Physiotherapist-led health promotion interventions in primary care can reduce metabolic risk factors for people with or at risk of metabolic syndrome: a systematic review.

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Systematic review

Physiotherapist-led health promotion interventions in primary care can reduce metabolic risk factors for people with or at risk of metabolic syndrome: a systematic review

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Abstract

Background Physiotherapists in primary care are well placed to provide health promotion interventions that target client metabolic risk factors.
Objective To determine the effectiveness of health promotion interventions delivered by physiotherapists in primary care on metabolic outcomes for people with or at risk of metabolic syndrome.
Data sources AMED, CINAHL, Cochrane, Medline, PEDro, PsycInfo, SPORTDiscus (searched up to February 2024).
Eligibility criteria Studies evaluating physiotherapist-delivered health promotion interventions for adults with at least one metabolic risk factor (abdominal obesity, hypertension, elevated triglycerides, reduced HDL-C or elevated glucose) delivered in primary care settings were included.
Study appraisal and synthesis Two reviewers extracted data, evaluated methodological quality using the Mixed Methods Appraisal Tool, and certainty of evidence using GRADE. Meta-analyses were conducted using a random effects model to calculate weighted mean differences (WMD) for outcomes on common scales, and standardised MD (SMD) for outcomes on different scales.
Results Twenty-five studies (n = 3619 participants) were included. Moderate-high certainty evidence indicated that physiotherapist-delivered health promotion interventions reduced waist circumference (WMD −2.42 cm, 95%CI −4.31 to −0.53), diastolic blood pressure (WMD −2.34 mmHg, 95%CI −3.77 to −0.91), triglycerides (WMD −0.18 mmol/L, 95%CI −0.36 to 0.00) and fasting blood glucose (WMD −0.18 mmol/L, 95%CI −0.28 to −0.08), and increased physical activity (SMD 0.18, 95%CI 0.04 to 0.32) compared to usual care.
Conclusion Physiotherapy-led health promotion interventions in primary care can improve metabolic risk factors and physical activity levels for people with or at risk of metabolic syndrome by small but clinically significant amounts.

Systematic Review Registration Number Systematic Review Registration Number PROSPERO CRD42022352725.

Contribution of the Paper

- This systematic review is the first to demonstrate that lifestyle interventions delivered by physiotherapists in primary care can improve metabolic risk factors for people with or at risk of metabolic syndrome.

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- Physiotherapy-led health promotion interventions likely improved waist circumference, diastolic blood pressure, triglycerides and blood sugar levels by a clinically significant amount.
- Physiotherapists working in primary care settings should have confidence in their ability to provide health promotion interventions to target metabolic risk factors that may contribute to chronic disease prevention.

Keywords: Physiotherapy; Health promotion; Metabolic syndrome; Primary health care; Systematic review

Introduction

In contemporary physiotherapy, there has been a shift towards a more holistic approach to practice with greater focus on health promotion and illness prevention as outlined in national and international physiotherapy practice standards [1,2]. The increasing attention to health promotion within physiotherapy practice stems from the global rise in noncommunicable diseases (NCDs), such as cardiovascular disease, cancer and diabetes. Noncommunicable diseases affect people of all ages, and are the leading cause of morbidity and mortality globally [3]. In 2021, 7 of the 10 leading causes of deaths worldwide were NCDs [4] and disability-adjusted life-years (DALYs) due to NCDs increased to 1.73 billion [5].

Although many factors contribute to NCDs (e.g. genetics, environmental factors, lifestyle and social determinants) [6] an important way to prevent them is to focus on the modifiable lifestyle factors such as an unhealthy diet, physical inactivity, tobacco smoking and harmful alcohol use. This is a priority outlined in the World Health Organization's Global Action Plan for the Prevention and Control of Noncommunicable Diseases [7]. Training of all healthcare professionals in the prevention and management of NCDs is recommended, with an emphasis on primary healthcare.

Primary healthcare encompasses a broad range of health services delivered outside of hospitals. It is frequently the initial point of contact for individuals seeking healthcare, thus primary care is pivotal in preventive health efforts. Physiotherapists working in primary care have a key opportunity to intervene early with health promotion interventions to aid in NCD prevention. This is particularly important in countries, such as Australia, England and Canada where physiotherapists in primary care work as primary contact practitioners.

To target health promotion interventions in physiotherapy practice to those who need them the most, understanding client's metabolic health is crucial. Metabolic syndrome is an early indicator of increased risk of developing many NCDs [8]. It occurs when an individual has three or more of the following metabolic risk factors: abdominal obesity, hypertension, elevated fasting glucose, lowered high-density lipoprotein cholesterol (HDL-C), and raised triglycerides [9]. It is highly prevalent in clients who present for physiotherapy services, likely due to its links with musculoskeletal conditions [10,11]: it is present in almost two-thirds of adults attending community rehabilitation physiotherapy [12] and more than one in three who attend physiotherapy in private practice [13]. Therefore, physiotherapists in primary care are well placed to intervene. Health promotion interventions involving lifestyle change that address physical inactivity and poor diet can reverse metabolic syndrome [14,15]. However, we do not know whether physiotherapist-led health promotion interventions targeting metabolic risk factors in primary care are effective.

Therefore, the primary aim of this systematic review was to determine whether health promotion interventions delivered by physiotherapists in primary care are effective for metabolic health outcomes for people with or at risk of metabolic syndrome.

Method

This systematic review was prospectively registered in the PROSPERO database (CRD42022352725) and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [16].

Identification and selection of studies

Search strategy

Electronic databases were searched from the earliest available date until February 2024 (Medline, CINAHL, PEDro, Cochrane, AMED, SPORTDiscus, PsycINFO). The search strategy included intervention and outcome keywords (health promotion and physiotherapy and metabolic syndrome) as well as synonyms for these words (Supplementary file). Reference lists of all included articles were manually searched, and citations of all included articles tracked using Google Scholar.

Eligibility criteria

Randomised controlled trials or non-randomised studies of intervention (NRSI) were eligible for inclusion if they met the criteria (Table 1). Key exclusion criteria were pregnant women with temporary increases in metabolic risk factors (e.g. gestational diabetes, preeclampsia); interventions with only a single session of exercise or education; or interventions provided in an inpatient hospital setting, university, or workplace because the focus of this review was on primary care settings.

Screening of studies for eligibility was independently completed by two reviewers (SM and CP or NT). Full text copies of studies that could not be clearly excluded based on title and abstract were reviewed. If consensus could not be reached between the two reviewers, a third reviewer (CP or NT) was consulted.

Assessment of characteristics of studies

Data were extracted by two reviewers independently (SM and AL or CD) into Excel on a customised form based on the Cochrane Data Collection tool [17]. Data were extracted on publication demographics, study design, participant characteristics, physiotherapy interventions using the template for intervention description and replication (TIDieR) checklist [18], and outcomes.

Primary outcomes were metabolic risk factors; and secondary outcomes included: physical activity; diet; health-related quality of life; disease-specific measures; and self-efficacy. Interventions where physical activity prescription was tailored to the individual and included monitoring were defined as 'individualised physical activity prescription'; and physical activity prescription that was not individualised was termed 'generalised physical activity advice'.

Methodological quality

Two reviewers (SM and AL or CD) independently assessed the included studies according to the Mixed Methods Appraisal Tool (MMAT) [19], which allows for the assessment of studies with quantitative and mixed methodological designs. This checklist consists of two initial screening questions applicable to all study designs, and five questions applicable to each of the designs. In this review Category 2 and Category 3 questions, for randomised and non-randomised quantitative studies respectively, were used. Any disagreements were resolved with a third reviewer (CP). Studies were not excluded based on quality, but the quality of the study was considered when interpreting the results.

