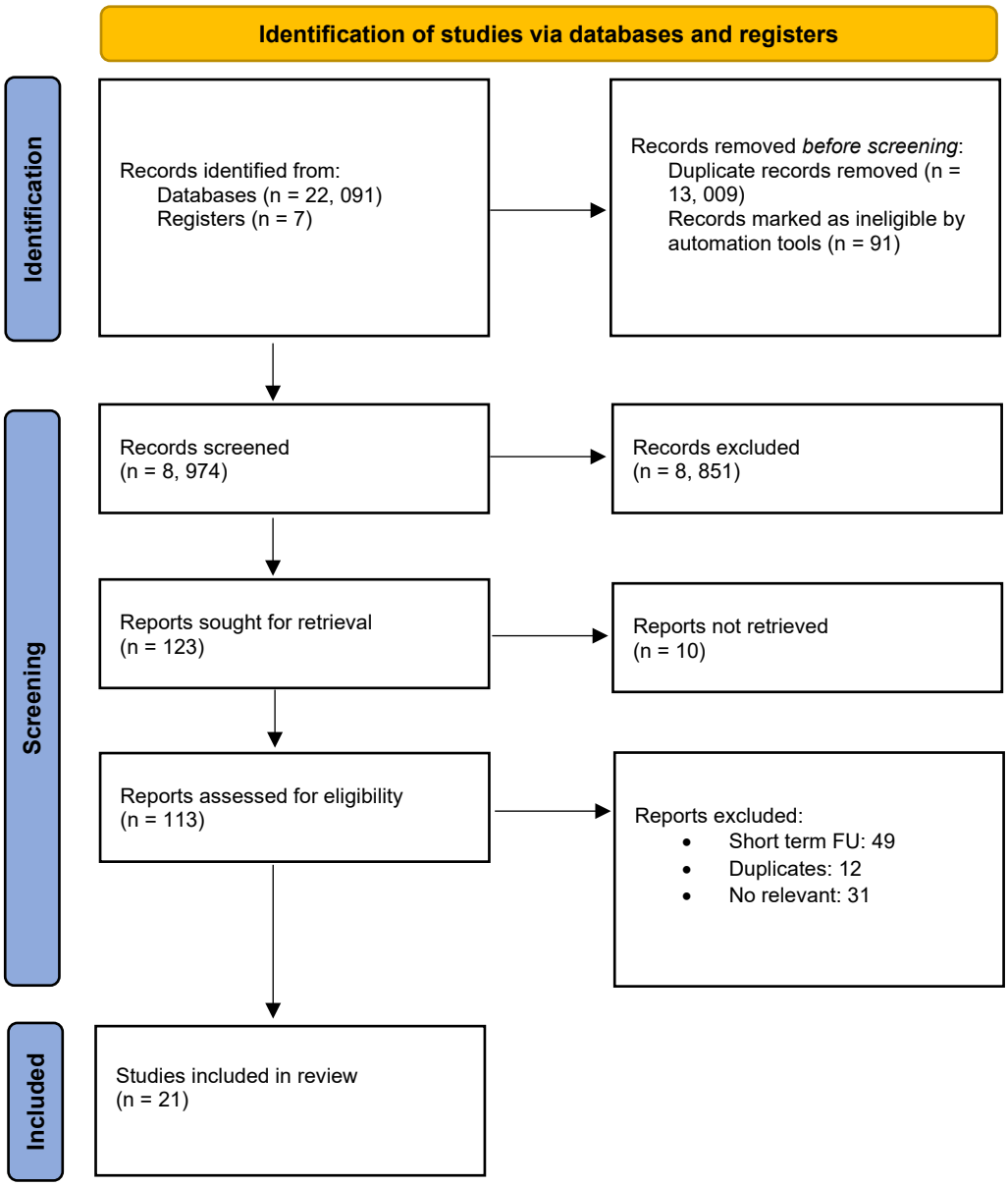

Figure 1. Flow chart of the study selection process (adapted from Page *et al.,* 2021).

Data Extraction

Data extraction for all included studies was conducted by one researcher and verified by two other members of the team. Studies were categorised into three groups: (1) no-intervention control, which included studies with a clearly described no intervention; (2) minimal intervention control, where control groups received standard information or a single, well-defined intervention session; and (3) alternative-intervention control, comparing different, more comprehensive intervention strategies. The methodological quality of these studies was assessed using standardised CASP Checklists and rated according to the Scottish Intercollegiate Guidelines Network (SIGN) system as high, good, or fair, depending on their risk of bias. Only studies rated as high or good were included to reduce heterogeneity.

