The effect of walking on risk factors for cardiovascular disease: An updated systematic review and meta-analysis of randomised control trials

Murtagh, Elaine M.; Nichols, Linda; Mohammed, Mohammed A.; Holder, Roger; Nevill, Alan M.; Murphy, Marie H.

DOI:
10.1016/j.ypmed.2014.12.041

The effect of walking on risk factors for cardiovascular disease: An updated systematic review and meta-analysis of randomised control trials

Elaine M. Murtagh, Linda Nichols, Mohammed A. Mohammed, Roger Holder, Alan M. Nevill, Marie H. Murphy

PII: S0091-7435(15)00002-X
DOI: doi: 10.1016/j.ypmed.2014.12.041
Reference: YPMED 4206

To appear in: *Preventive Medicine*

Please cite this article as: Murtagh Elaine M., Nichols Linda, Mohammed Mohammed A., Holder Roger, Nevill Alan M., Murphy Marie H., The effect of walking on risk factors for cardiovascular disease: An updated systematic review and meta-analysis of randomised control trials, *Preventive Medicine* (2015), doi: 10.1016/j.ypmed.2014.12.041

Title: The effect of walking on risk factors for cardiovascular disease: an updated systematic review and meta-analysis of randomised control trials

Authors:

Elaine M Murtagh[a] Linda Nichols[b] Mohammed A Mohammed[c] Roger Holder[b] Alan M Nevill[d] and Marie H Murphy[e]

a. Department of Arts Education and Physical Education, Mary Immaculate College, University of Limerick, Limerick, Ireland
b. School of Health and Population Sciences, University of Birmingham, Birmingham, England
c. School of Health Studies, University of Bradford, Bradford, England
d. School of Sports, Performing Arts and Leisure, University of Wolverhampton, Wolverhampton, England
e. Sport and Exercise Science Research Institute, University of Ulster, Newtownabbey, Co. Antrim, Northern Ireland

Corresponding Author:

Elaine Murtagh
Department of Arts Education and Physical Education,
Mary Immaculate College, University of Limerick,
South Circular Road, Limerick, Ireland
Email: elaine.murtagh@mic.ul.ie
Tel: 00 353 61 204569

Keywords: walking, exercise, health, cardiovascular risk

Word count: 3,864 (not including abstract or references)

ABSTRACT

Objective: To conduct a systematic review and meta-analysis of randomised control trials that examined the effect of walking on risk factors for cardiovascular disease.

Methods: Four electronic databases and reference lists were searched (Jan 1971–June 2012). Two authors identified randomised control trials of interventions $\geq$ 4 weeks duration that included at least one group with walking as the only treatment and a no-exercise comparator group. Participants were inactive at baseline. Pooled results were reported as weighted mean treatment effects and 95% confidence intervals using a random effects model.

Results: 32 articles reported the effects of walking interventions on cardiovascular disease risk factors. Walking increased aerobic capacity (3.04mL/kg/min, 95% CI 2.48 to 3.60) and reduced systolic (-3.58mmHg, 95% CI -5.19 to -1.97) and diastolic (-1.54mmHg, 95% CI -2.83 to -0.26) blood pressure, waist circumference (-1.51cm, 95% CI -2.34 to -0.68) , weight (-1.37kg, 95% CI -1.75 to -1.00), percentage body fat (-1.22%, 95% CI -1.70 to -0.73) and body mass index (-0.53kg/m^2, 95% CI -0.72 to -0.35) but failed to alter blood lipids.

Conclusions: Walking interventions improve many risk factors for cardiovascular disease. This underscores the central role of walking in physical activity for health promotion.