Data analysis

For clinically homogenous data from two or more randomised controlled trials on primary (metabolic risk factors) or secondary (physical activity) outcomes, meta-analyses were completed. Data were regarded as clinically homogenous if the interventions contained physiotherapist-led health promotion activities, including exercise or physical activity prescription on a common outcome. Data were pooled to determine weighted mean difference (WMD) for outcomes reported on the same scale, or standardised mean differences (SMD) for outcomes reported using different scales, and 95% confidence intervals (CI). Following Cochrane recommendations [20], if change scores and post-intervention scores were reported on common scales, these were combined using WMD. For outcomes reported on different scales, SMDs were calculated using post-intervention data; and if change scores were presented, post-intervention means were calculated using baseline and change scores and the post-intervention standard deviation was imputed using baseline data [20]. When the standard deviation was not reported, this information was imputed using the standard error or 95%CI [20]. Where data could be converted to the same scale using accepted conversion rates (e.g. mg/dL to mmol/L) this was done to allow calculation of WMD. A SMD of 0.2 represents a small effect, 0.5 a moderate effect, and 0.8 a large effect [21]. Where trials included post-intervention data at multiple time points, data from the first post-intervention assessment were used. To account for heterogeneity, a pooled random effects model was applied using RevMan Web. Statistical heterogeneity was assessed by calculating I^2 [17]. Sensitivity analyses were conducted if there was significant statistical (I^2 values > 50%) [17], or clinical heterogeneity (e.g. different duration of intervention). Results for non-randomised studies of intervention and studies that lacked sufficient post-intervention data were presented descriptively.

Assessment of certainty of evidence

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [22] was used to assess the certainty of evidence (very low to high) obtained for each meta-analysis. Because the meta-analyses included only randomised controlled trials, certainty of evidence was rated as high and then downgraded by one level if: there were concerns about the methodological quality (trial fulfilled < 50% of the MMAT quality criteria) [19] in the majority (> 50%) of trials; there was a high level of statistical heterogeneity between trials (I^2 > 50%) (inconsistency) [17]; there were significant concerns that the participants, intervention, comparator or outcome were inconsistent with usual clinical practice (indirectness) [23]; the 95% confidence interval of the SMD was wide (> 0.80) (imprecision) [24]; or if publication bias was strongly suspected, for example if the analysis included mostly small studies demonstrating statistically significant results or inclusion of trials with industry sponsorship [25].

Results

Flow of studies through the review

The electronic database search yielded 2094 records, and three records were found via citation searching. After duplicates were removed, 1672 remained, and 1592 were excluded after screening title and abstract. The full texts of

Table 1
Inclusion criteria.

Design	Randomised controlled trials and non-randomised studies of interventions
Participants	Adults (18+ years) with or at risk of metabolic syndrome (i.e. with at least 1 of the following metabolic risk factors: abdominal obesity, hypertension, elevated triglycerides, reduced HDL-C or elevated glucose)
Intervention	Health promotion, physical activity or exercise prescription, self-management, education, or advice provided by a physiotherapist (including physiotherapist within a multidisciplinary team); delivered in any mode (1:1 or group, face-face or telehealth); provided in a primary healthcare setting i.e. private practice, outpatient setting, community health
Outcome measures	Measures of metabolic risk factors: waist circumference (or weight or body mass index as proxies for waist circumference), blood pressure, triglycerides, HDL-C or blood glucose
Comparisons	Standard care or physiotherapy without health promotion interventions

83 records were assessed for eligibility, of which 25 studies were included in the review (Fig. 1).

Characteristics of included studies

Participants

The review included 3619 participants from 10 randomised controlled trials and 15 NRSI (Table 2). More than 40% of participants (*n* = 1528) were from one NRSI [26]. Five of the studies included only female participants, from the rest 48% of participants were female. Mean age of participants ranged from 38 to 73 years. Fourteen studies were conducted in Europe [27–40], seven in North America [41–47], three in Australasia [48–50], and one in South America [26]. Nine studies focused on people affected by overweight/obesity [27,30,34,37,41–44,47]; eight studies on people with type 2 diabetes, prediabetes or diabetes risk [28,31,33,35,46,48–50]; three studies on people affected by overweight/obesity and at least one other metabolic risk factor or chronic disease [26,32,40]; three studies on adults with at least one metabolic risk factor [29,36,45]; and two studies on people with mental illness who had or were at risk of metabolic syndrome [38,39].

Interventions

All studies evaluated interventions that included supervised exercise or unsupervised physical activity prescription delivered by a physiotherapist in primary care. Of the 25 included studies, 15 included dietary intervention or advice.

Supervised exercise interventions delivered by a physiotherapist were investigated in 14 studies (four RCTs, 10 NRSI). All the supervised exercise occurred in groups and

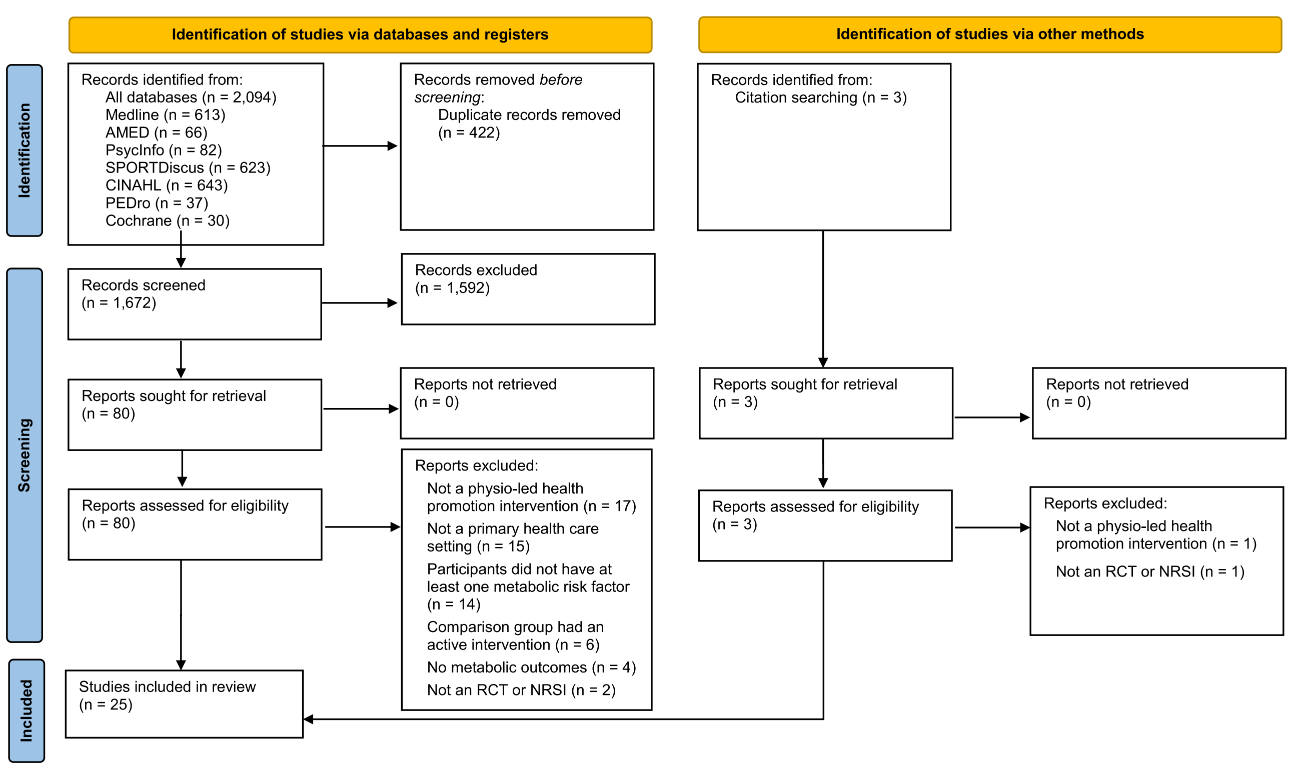

Fig. 1. Flow of studies through the review.

Table 2
Study characteristics.