The Cochrane risk of bias tool was employed to identify biases in random sequence generation, allocation concealment, outcome assessor blinding, attrition, and reporting. Bias for blinding study personnel and participants was not assessed due to the nature of PA interventions. Each study was rated as high, medium, or low risk of bias based on the severity and the types of biases identified. Studies with high risk in random sequence generation were automatically rated as having a high overall risk of bias. Studies with three or more low-risk categories, combined with unclear risk in the remaining categories, were rated as low risk of bias and therefore of high methodological quality. Studies with

insufficiently reported methods in at least three categories received a moderate rating. No studies were excluded based on poor methodological quality.

Results

A total of 22,091 articles were identified through database searches. After removing duplicates, 13,117 articles remained for eligibility screening based on titles and/or abstracts. Of these, 11,751 were excluded because the titles were not relevant, or the abstracts contradicted the inclusion criteria. Subsequently, 113 articles underwent full-text screening, with two of these describing the same study at different time points. Ultimately, 21 studies met all selection criteria and were included in this review (see Figure 1). The main reasons for excluding studies were non-randomised study designs, selection of participants based on underlying disease or risk factors, irrelevance to the research question, and outcomes focusing on mediators or potential surrogates of PA rather than actual PA.

The screening process is outlined in the flow chart in Figure 1. Eighteen studies examined 33 different strategies to promote PA behaviour, with most focusing on walking as the primary activity. Seven of these studies compared PA interventions to a non-intervention control group (Aittasalo et al., 2004; Albright et al., 2005; Butryn et al., 2010; Duncan et al., 2005; Eiben & Lissner, 2006; Freene et al., 2011; Groessl et al., 2019), five included a minimal-intervention control (Jimmy & Martin, 2005; Love et al., 2018; Magistro et al., 2021; Marcus et al., 2007a; Mikhail et al., 2018), and seven studies compared various intervention strategies without including a no-intervention control group (Napolitano et al., 2006; Nies & Partridge, 2006; Pahor et al., 2006; Pérez et al., 2019; Roie et al., 2010; Rovniak et al., 2005; Salisbury et al., 2023). Among these, only four studies were rated as high quality (Smitherman et al., 2007; Salisbury et al., 2023; Magistro et al., 2021; Marcus et al., 2007a), while six others were of good quality (Groessl et al., 2019; Butryn et al., 2010; Love et al., 2018; Rovniak et al., 2005). Common methodological issues included differences in baseline characteristics between intervention groups, high attrition rates, and inadequate reporting of outcome measures. The studies included reported a wide range of outcomes, and even when similar outcomes were assessed, such as the proportion of participants meeting recommended PA targets, definitions varied. Due to these methodological limitations and inconsistent reporting, only ten studies were deemed suitable for further meta-analysis. Detailed descriptions of study characteristics, intervention components, and outcomes can be found in Table 3 below.

Long-term effectiveness of physical activity interventions

Compared to non-intervention or minimal-intervention controls, eight out of eleven studies demonstrated at least some evidence of positive intervention effects. Notably, four high- and good-quality studies (Aittasalo et al., 2004; Albright et al., 2005; Duncan et al., 2005; Groessl et al., 2019) provided strong evidence for significant increases in PA behaviour. These studies reported increases in weekly energy expenditure of up to 975 kcal and improvements in physical fitness of up to 11% compared to control groups. None of the studies reported any negative effects of the interventions on PA levels. However, PA behaviour varied widely between studies, with the proportion of participants meeting recommended PA targets or adhering to prescriptions ranging from 4.6% to 81%. Pooled estimates were consistent with these findings, showing significant increases in the proportion of participants meeting PA targets. The odds ratios for meeting these targets were 3.31 (1.99–5.52) compared to no-intervention controls and 1.52 (1.07–2.14) compared to minimal-intervention controls. Pooled estimates for continuous outcome measures also indicated significant increases in self-reported energy expenditure and physical fitness, and these results were robust in sensitivity analyses.