Study (Country)	Participants	Metabolic syndrome risk factors	Outcome measures
Randomised Controlled Trials			
de Vos et al., 2016 (Netherlands)	Females 50 to 60 y/o with overweight *n* = Exp 203, Con 204 Age *(y)* = Exp 56 (3), Con 56 (3) % female = 100 Setting: GP, Physiotherapy and Dietician Clinics	BMI ≥ 27 kg/m^2, Hypertension (Exp 68%, Con 74%)	Weight, SQUASH (minutes per week)
Duiizer et al., 2017 (Netherlands)	Adults at risk of type 2 diabetes *n* = Exp 139, Con 136 Age *(y)* = Exp 61 (6), Con 61 (7) % female = Exp 46, Con 49 Setting: GP, physio and dietician clinic	Impaired fasting glucose or high risk of type 2 diabetes	Weight, BMI, WC, SBP, DBP, FBG, HDL, triglycerides, SQUASH (mins per week), Dutch Healthy Diet index, SF-36
Eriksson et al., 2006 (Sweden)	Adults with metabolic risk factors *n* = Exp 75, Con 76 Age *(y)* = Exp 55 (7), Con 53 (8) % female = Exp 52, Con 62 Setting: Primary health care centre	Hypertension 64% Dyslipidaemia 29% Type 2 diabetes 29% Overweight 44%	Weight, BMI, WC, SBP, DBP, HDL cholesterol, triglycerides, FBG, self-reported physical activity levels, HRQOL(EQ-VAS)
Jadhav et al., 2024 (India)	Sedentary adults with pre-diabetes *n* = Exp 79, Con 79 Age *(y)* = Exp 48 (8), Con 50 (7) % female = Exp 60 Con 66 Setting: Hospital outpatients	Pre-diabetes	Visceral fat, FBG
Littman et al., 2019 (USA)	Adults with overweight or obesity post amputation *n* = Exp 7, Con 8 Age *(y)* = Exp 56 (11), Con 57 (11) % female = Exp 14, Con 37 Setting: Home	BMI ≥ 25 kg/m^2	Weight, BMI, WC, diet quality, steps per day, hours per day sedentary time, behaviour change strategies for healthy eating, decisional balance for physical activity
Matsushita et al., 2022 (Japan)	Adults with Type 2 Diabetes Mellitus *n* = Exp 16, Con 13 Age *(y)* = Exp 62, Con 61 % female = Exp 12, Con 15 Setting: Hospital outpatients	Type 2 diabetes	BMI, SBP, DBP, HbA1C, FBG, triglycerides, steps per day, MET-hours per week
Molenaar et al., 2010 (Netherlands)	Adults with overweight *n* = Exp 67, Con 67 Age *(y)* = Exp 43 (9), Con 43 (10) % female = Exp 42, Con 42 Setting: Primary health care centre	BMI 28 to 35 kg/m^2	Weight, WC
Oldroyd et al., 2006 (UK)	Adults with impaired glucose tolerance *n* = Exp 37, Con 32 Age *(y)* = Exp 58, Con 58 % female = Exp 54, Con 31 Setting: Hospital outpatients	Pre-diabetic	Weight, WC, FBG, engagement in regular physical activity, change in dietary fat and dietary fibre
Uijl et al., 2023 (Netherlands)	Adults with heart disease and obesity *n* = Exp 102, Con 99 Age *(y)* = Exp 59 (10), Con 59 (9)	Obesity, Type 2 diabetes, Hypertension, Dyslipidaemia	Weight, steps per day, % in light and moderate-to-vigorous PA

Table 2 (*Continued*)

Study (Country)	Participants	Metabolic syndrome risk factors	Outcome measures
	% female = Exp 33, Con 21 Setting: Community centre		
Wisse et al., 2010 (Netherlands)	Adults with type 2 diabetes *n* = Exp 38, Con 36 Age *(y)* = Exp 54 (6), Con 52 (7) % female = Exp 38, Con 38 Setting: Hospital outpatients	Type 2 diabetes	Weight, BMI, WC, SBP, DBP, FBG, HDL cholesterol, triglycerides, METS/Week
Non-Randomised Studies of Interventions			
Batsis et al., 2020 (USA)	9 older adults with obesity Age *(y)* = 71 (5), % female = 67 Setting: Community centre	BMI > 30 kg/m2 Hypertension (56%), High cholesterol (44%) Diabetes (22%)	Weight, BMI, WC, PROMIS mental health and physical health score, patient activation measure
Batsis et al., 2021a (USA)	28 older adults with obesity Age *(y)* = 73 (5), % female = 82 Setting: Community centre	BMI > 30 kg/m2 Hypertension (50%) High cholesterol (32%) Diabetes (18%)	Weight, BMI, WC, PROMIS mental health and physical health score, physical activity (steps per day)
Batsis et al., 2021b (USA)	53 older adults with obesity Age *(y)* = 73 (4), % female = 70 Setting: Community centre	BMI > 30 kg/m^2 Hypertension (72%) High cholesterol (40%) Diabetes (26%)	Weight, BMI, WC, steps per day
Cibulkova et al., 2022 (Czech Republic)	Adults with obesity following bariatric surgery *n* = Exp 10, Con 12 Age *(y)* = Exp 49 (8), Con 45 (14) % female = Exp 40, Con 33 Setting: Hospital outpatients	BMI ≥ 35 kg/m2,	Weight, BMI
Duijzer et al., 2014 (Netherlands)	1528 adults with impaired fasting glucose Age *(y)* = 36 (median), % female = 100 Setting: GP, physio and dietician clinics	Impaired fasting glucose, Hypertension (19%), High cholesterol (36%) CVD (21%)	Weight, BMI, WC, SBP, DBP, FBG, physical activity (number of days per week), fruit and vegetable intake
Echenique, 2011 (Chile)	31 women with overweight or obesity Age *(y)* = 54 (9), % female = 100 Setting: Primary health care centres	BMI >25 kg/m^2, Elevated glucose 12%, Hypertension 18%	Weight, BMI, WC, FBG
Espinel et al., 2023 (Spain)	30 adults with resistant hypertension Age *(y)* = 60, % female = 27 Setting: Hospital outpatients	Hypertension	BP
Gilstrap et al., 2013 (USA)	64 women with at least 2 CVD risk factors Age *(y)* = 51, % female = 100 Setting: Community centre	Hypertension 63% High cholesterol 49%, Type 2 diabetes 22%	WC, triglycerides, HDL cholesterol, SBP, DBP, FBG, Metabolic Syndrome Score, exercise frequency, fruit & vegetable intake
Higgs et al., 2016 (New Zealand)	36 adults with diabetes or pre-diabetes Age *(y)* = 62 (11), % female = 58 Setting: Community centre	Type 2 diabetes, pre-diabetes or at risk of developing diabetes	BMI, WC, Stanford Exercise Behaviour questionnaire, Stanford Self-Efficacy for Managing Chronic Disease
Janssen et al., 2023 (Canada)	12 adults with Type 2 Diabetes Mellitus Age *(y)* = 64 (14), % female = 58 Setting: Community Centre	Type 2 diabetes	Weight, BMI, WC, FBG, SBP, DBP
Quinn et al., 2008 (Ireland)	18 women with obesity Age *(y)* = 38 (11), % female = 100 Setting: Hospital outpatients	BMI ≥ 35 kg/m^2	Weight, IPAQ (MET-minutes/week), IWQOL-Lite
Sabbahi et al., 2018 (USA)		BMI > 25 kg/m^2	Weight, BMI, WC, SBP, DBP, FBG

Table 2 (*Continued*)

Study (Country)	Participants	Metabolic syndrome risk factors	Outcome measures
	192 adults with overweight Age *(y)* = 52 (14), % female = 34 Setting: Hospital outpatients		
Sameby et al., 2008 (Sweden)	14 people with psychosis at risk of metabolic syndrome Age and sex = not reported Setting: Hospital outpatients	BMI > 27 kg/m^2	BMI, WC, SBP, DBP
Vlčková et al., 2009 (Czech Republic)	46 women with low back pain, osteoarthritis and obesity Age *(y)* = not reported, % female = 100 Setting: Hospital outpatients	Obesity	Weight, BMI, WC, triglycerides, HDL cholesterol
Waugh et al., 2018 (Ireland)	16 adults with major mental illness and at least 1 metabolic risk factor Age *(y)* = 43 (11), % female = 69 Setting: Hospital outpatients	At least 1 metabolic risk factor or metabolic syndrome	BMI, WC, SBP, DBP, HDL cholesterol, FBG, triglycerides, (MET-minutes/week), light/moderate/ vigorous activity (min per day)

Note: RCT, randomised controlled trial; y/o, years old; Exp, experimental; Con, control; Y, years; BMI, body mass index; GP, general practitioner; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL, high-density lipoprotein; IPAQ, International Physical Activity Questionnaire; MET, Metabolic Equivalent of Task; SQUASH, Short Questionnaire to Assess Health-enhancing physical activity; FBG, fasting blood glucose; PROMIS, Patient Reported Outcome Measurement Information System; IWQOL-Lite, The Impact of Weight on Quality of Life Questionnaire-Short Form.

included a prescribed home exercise program (eight of which were individualised). Supervised exercise comprised of combined aerobic and resistance circuit training in 10 studies, progressive resistance training in two studies, and aerobic or sports activities in one study each. Supervised exercise was combined with group education sessions (led by dietitian, physiotherapist or a multidisciplinary team) in eight studies; and combined with dietitian-delivered diet intervention (commonly low calorie) in 11 studies (Table 3a, 3b).

Unsupervised physical activity prescription by a physiotherapist was investigated in 11 studies (six RCTs, five NRSI), with nine providing individualised physical activity prescription, and two general physical activity advice. Physical activity prescription was combined with dietitian-delivered diet intervention in four studies. Health behaviour change interventions with motivational interviewing or health coaching were included in 48% (12/25) of the studies. Health promotion interventions ranged from 4 weeks to two years duration, with 56% (14/25) occurring in community primary care settings and 44% (11/25) in hospital outpatient clinics. Individualised tailoring of exercise programs occurred in most (18/25) studies but few studies adequately reported intervention adherence or fidelity. Data most reported were dropout rates and attendance rates for face-face components of interventions. Attendance rates ranged between 36% and 94%. Adherence to unsupervised intervention components were rarely reported. Comparison interventions included usual care in four RCTs [30,32,33,48]; nil intervention in three RCTs [27,31,49]; usual care plus information about healthy diet and increasing physical activity in three RCTs [28,29,41].

Outcome measures

At least one metabolic risk factor was measured in all studies (Table 2). Abdominal obesity was measured via waist circumference in 18 studies, body weight in 18, BMI in 17, and visceral fat using a body composition scale in a single study [48]. Fasting blood glucose was measured in 12 studies, blood pressure in 11 studies, and each of HDL-C and triglycerides in seven studies. The secondary outcome of physical activity was measured in 15 studies. The most common measures were self-reported physical activity, most frequently the International Physical Activity Questionnaire (IPAQ) [37,39] and the Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH) [27,28]. Objective measures of physical activity using wearable activity monitors were used in six studies [32,39,41,42,44,49]. Diet quality was measured in three studies with a self-reported food frequency instrument [41], adherence to national dietary guidelines [28] and a four day food diary [31]. Quality of life was measured in three studies [28,29,37] and self-efficacy was measured in a single study [50].

Methodological quality

Overall, 12 out of the 25 studies (48%) fulfilled more than half of the MMAT quality criteria (Table 4). Fifty-two percent of studies had incomplete data (*n* = 13), and 32% reported adequate adherence to interventions (n = 8). For RCTs (n = 10), the majority reported baseline comparability (*n* = 9) and adequate randomisation (*n* = 9), but only one reported sufficient assessor blinding. For NRSI (*n* = 15), all reported appropriate measures, and the majority had a

Table 3a
Intervention characteristics for randomised controlled trials (n = 10).

Study	What? (Intervention types)	Who? (Intervention provider)	How?	Where?	When & How Much?	Control
de Vos et al., 2016	Diet: Low fat &/or low-calorie using MI Exercise: Individualised physical activity prescription using MI and supervised group sports activities	Dietician Physiotherapist	Individual and group face-face	Dietician Clinic Physiotherapy Clinic	MI: 3 appointments in 2 weeks then up to 4 hours per year Exercise: 60 minutes × 20 over 6 months	Nil intervention
Duijzer et al., 2017	Diet: Advice based on national dietary guidelines using MI Exercise: Supervised aerobic and resistance training + Individualised physical activity prescription + Sports clinics	Dietician Physiotherapist	Individual and group, face-face	Dietician Clinic Physiotherapy Clinic Local sports clubs	Diet: 30 to 60 mins, 5 to 8 consults (max 4 hours) in 10 months Exercise: 1 to 2 hours/week for 10 months	Usual care + written information about diet and physical activity
Eriksson et al., 2006	Diet: Advice based on national dietary guidelines Exercise: Supervised circuit Education: Lifestyle change (diet and exercise)	Dietician Physiotherapist GP	Group, face-face	Primary healthcare centre	Diet: 20 minutes × 5 in 3 months Exercise: 40 to 60 minutes, 3 × week for 3 months Education: 1 × month for 6 months	Usual care + generalised group physical activity and diet advice – 1 hour
Jadhav et al., 2024	Exercise: Individualised physical activity prescription	Physiotherapist	Individual, telephone	Hospital outpatients	Duration and frequency NR, for 24 weeks	Generalised physical activity advice
Littman et al., 2019	Exercise: Individualised physical activity prescription + health coaching using MI	Physiotherapist Health coach	Individual, face-face and telephone	Home or gym	Exercise: × 1 (duration NR) MI: 10 to 20 minutes × 11 sessions for 20 weeks	Nil intervention
Matsushita et al., 2022	Exercise: Generalised physical activity advice	Physiotherapist	Individual, face-face	Hospital outpatients	2 sessions (week 0 and week 4), duration NR	Nil intervention
Molenaar et al., 2010	Diet: Low calorie Exercise: Individualised physical activity prescription	Dietician Physiotherapist	Individual, face-face	Primary healthcare centre	Diet: 20 to 40 minutes × 7 sessions in 6 months + 1 session at 12 months Exercise: 30 to 60 minutes × 6 sessions in 6 months + 1 session at 12 months	Usual care (also had a diet only comparator)
Oldroyd et al., 2006	Diet: Reduced fat and sugar using MI Exercise: Individualised physical activity prescription using MI	Dietician Physiotherapist	Individual, face-face	Hospital outpatients	MI: 15 to 20 minutes × 12 sessions over 24 months	Nil intervention
Uijl et al., 2023	*Enhanced cardiac rehab* Exercise: Supervised aerobic and resistance + education Health promotion coaching	Physiotherapist Dietician	Group, face-face	Rehabilitation centre	Exercise: 60 to 90 minutes, 2 × week for 12 weeks Health coaching: 1/week for 12 weeks, then 9 over 12 months	Standard cardiac rehabilitation with group exercise
Wisse et al., 2010	Exercise: Individualised physical activity prescription	Physiotherapist	Individual, face-face/telephone	Hospital outpatients/home	2 × 1 hour initial consults, 15 minutes tele consults at 2 & 6 weeks, then alternating 30 minutes face-face and 15-minute tele consult every 6 weeks for 2 years	Usual care

Table 3b
Intervention characteristics for non-randomised studies of interventions (n = 15).