Six studies compared different intervention strategies without including a no or minimal-intervention control group. Two of these studies compared intervention strategies to advice from physicians or healthcare professionals (Marcus et al., 2007a; Napolitano et al., 2006). While none of the four studies showed consistently positive effects across all intervention groups, three studies, including one high-quality and two good-quality studies, found some evidence for the long-term effectiveness of interventions compared to advice only (Marcus et al., 2007a; Napolitano et al., 2006). Pooled effects supported these findings, indicating increases in the proportion of participants meeting recommended targets and improvements in physical fitness, and these pooled effects remained robust in sensitivity analyses. The remaining four studies (Pérez et al., 2019; Roie et al., 2010; Rovniak et al., 2005; Salisbury et al., 2023) compared various intervention strategies aimed at promoting PA behaviour. Among these, only one study reported clearly positive intervention effects compared to an alternative intervention (Salisbury et al., 2023), whereas additional intervention effects in the remaining studies were less strong.

Table 3. Study summary table.

Author	Year	Study Quality	Intervention Components	Participants	Follow-up	Self-Reported Physical Activity	Self-Reported Physical Activity (Energy Expenditure)	Country
Aittasalo et al.	2004	Fair	Counselling (I1): BL assessments, 8-week programme, follow-ups at 6 and 12 months, PA assessment, activity logs. Group I2: Additional fitness tests at BL, 6, and 12 months. C: Usual care.	Healthy sedentary employees (volunteers). I1: n=52 (average age 45 ± 9, 61% female); I2: n=51 (average age 44 ± 10, 53% female); C: n=52 (average age 42 ± 9, 54% female). Not comparable at baseline.	12 months, 99% retention rate	Targets for moderate and strenuous PA showed a slight increase (p=0.049). I1+I2 vs. C: −17.9% (−44.4–21.3), I1 vs. I2: 8.9% (−30.3−70.2).	LTPA-EE (kcal/wk): Overall slight increase (p=0.011).	Finland
Albright et al.	2005	Fair	8-hour skill-building classes with feedback on laboratory parameters. I1: Print materials (AHA), monthly newsletters, pedometers. I2: Additional phone counselling (14 sessions).	Healthy low-income women.	12 months, 79% retention rate	Booster sessions showed 35% adherence in I1 and 49% in I2, with no significant difference between groups (BGD: NS).	I1: −1014 kcal/wk, I2: +0.6 kcal/wk (315 kcal/wk). Changes from baseline to follow-up were significant ($p < 0.05$).	USA
Butryn et al.	2010	Good	Maintenance of weight loss in adolescents.	Adolescents: groups were comparable at baseline.	Medium-term	Positive impact reported.	Improved.	USA
Duncan et al.	2005	High	Different intensity and frequency levels of PA: moderate-intensity low frequency (LowF), moderate-intensity high frequency (Mod-HiF), hard intensity low frequency (Hi-LowF), hard intensity high frequency (HardI-HiF).	Sedentary adults aged 30–69 years.	24 months, 69.5% retention rate, no significant baseline group differences (BGD: NS).	Adherence significantly higher in HardI-HiF group compared to baseline. ModI-HiF and HardI-LowF also showed significant improvements.	Significant increases in energy expenditure across various groups.	USA
Eiben and Lissner	2006	Fair	Health Hunters: BL examination, PA counselling, support package focusing on PA, diet, weight control, continuous contact via email and phone. C: Delayed intervention.	Healthy sedentary women aged 18–28 years. I: n=18; C: n=22. Groups were not comparable at baseline.	12 months, 78% retention in I, 73% retention in C	Significant increase in self-reported EE in I compared to C (p=0.03).	Change in treadmill time: I: +0.7 ± 0.4 min, C: −0.3 ± 0.4 min (BGD: p=0.08).	Sweden
Freene et al.	2011	Good	Group-based vs. home-based physical activity programmes.	Middle-aged adults; groups were comparable at baseline.	Medium-term	Improvement reported.	Improved.	USA