Study	What? (Intervention types)	Who? (Intervention provider)	How?	Where?	When & How Much?
Batsis et al., 2020	Diet: Low calorie using MI Exercise: Supervised progressive resistance training + individualised physical activity prescription	Dietician Physiotherapist	Individual and group, face-face	Community centre	Diet: 30 minutes, 1 × week for 12 weeks Exercise: Duration NR, 2 × week for 12 weeks + 150 minutes aerobic exercise + 1 strength session per week
Batsis et al., 2021a	Diet: Low calorie using MI Exercise: Supervised progressive resistance training + Individualised physical activity prescription	Dietician Physiotherapist	Individual and group, face-face	Community centre	Diet: 30 minutes, 1 × week for 12 weeks Exercise: Duration NR, 2 × week for 12 weeks + 150 mins aerobic exercise + x 1 strength session per week
Batsis et al., 2021b	Diet: Calorie restriction using MI Exercise: Supervised circuit + Individualised physical activity prescription	Dietician Physiotherapist	Individual, online + group, online and face-face	Community centre	Diet: 30 minutes, 1 × week for 18 weeks, and group diet: 60 minutes, 1 × month for 6 months Exercise: 75 minutes, 2 × week for 6 months online, and 75 minutes, 1 × month for 6 months face-to-face + 150 minutes walking + 1 unsupervised circuit session per week
Cibulkova et al., 2022	Diet: Low calorie Exercise: Supervised circuit + generalised physical activity advice	Nutrition therapist Physiotherapist or trained instructor	Group, face-face	Hospital outpatients	Diet: NR Exercise: 60 to 75 minutes, 2 × week for 3 months + 30 to 40 minutes, 1 × week for 3 months
Duijzer et al., 2014	Diet: Advice based on National dietary guidelines using MI Exercise: Supervised aerobic and resistance training + sports class + individualised physical activity prescription	Dietician Physiotherapist	Individual, face-face Group, face-face	Physiotherapy Clinic	Diet: 30 to 60 minutes × 9 individual and x 3 group over 10 months Exercise: 60 minutes, 1 × week supervised + at least 60 minutes, 1 × week independent for 10 months
Echenique, 2011	Exercise: Supervised aerobic + generalised physical activity advice Education: healthy eating, increasing physical activity	Physiotherapist or PE teacher Doctors, nutritionists, psychologists, physiotherapists	Group, face-face	Primary care centre	Exercise: 30 minutes, 2 × week for 4 months Education: Weekly. Duration and total number of sessions NR
Espinel et al., 2023	Diet: low calorie, low-salt diet Exercise: Individualised physical activity prescription	Dieticians and nurses Physiotherapist	Individual, face-face	Hospital outpatients	Diet: Duration NR, 1 × month for 6 months Exercise: Duration NR, 1 × month for 6 months
Gilstrap et al., 2013	Diet: nutrition plan Exercise: Individualised physical activity prescription + relaxation, and tai chi Health coaching	Dietician Physiotherapist Health coach	Individual, face-face and telephone	Community centre	Diet: Duration NR x 1 consult Exercise: Duration NR x 1 consult Health coaching: Duration NR, 1 to 2 × week for 3 months, then 1 × month up to 2 years
Higgs et al., 2016	Exercise: Supervised circuit Education: Healthy lifestyle and wellness	Physiotherapist, physiotherapy students, nurse, dietician, pharmacist, diabetes educator, podiatrist	Group, face-face	Community centre	Exercise: 45 minutes, 2 × week for 12 weeks Education: 45 minutes, 2 × week for 12 weeks
Janssen et al., 2023	Exercise: Supervised circuit Education: Exercise, healthy eating, disease prevention	Physiotherapy student	Group, face-face	Community centre	Exercise: 60 minutes, 2 × week for 8 weeks Education: 60 minutes, 1 × week for 8 weeks
		Physiotherapist	Group, face-face	Hospital outpatients	60 minutes, 1 × month for 4 months

Table 3b (*Continued*)

Study	What? (Intervention types)	Who? (Intervention provider)	How?	Where?	When & How Much?
Quinn et al., 2008	Exercise: Generalised physical activity advice				
Sabbahi et al., 2018	Exercise: Supervised circuit + Generalised physical activity advice Diet: nutrition education; calories based Behavioural counselling	Physiotherapist or exercise physiologist Dietician Behavioural counsellor	Group, face-face Individual, face-face	Hospital outpatients	Exercise: 45 to 60, 3 x week supervised for 8 to 10 weeks Diet: Duration NR, 1 × week for 8 weeks Counselling: Duration NR, 1xweek for 9 weeks
Sameby et al., 2008	Education: physical ill-health, exercise, dietary habits, stress management, smoking	Physiotherapist and psychiatric nurse	Group, face-face	Hospital outpatients	Duration NR, 1 × week for 10 weeks, then 1 × week/fortnight for 4 to 6 months
Vlčková et al., 2009	Exercise: Supervised aerobic and resistance training + generalised physical activity advice Diet: low calorie, Mediterranean diet	Physiotherapist Nutritional Therapist	Group, face-face Individual, face-face	Hospital outpatients	Exercise: 45 mins, 2 × week (gym), + 45 minutes, 1 × week (pool) for 6 months Diet: Duration NR, every 4 weeks for 6 months
Waugh et al., 2018	Exercise: Individualised physical activity prescription using MI	Physiotherapist	Individual, face-face	Hospital outpatients	20 to 40 minutes, 1 × week for 8 weeks

MI, motivational interviewing; Exp, experimental; Comp, comparator; Con, control; MI, motivational interviewing; NR, not reported.

Table 4
Quality assessment (MMAT).

Study	Randomisation appropriate	Baseline comparability	Complete outcome data	Assessor blinding	Intervention adherence
Randomised Controlled Trials					
de Vos et al., 2016	+	+	+	?	-
Eriksson et al., 2006	+	+	-	?	+
Duijzer et al., 2017	+	+	+	?	?
Jadhav et al., 2024	+	+	+	?	?
Littman et al., 2019	+	+	+	?	-
Matsushita et al., 2022	+	+	-	?	+
Molenaar et al., 2010	+	+	+	?	+
Oldroyd et al., 2006	+	+	-	?	-
Uijl et al., 2023	+	+	-	?	?
Wisse et al., 2010	?	-	-	+	?

Study	Representative sample	Appropriate measures	Complete outcome data	Confounders accounted for	Intervention fidelity
Non-Randomised Studies of Interventions					
Batsis et al., 2020	+	+	+	-	+
Batsis et al., 2021a	+	+	+	-	+
Batsis et al., 2021b	+	+	-	-	+
Cibulkova et al., 2022	+	+	+	-	?
Duijzer et al., 2014	+	+	+	-	-
Echenique, 2011	+	+	?	?	?
Espinel et al., 2023	+	+	-	-	?
Gilstrap et al., 2013	+	+	-	-	?
Higgs et al., 2016	+	+	-	-	-
Janssen et al., 2023	+	+	+	-	+
Quinn et al., 2008	+	+	+	-	-
Sabbahi et al., 2018	+	+	-	-	?
Sameby et al., 2008	?	+	+	-	?
Vlčková et al., 2009	?	+	-	-	?
Waugh et al., 2018	+	+	-	-	+

+ Low risk ? Some concerns - High risk

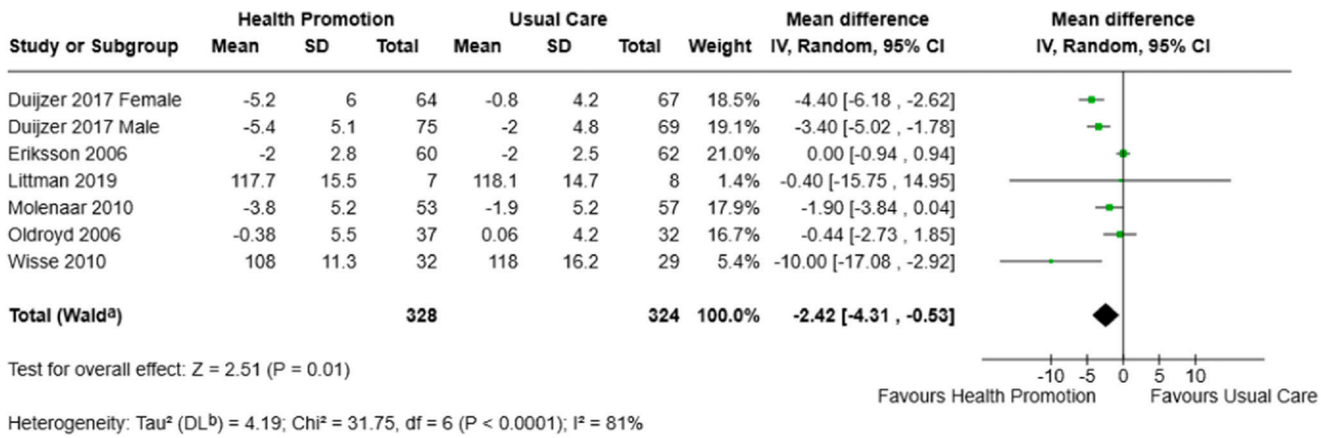

Fig. 2. Weighted mean difference (95% CI) for the effect of physiotherapy health promotion interventions on waist circumference (cm).

representative sample (n = 13), but no study adequately accounted for confounders.

Effects of health promotion interventions on metabolic risk factors

Abdominal obesity

Meta-analysis of six trials with 652 participants [28–31,33,41] showed physiotherapist-delivered health promotion interventions reduced waist circumference by 2.42 cm (95%CI −4.31 to −0.53, I^2 81%) (Fig. 2) when compared to usual care. The certainty of evidence for this meta-analysis was moderate after downgrading for inconsistency (Table 5). Meta-analysis of four trials [27,32,48,49] showed minimal change in abdominal obesity via measures other than waist circumference (SMD −0.14, 95%CI −0.28 to 0.01, I^2 0%) when compared to usual care.

From the studies not included in the meta-analysis, 12 NRSI all reported a decrease in waist circumference, between 2.0 and 10.6 cm, following health promotion interventions [26,35,38–40,42–47,50]. Body weight reduced in nine out of 10 studies (between 0.1 and 6.2 kg) [26,35,37,40,42–44,46,47]; and BMI decreased post-intervention in 11 out of 12 NRSI (between 0.3 and 2.1 kg/m^2) [26,35,38–40,42–44,46,47,50]. One study [34] reported no change in body weight or BMI following health promotion intervention in participants four months after bariatric surgery.

Table 5
GRADE summary of findings - physiotherapy-led health promotion compared with usual care.

		Bias	Inconsistency	Indirectness	Imprecision	Publication bias	Rating
Waist circumference 6 RCTs (n = 652)	WMD −2.42 cm, 95% CI −4.31 to −0.53, I^2 81%	0	−1*	0	0	0	⊕⊕⊕O Moderate
Abdominal obesity 4 RCTs (n = 734)	SMD −0.14, 95%CI −0.28 to 0.01, I^2 0%	0	0	0	0	0	⊕⊕⊕⊕ High
Systolic BP 4 RCTs (n = 479)	WMD −1.73 mmHg, 95%CI −3.85 to 0.39, I^2 0%	0	0	0	−1^	0	⊕⊕⊕O Moderate
Diastolic BP 4 RCTs (n = 479)	WMD −2.34 mmHg, 95%CI −3.77 to −0.91, I^2 16%	0	0	0	0	0	⊕⊕⊕⊕ High
Triglycerides 3 RCTs (n = 459)	WMD -0.13 mmol/L, 95%CI -0.28 to 0.01, I^2 0%	0	0	0	0	0	⊕⊕⊕⊕ High
HDL cholesterol 3 RCTs (n = 459)	WMD 0.00 mmol/L, 95%CI −0.03 to 0.03, I^2 0%	0	0	0	0	0	⊕⊕⊕⊕ High
Fasting blood glucose 5 RCTs (n = 634)	WMD −0.18 mmol/L, 95%CI −0.28 to −0.08, I^2 0%	0	0	0	0	0	⊕⊕⊕⊕ High
Physical activity 7 RCTs (n = 1055)	SMD 0.18, 95%CI 0.04 to 0.32, I^2 14%	0	0	0	0	0	⊕⊕⊕⊕ High

RCTs, Randomised Controlled Trials; WMD, weighted mean difference; CI, confidence interval; SMD, standardised mean difference; HDL, high density lipoprotein.
* High heterogeneity (I^2 > 50%).
^ Wide 95% CI ranging from negative to positive effect.

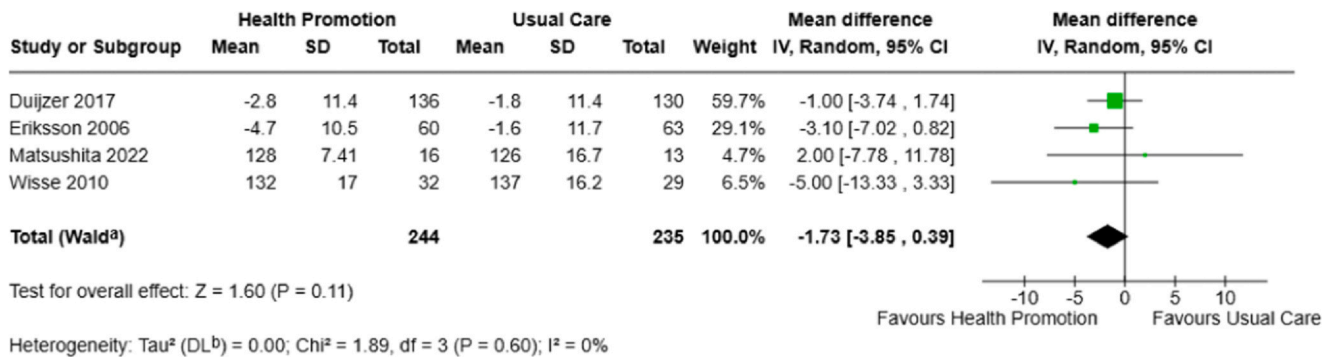

Fig. 3. Weighted mean difference (95% CI) for the effect of physiotherapy health promotion interventions on systolic blood pressure (mmHg).

Blood pressure

Meta-analysis of four trials with 479 participants [28,29,33,49] showed health promotion interventions likely resulted in little to no difference in systolic blood pressure (WMD −1.73 mmHg, 95%CI −3.85 to 0.39, I^2 0%) (Fig. 3) when compared to usual care. The certainty of evidence for this meta-analysis was moderate after downgrading for imprecision (Table 5).

Meta-analysis of the same four trials [28,29,33,49] showed health promotion interventions delivered by physiotherapists reduced diastolic blood pressure by 2.34 mmHg (95%CI −3.77 to −0.91, I^2 16%) (Fig. 4) when compared to usual care. The certainty of evidence for this meta-analysis was high (Table 5).

From the studies not included in the meta-analyses, seven NRSI reported on systolic blood pressure. From these, five found a decrease of 4.1 to 15.1 mmHg; [35,36,45–47] and two [38,39] found an increase by 1.5 and 3.8 mmHg respectively following physiotherapist-delivered health promotion interventions. Of the seven NRSI that reported on diastolic blood pressure, [35,36,38,39,45–47] six found a decrease of 3.3 to 8.9 mmHg, and one observed an increase by 1 mmHg [39].

Lipids

Meta-analysis of four trials with 488 participants [28,29,33,49] showed health promotion interventions reduced triglycerides by 0.18 mmol/L (95%CI −0.36 to 0.00, I^2 0%) (Fig. 5) when compared to usual care.

Meta-analysis of the same four trials [28,29,33,49] showed health promotion interventions likely had no effect on HDL (WMD 0.00 mmol/L, 95%CI −0.03 to 0.03, I^2 0%) (Fig. 6) when compared to usual care. The certainty of evidence for these meta-analyses was high (Table 5).

The four NRSI that reported on the effect of health promotion interventions on lipids [36,39,40,45] found that triglycerides decreased by 0.1 to 0.6 mmol/L and HDL increased by 0.05 to 0.15 mmol/L following physiotherapist-delivered health promotion interventions.

Blood glucose

Meta-analyses showed health promotion interventions reduced fasting blood glucose by 0.18 mmol/L (95%CI −0.28 to −0.08, I^2 0%) (Fig. 7a) in five trials with 634 participants [28,29,31,48,49]. The certainty of evidence for this meta-analysis was high (Table 5).