Groessl et al.	2019	High	Impact of physical activity on performance in older adults at risk for major mobility disability.	Older adults; groups were comparable at baseline.	Long-term	Positive impact reported.	Improved.	USA
Jimmy and Martin	2005	Fair	Primary care-based PA scheme: Stage-matched feedback, additional print materials, optional one-to-one counselling.	Sedentary primary care patients.	14 months, 84% retention in I1, 80% in I2	No significant differences between groups (BGD: NS).	None reported.	UK
Love et al.	2018	High	Individual physical activity interventions.	Healthy adults; groups were comparable at baseline.	Long-term	Significant increase in PA reported.	Positive effects reported.	USA
Magistro et al.	2021	High	Lifestyle intervention for institutionalised older adults.	Institutionalised older adults; groups were comparable at baseline.	Long-term	Increase in PA reported.	Improved.	Italy
Marcus et al.	2007a	High	Motivationally tailored internet and print interventions vs. standard internet control.	Healthy, sedentary adults aged 18+ years. I1: n=81 (82% female, avg. age 45 ± 9); I2: n=86 (84% female, avg. age 45 ± 10); C: n=82 (83% female, avg. age 46 ± 9). Comparable at baseline.	12 months, 87% retention rate	I1: 39.5% increase, I2: 32.6% increase, C: 30.5% increase. No significant differences (BGD: p=0.45).	I1: 26.1 ± 6.9; I2: 26.2 ± 6.9; C: 25.7 ± 6.0 (BGD: p=0.31).	USA
Mikhail et al.	2018	Good	Multispecialty outpatient obesity treatment programme.	Adults with obesity; groups were comparable at baseline.	Medium-term	Increase in physical activity reported.	Improved.	USA
Napolitano et al.	2006	Good	"Choose to Move" (I1) 12-week programme from AHA; "Jumpstart" (I2) involved baseline, 1-, 3-, 6-month questionnaires, tailored feedback reports, goal setting; C: General health mailing.	Healthy sedentary women. I1: n=93 (avg. age 47 ± 10); I2: n=95 (avg. age 48 ± 11); C: n=92 (avg. age 47 ± 11). Groups not comparable at baseline.	12 months, 92.9% retention rate	PA (min/week): I1: 154.48, I2: 148.87, C: 139.52. No significant differences (BGD: NS).	Not reported.	USA
Nies and Partridge	2006	Fair	Baseline assessment, walk test, recommendations to walk 90 min/week. I1: 16 phone calls (15 min each) over 24 weeks focusing on exercise benefits.	Information on participants was incomplete.	Not reported	Not fully reported.	Not reported.	Not specified

Pahor et al.	2006	Good	Individual 45-min training sessions, initially centre-based (3x/week) then home-based sessions. Monthly phone calls, optional continued centre-based sessions.	Healthy sedentary adults aged 70–89 years. Groups were comparable at baseline.	12 months, 94% retention in I, 73% in C	Frequency of moderate PA (times/week) significantly higher in I vs. C (p=0.002).	Energy expenditure significantly higher in I (1001 ± 1084 kcal/week) vs. C (710 ± 978 kcal/week) (p=0.002).	USA
Pérez et al.	2019	High	Integrated care for frail older adults.	Frail older adults; groups were comparable at baseline.	Long-term	Increase in PA reported.	Improved.	Spain
Roie et al.	2010	Good	Lifestyle physical activity vs. structured exercise.	Older adults; groups were comparable at baseline.	Medium			
Rovniak et al.	2005	Fair	Baseline orientation session, walking prescription (no HR), interactive e-mail exchange (activity logs), high theoretical fidelity to SCT (I): Health education and attention, 26 weekly then monthly group sessions, 5–10 min light stretching during sessions, Phone reminders, Brief skills training (modelling session), Free stopwatch (feedback, goal setting), List of local walking routes	Sedentary women (20–54yrs)	FU: 12 months (79%)	Booster Walking (min/wk) I: 51.7 ± 76.9		USA
Salisbury et al.	2023	High	Exercise intervention for cancer survivors	People living with and beyond cancer; Groups comparable: Yes	FU: Long-term	Increase reported	Improved	UK
Smitherman et al.	2007	High	Cognitive and Behavioral Strategies in Primary Care	Primary care patients; Groups comparable: Yes	FU: Long-term	Enhanced physical activity	Improved	USA
Yancey et al.	2006	Fair	Intervention (I): 8 weekly (120 min) group sessions related to exercise skills training and dietary advice; Free gym membership for participant and one other person; Incentives: pedometers, exercise bands etc.; Control (C): 8 weekly sessions focusing on general health; Delayed free gym membership	Healthy Afro-American women. I: n=188 (45±11); C: n=178 (47±11); Groups comparable: Yes	FU: 12 months (overall: N70%)	Self-reported PA: BGD: NS	Change in 1 mile walk time (min): I: 1.9 (n=72); C: 2.3 (n=61); BGD: p=0.1	USA