One trial [33] not included in the meta-analysis because all participants were on insulin, found a large reduction in fasting blood glucose (1.0 mmol/L) following health promotion intervention. Seven NRSI reported on the effect of health promotion interventions on fasting blood glucose, of which six [26,36,39,45–47] found a decrease of 0.1 to 0.6 mmol/L, and a single study [35] observed an increase of 0.3 mmol/L.

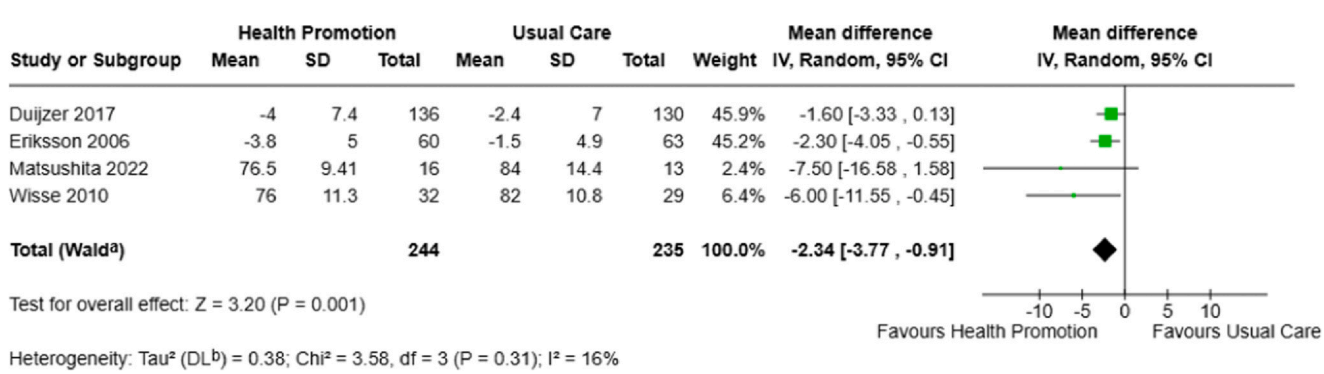

Fig. 4. Weighted mean difference (95% CI) for the effect of physiotherapy health promotion interventions on diastolic blood pressure (mmHg).

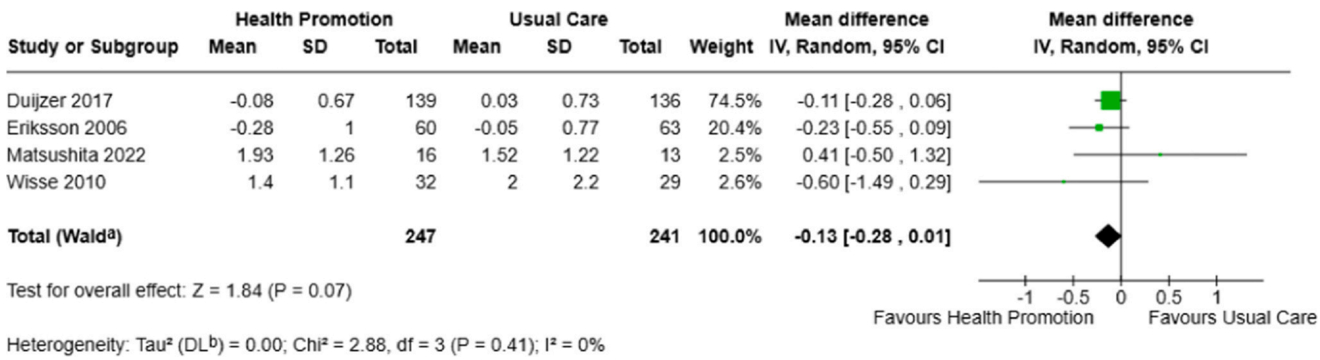

Fig. 5. Weighted mean difference (95% CI) for the effect of physiotherapy health promotion interventions on triglycerides (mmol/L).

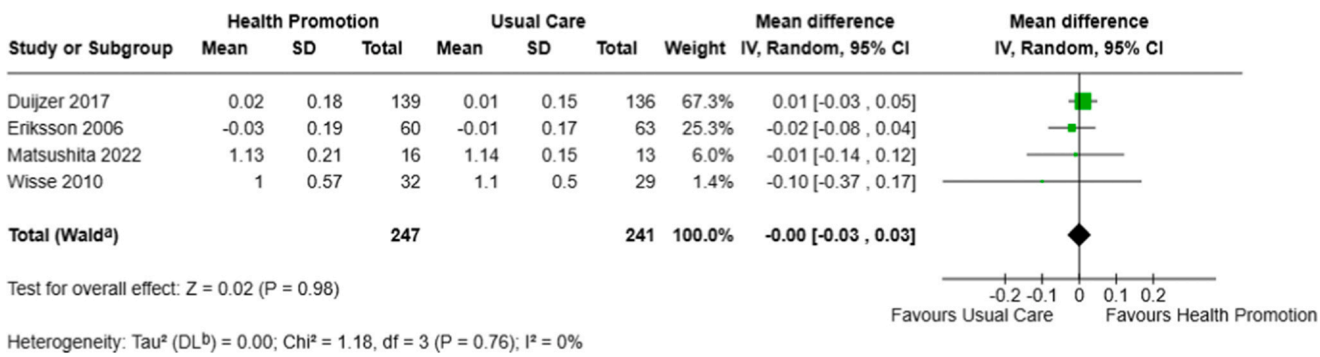

Fig. 6. Weighted mean difference (95% CI) for the effect of physiotherapy health promotion interventions on HDL-Cholesterol (mmol/L).

Effects of health promotion interventions on measures of physical activity

Meta-analysis of seven trials with 1055 participants [27,28,31–33,41,49] showed physiotherapist-delivered health promotion interventions increased physical activity by a small amount (SMD 0.18, 95%CI 0.04 to 0.32, I^2 14%) (Fig. 8) when compared to usual care. The certainty of evidence for this meta-analysis was high (Table 5). Six NRSI [35,39,42,44,45,50] reported that physical activity levels increased following health promotion interventions, with an increase of 3443 to 5467 daily steps reported in two studies [42,44]. A single NRSI [37] found no improvement in physical activity after a four month, unsupervised health promotion intervention of generalised advice for women with obesity.

Effects of health promotion interventions on other secondary measures

The effect of health promotion interventions on diet was reported in three studies with mixed results. One study [28]

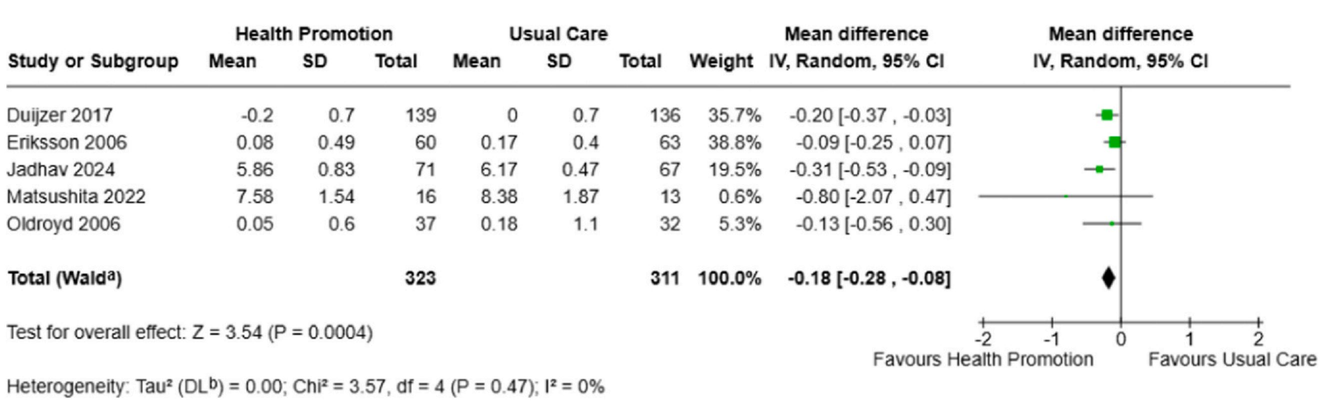

Fig. 7. Weighted Mean Difference (95% CI) for the effect of physiotherapy health promotion interventions on fasting blood glucose (mmol/L).

	Health Promotion			Usual Care				Std. mean difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
de Vos 2016	8063	3785	203	7421	3785	204	34.1%	0.17 [-0.03 , 0.36]
Duijzer 2017	2406.5	1337	139	2225.9	1337	134	25.7%	0.13 [-0.10 , 0.37]
Littman 2019	2877	1493	7	2872	1136	8	1.9%	0.00 [-1.01 , 1.02]
Matsushita 2022	35.4	16.07	16	27.3	19.19	13	3.4%	0.45 [-0.29 , 1.19]
Oldroyd 2006	33.3	57.4	37	-3.1	32.5	32	7.5%	0.76 [0.27 , 1.25]
Uijl 2023	6106	3774.4	102	5878	4368.3	99	20.3%	0.06 [-0.22 , 0.33]
Wisse 2010	18	15.6	32	16	23.4	29	7.1%	0.10 [-0.40 , 0.60]
Total (Wald[a])			**536**			**519**	**100.0%**	**0.18 [0.04 , 0.32]**

Test for overall effect: Z = 2.57 (P = 0.01)

Heterogeneity: Tau² (DL[b]) = 0.00; Chi² = 6.96, df = 6 (P = 0.32); I² = 14%

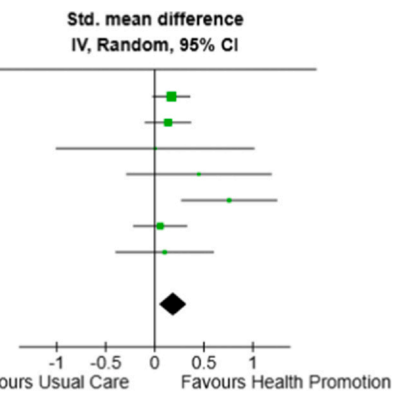

Fig. 8. Standardised mean difference (95% CI) for the effect of physiotherapy health promotion interventions on physical activity.

observed significant improvement in diet index scores; one study [31] reported significant reduction in dietary fat intake; and another study [41] observed no significant difference in diet quality between intervention and control groups.

The effect of health promotion interventions on quality of life was investigated in three studies with mixed results. Two RCTs [28,29] found a significant increase in quality of life post-intervention compared to a group receiving usual care; and a single NRSI [37] found no improvement in quality of life following a health promotion intervention. A single health promotion intervention [50] was shown to increase self-efficacy.

Discussion

This systematic review found moderate to high certainty evidence to support the use of physiotherapist-led health promotion interventions involving supervised exercise or physical activity prescription in primary care to improve metabolic outcomes. Waist circumference, diastolic blood pressure, triglycerides and blood glucose levels were all reduced, and physical activity levels increased in people with or at risk of metabolic syndrome. There were no significant changes in systolic blood pressure or HDL-cholesterol. This systematic review is the first to demonstrate that lifestyle interventions delivered by physiotherapists in primary care, with or without dietician involvement, can improve metabolic risk factors for people with or at risk of metabolic syndrome.

The improvements in metabolic risk factors observed in these meta-analyses are expected to have clinical significance. The 2.4 cm reduction in waist circumference reported in this meta-analysis is likely to be meaningful for people with or at risk of metabolic syndrome given that a 1 cm increase in waist circumference is linked to a higher risk of cardiovascular events [51]. The reduction in diastolic blood pressure of 2.3 mmHg reported in this review is comparable to those achieved with blood pressure lowering medication [52], and the reduction in triglycerides of 0.15 mmol/L is likely to be clinically important given a 1 mmol/L increase in triglycerides doubles the risk of all-cause mortality [53].

Because of the observed increases in physical activity levels, the results from this review suggest that improvements in metabolic factors were mediated by increased physical activity. This finding is consistent with the literature that demonstrates the important role that aerobic, resistance and/or combined exercise plays in improving metabolic health [54–56]. There was insufficient evidence about the mediating role of dietary behaviour change from our included studies, but others have reported that a variety of different diets can improve metabolic health despite debate within the literature on which diets are most appropriate [57–60]. Although all dietary interventions were delivered by dietitians or nutritionists in the included studies, general dietary advice was also provided by physiotherapists in education sessions which is part of health promotion and fits well within their scope of practice [1,2]. As exercise alone has been shown to be effective in managing metabolic syndrome [54] via changes in skeletal muscle and vascular systems and through its anti-inflammatory effects [61], physiotherapists should be confident in their ability to provide physical activity and exercise interventions to improve the metabolic health of their clients.

When implementing exercise-based physiotherapy health promotion interventions for people with metabolic risk factors, key clinical considerations include the need for individualised tailoring and monitoring of the intervention, and sufficient intervention duration and intensity. Individualised tailoring and supervision of exercise occurred in most studies and have been shown to be important determinants of adherence to programs in people with metabolic syndrome [62,63]. Duration of the intervention of at least 12 weeks may be required if improving lipids is a key aim [55,64]. Like other reviews of lifestyle interventions for people with metabolic syndrome [14,15], our review did not find any effect on HDL-cholesterol. This may be attributed to the fact that the baseline mean HDL-cholesterol levels of the majority of participants were already within normal ranges, or that exercise was not of sufficient intensity [65]. Exercise intensity and volume are also important considerations for improving systolic blood pressure, with greatest improvements observed when exercise is performed at higher volumes and intensity [54,56]. Physiotherapists in primary care should be confident to supervise and prescribe sufficiently intense exercise for people with metabolic syndrome knowing that exercise is safe even for people with multimorbidity [66]. Therefore, when designing interventions for their clients, physiotherapists in primary care should tailor programs to each client's specific metabolic risk factors ensuring sufficient duration and intensity to elicit change.

The findings of this review have implications for the physiotherapy workforce. Traditionally, physiotherapists have focused on treating the consequences of chronic disease, but this work highlights the important role physiotherapists could play in NCD prevention. This has been emphasised as an important part of future planning for the profession to meet the evolving needs of our future population [67,68]. The population is changing; people are living longer, and due to the rise in NCDs, people are spending more time in ill health [5], with the poorest and most vulnerable communities disproportionately affected [69]. As a result, physiotherapists need to adapt by focusing on holistic care that supports clients' wellbeing [70]; recognising common risk factors across health conditions [68]; and by providing more upstream interventions and population-based health approaches [71]. For this shift in practice to occur, previously identified barriers [72,73] such as time constraints, inadequate funding models and lack of training [74] will need to be addressed. Additionally, physiotherapists are going to need to be able to identify those most in need of health promotion interventions. Given metabolic syndrome is currently under-recognised [75] and rarely diagnosed [12,13], physiotherapists will require training and resources to support identification of metabolic risk factors in their clients.

A possible limitation of the review is that interventions that had physiotherapist delivered health promotion as part of a multi-disciplinary team were included. Therefore, we cannot assume that interventions delivered solely by physiotherapists will result in the same effect. However, in all studies physiotherapists led the exercise component of the intervention, with other health professionals such as dietitians contributing to dietary education. Another limitation was the exclusion of studies on pregnant women with gestational diabetes and preeclampsia, as these women may have ongoing metabolic disturbances. People who volunteer for lifestyle intervention studies are likely to be more inclined to make changes, therefore we cannot assume that results are generalisable to the entire population. Strengths of this review include that it is reported according to the PRISMA guidelines, and the quality of each meta-analysis was assessed using the GRADE system, enhancing the rigour of the review.

Conclusion

Health promotion interventions delivered by physiotherapists in primary care can improve metabolic risk factors and physical activity levels for people with or at risk of metabolic syndrome. Physiotherapists should have confidence in their ability to provide exercise-based health promotion interventions to target metabolic risk factors that may contribute to chronic disease prevention.

Ethical approval:

Ethical approval not required.

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Conflict of interest:

Nil.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.physio.2025.101837.

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