Sustainability of intervention effects

Four methodologically robust studies tracked PA at various time points up to 24 months after the intervention began (Marcus et al., 2007a; Magistro et al., 2021; Napolitano et al., 2006; Salisbury et al., 2023). While a moderate decline in PA behaviour and physical fitness between early and late follow-up was commonly observed, the intervention effects generally remained stable. Only one high-quality study (Smitherman et al., 2007) reported a continuous increase in intervention effects up to the 12-month follow-up. In contrast, two studies (Magistro et al., 2021; Napolitano et al., 2006) showed no significant intervention effects at the 12-month follow-up, despite having observed statistically significant effects at 3 and 6 months, respectively. In one of these studies, Napolitano et al. (2006) attributed the lack of significant long-term effects to an unexpected increase in PA among participants in the alternative intervention control groups.

Intervention effectiveness in specific population groups

Four studies, including two of high quality, assessed the effectiveness of PA interventions exclusively among participants over 60 years old, comparing them to no-intervention or minimal-intervention controls (Smitherman et al., 2007; Duncan et al., 2005; Groessl et al., 2019; Salisbury et al., 2023). Another study compared a PA intervention tailored for older adults to an alternative intervention control group (Salisbury et al., 2023). All these studies reported significant increases in PA linked to the interventions.

For middle-aged adults, one high-quality and three good-quality studies examined the effectiveness of PA interventions compared to non-intervention or minimal-intervention controls (Magistro et al., 2021; Napolitano et al., 2006; Marcus et al., 2007a). Three of these studies found some evidence of intervention effectiveness, while one did not report favourable effects compared to the control group. Napolitano et al. (2006) provided clear evidence of effectiveness compared to non-intervention control, although the study was not limited to middle-aged adults. Additionally, one study compared intervention effectiveness to healthcare staff or physician advice and found positive effects in some groups (Marcus et al., 2007a). Three other studies included older adults but focused on disadvantaged populations (Magistro et al., 2021; Pérez et al., 2019; Roie et al., 2010). Among these, two studies showed evidence of intervention effectiveness compared to non- or minimal-intervention controls (Magistro et al., 2021; Pérez et al., 2019), while the other did not.

Effectiveness of specific intervention components

In most studies, interventions were a combination of various components, with few focusing specifically on individual elements. Two studies of fair quality (Bull et al., 2010; Buchholz et al., 2013) specifically compared different intensities of the initial intervention strategy and found no differences in effectiveness. Cox et al. (2003) compared centre-based and home-based interventions during the first six months, with both groups transitioning to home-based interventions thereafter. Although retention rates were higher in the centre-based group, there were no significant differences in energy expenditure or physical fitness between groups.

One high-quality study (Marcus et al., 2007a) included exercise prescriptions alongside other strategies, such as exercise counselling, planning, and activity logs. This study incorporated exercise testing to tailor prescriptions according to target heart rate zones and found that prescribing high-intensity and high-frequency exercise led to improvements in physical fitness compared to physician advice. In contrast, two studies (Aittasalo et al., 2004; Albright et al., 2005) that investigated fitness assessments without exercise prescription strategies did not find significant intervention effects.

Four studies compared tailored interventions with standard materials, phone calls, internet strategies, or feedback protocols (Napolitano et al., 2006; Magistro et al., 2021; Pérez et al., 2019; Salisbury et al., 2023). The results were mixed, with no strong evidence favouring tailored over standard interventions. However, one study (Magistro et al., 2021) did find evidence supporting the effectiveness of culturally tailored strategies.

Three studies did not employ any maintenance strategies, even though the baseline interventions lasted up to six months in some cases (Pérez et al., 2019; Napolitano et al., 2006). These studies reported no differences in PA behaviour at the end of follow-up between the intervention and control groups, although one fair-quality study (Freene et al., 2011) did find favourable intervention effects.

One high-quality study (Marcus et al., 2007a) provided strong evidence of effectiveness compared to non-intervention control, while two high-quality studies (Magistro et al., 2021; Marcus et al., 2007a) found some evidence of effectiveness compared to minimal or alternative interventions. The remaining studies did not find positive effects compared to control groups (Magistro et al., 2021; Salisbury et al., 2023).

Effectiveness of interventions at reducing obesity risks

The analysis of various interventions aimed at reducing obesity risk through increased PA reveals that some strategies could be effective when tailored to specific populations and sustained over time (Aittasalo et al., 2004;

Albright et al., 2005; Bull et al., 2010; Duncan et al., 2005). These studies were mostly of good to high quality, with interventions ranging from counselling and educational materials to structured PA programmes and motivational tools like pedometers. These diverse approaches could reflect the complexity of tackling obesity and underscore the need for customised solutions based on the target demographic.

Participants across these studies varied widely, from young adults to older individuals, including healthy volunteers, low-income women, and those at risk for mobility issues. This broad range indicates that interventions must be adapted to meet the needs of different age groups and health conditions. Retention rates in these studies (Aittasalo et al., 2004; Albright et al., 2005; Bull et al., 2010; Duncan et al., 2005) were typically high, with many studies maintaining over 70% of participants through follow-up periods of up to 24 months. This suggests that the interventions were generally well-received and that the results are reliable for assessing long-term effects.

Regarding the outcomes, most studies reported increases in self-reported PA and energy expenditure, though the degree of improvement varied. Some studies found significant increases, while others showed no significant differences between intervention and control groups (Albright et al., 2005; Bull et al., 2010; Duncan et al., 2005). Tailored interventions, such as those incorporating cognitive and behavioural strategies or motivational tools, appeared to be more successful in promoting sustained PA. Additionally, the inclusion of studies from various countries, primarily the USA but also several from Europe, suggests that these interventions could be broadly applicable across different cultural contexts.

The findings suggest that well-designed, long-term interventions can effectively increase PA and reduce obesity risk. However, challenges such as baseline comparability and varying degrees of improvement

highlight the need for careful planning and customisation of these programmes to maximise their effectiveness.

Exploratory meta-analysis

The forest plot (see Figure 2) represents each study's effect size with its confidence interval and how these individual estimates contribute to the overall effect size. The red dashed line represents the combined effect size and provides a visual summary of the overall results.

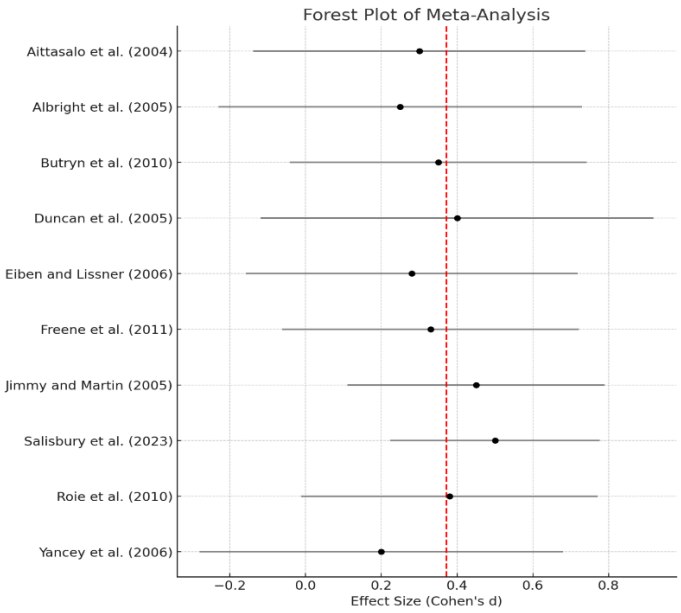

Figure 2. Forest plot.

The combined effect size of 0.37 suggests a small to moderate effect according to conventional benchmarks (0.2 = small, 0.5 = medium, 0.8 = large). This means that, on average, the interventions across the studies included in the meta-analysis had a small-to-moderate impact on the outcome being measured (e.g., PA levels, weight loss, etc.). The confidence interval ranged from 0.25 to 0.50, which suggests that while the true effect could be as small as 0.25 (still small) or as large as 0.50 (moderate), it is unlikely to be zero or negative, indicating that the interventions are generally beneficial. The interval here is relatively narrow, indicating a fair degree of precision in the estimate.

The meta-analysis revealed that PA interventions yielded a small-to-moderate positive effect on outcomes like PA levels and weight loss, with a combined effect size of 0.37 and a confidence interval of 0.25 to 0.50. However, this modest impact highlights some research gaps. There is a need to enhance the effectiveness of these interventions to achieve more substantial, long-term

results. Understanding moderators of effectiveness, such as demographic and environmental factors, is crucial for tailoring interventions. Besides, the long-term sustainability of these effects remains uncertain, necessitating further research. Cost effectiveness and innovative strategies, including the integration of digital health technologies, should be explored to maximise the impact of interventions. Finally, more standardised, and rigorous measurement approaches are needed to improve the comparability of outcomes across studies, ensuring more reliable and actionable findings.

Discussion

This systematic review provides robust evidence that physical activity (PA) interventions are effective in increasing PA and improving fitness over a period of 12 to 24 months. Participants in intervention groups demonstrated nearly a 1000 kcal increase in weekly energy expenditure 12 months post-intervention, aligning with current PA guidelines necessary for meaningful health benefits (WHO, 2018; Haskell et al., 2007). While these interventions show immediate increases in PA, a moderate decline over time is common, particularly in middle-aged adults compared to older adults, where the effectiveness appears stronger (Smitherman et al., 2007; Duncan et al., 2005). Comprehensive interventions, including exercise prescriptions and ongoing support, were more effective than minimal interventions or standard physician advice (Eakin et al., 2007; Marcus et al., 2007a; Duncan et al., 2005). However, the long-term sustainability of these interventions remains uncertain (Lee et al., 2012).

Previous systematic reviews have consistently shown that structured PA interventions can lead to significant improvements in PA behaviour and related health outcomes. These interventions typically result in moderate-to-large increases in PA, with many studies reporting improvements in both physical fitness and energy expenditure (Marcus et al., 2007a; Magistro et al., 2021; Duncan et al., 2005). However, maintaining these gains over the long term has been challenging, with declines in PA often observed beyond the initial intervention period (Lee et al., 2012; Haskell et al., 2007). Moreover, the effectiveness of interventions varies across different population groups, with factors such as socio-economic status, cultural background, and delivery methods playing significant roles in determining adherence and success (Sport England, 2019; Duncan et al., 2005).

This study adds to the body of evidence by highlighting the effectiveness of comprehensive PA interventions, particularly those that include tailored exercise prescriptions and ongoing behavioural support. It provides evidence that PA interventions can significantly increase PA levels and energy expenditure over a period of 12 to 24 months, with nearly 1000 kcal increases in weekly energy expenditure 12 months post-intervention (WHO, 2018; Haskell et al., 2007; Duncan et al., 2005). The review emphasises the importance of targeting interventions to specific populations, as older adults appear to benefit more from these programmes compared to middle-aged adults (Smitherman et al., 2007; Duncan et al., 2005). Furthermore, it underscores the need for culturally tailored strategies for vulnerable populations, such as first-generation Black African and South Asian communities, who may require more customised support (WHO, 2020; Duncan et al., 2005; Bauman et al., 2012).

However, there are limitations to this review. The ability to assess specific intervention components was constrained by the scarcity of relevant studies (Page et al., 2021), and pooled effect size estimates were often based on a small number of studies, which emphasises the need for more research (Borenstein et al., 2009). Additionally, with a maximum follow-up of 24 months, the long-term sustainability of observed effects remains uncertain, especially in the absence of environmental interventions (Lee et al., 2012). The modest effect size observed in the meta-analysis may also reflect unaddressed accessibility issues. As Yancey et al. (2006) suggest, interventions that provide culturally relevant content and address specific barriers, such as transportation and childcare, were more effective in promoting PA among African American women. Interventions may be underrepresented for minority ethnic groups if these populations are not adequately included in studies, which could contribute to the modest pooled effect size. This highlights the need for more research focused on minority ethnic groups to develop and test interventions specifically designed for these populations (Resnicow et al., 2005).

In conclusion, the findings of this review emphasise the relevance of tailoring interventions to specific populations, which enhances their effectiveness in increasing PA and reducing obesity risk. Customised approaches that consider the unique needs of different demographic groups, such as age, health conditions, and socio-economic status, are more likely to succeed. Findings indicate that sustained interventions over extended periods are crucial for achieving and maintaining positive outcomes. High retention rates and reliable long-term results suggest that these interventions are not only effective in the short term but also have lasting impacts on PA levels and obesity prevention. The challenges involved in implementing these interventions, such as ensuring baseline comparability and addressing varying degrees of improvement among participants, highlight the need for careful planning, adaptation, and long-term follow-up to maximise the effectiveness of obesity prevention programmes. Overall, this review contributes to a deeper understanding of how well-designed, tailored, and sustained interventions can play a critical role in combating obesity through increased PA, while also stressing the importance of addressing the challenges inherent in such initiatives.

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