INTRODUCTION

Physical inactivity is the fourth leading cause of global mortality (World Health Organisation, 2009) responsible for 6-10% of the major non-communicable diseases of coronary heart disease, type 2 diabetes, and breast and colon cancer (Lee et al., 2012). Whilst sport, running and vigorous gym based exercise are often seen as counter measures, walking offers a natural, widely accepted, low cost, low injury risk (Hootman et al., 2001), environmentally friendly approach to physical activity which can be incorporated into activities of daily living and/or undertaken recreationally. Walking is also likely to be more accessible and suitable to a considerable portion of the higher-risk population who may be obese, sedentary, at high risk of cardiovascular disease and for whom strenuous forms of exercise may be unsuitable. Walking at a self-selected pace is moderate intensity for most adults (Ainsworth et al., 2000; Murtagh et al., 2002). Indeed it is estimated that walking at 3mph would be vigorous intensity for approximately 20% of the population (Kelly et al., 2011). Systematic reviews have indicated that inactive people can be encouraged to walk more by tailored interventions (Ogilvie et al., 2007) and the National Institute for Health and Clinical Excellence have recently produced guidelines to promote walking for travel and recreational purposes (National institute for Health and Clinical Excellence, 2012).

Whilst it is unsurprising that walking has become a cornerstone of physical activity promotion strategies, a challenge faced by healthcare professionals and patients is knowing the effects of walking on health, especially as many published walking interventions employ relatively small samples and findings are often inconsistent between studies. Conversely, the use of meta-analysis increases the precision and accuracy of the estimates of the effects of walking, quantifies the inconsistency between studies and enhances generalizability to a larger population. We previously reported a meta-analysis of walking interventions published up to 2004, that included aerobic fitness, blood pressure, and body composition (Murphy et al., 2007). Since then there has been an increase in the number of published interventions examining the effects of walking on risk factors for cardiovascular disease. In addition, an increased range of outcome measures have been included in these studies, such as blood lipids and several measures of adiposity. While there is now greater evidence of the concomitant dangers of these factors to public health (Physical Activity Guidelines Advisory Committee, 2008) a recent comprehensive synthesis of evidence from randomised control trials on the effect of walking on health is lacking. This updated meta-analysis therefore expands our understanding of the treatment-effect relationship between walking and health.

The objective of this study was to assess the effect of walking interventions on risk factors for cardiovascular disease in previously inactive adults. This updates our previous review and provides healthcare professionals with a synthesis of the effects accruing when inactive adults undertake a walking programme.

METHODS

We followed the PRISMA statement (preferred reporting items for systemic reviews and meta-analyses) in conducting and reporting the meta-analysis (Moher et al., 2009). A review protocol has not been published separately.

Data sources and searches

The following electronic databases were searched: PubMed, Web of Science, ScienceDirect and the Cochrane Central Register of Controlled Trials. In addition, we hand-searched reference lists from review and original articles. Authors were contacted, if necessary, to confirm eligibility criteria. The following search terms were used: walking, exercise, health, cardiovascular risk. Date limits of Sept 2004 – Sept 2012 were applied.

Study selection

The study selection process is summarised in figure 1. Initial eligibility assessment was performed by one author by reviewing the title and abstracts. The full text versions of 48 articles were then reviewed independently by two authors. Disagreements between reviewers were resolved by consensus by reassessing each of the eligibility criteria for the study.

The following eligibility criteria were used: randomised, controlled trials studying the effect of walking on one or more cardiovascular risk factors; trials with at least one group who completed walking as the only intervention; training for a minimum of four weeks; no-exercise control group; participants aged 18 years or older who were reported as being apparently sedentary but otherwise healthy at baseline; selected cardiovascular disease risk factors assessed pre- and post-intervention (or change from pre- to post-intervention reported); English language articles published in peer-reviewed journals between January 1971 and June 2012.

Data extraction and quality assessment

We used a modified version of the data extraction sheet developed for the previous meta-analysis. Two individuals extracted the data from included studies and a second author checked the extracted data. Disagreements were resolved by consensus. Two of the selected studies were suspected to be reports from the same participants - this was confirmed by contacting the authors. The authors of eight articles were contacted for further information (Aldred and Rohalu, 2011; Baker et al., 2008; Osei-Tutu and Campagna, 2005; Stensel et al., 1994; Stensel et al., 1993; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011). All responded and provided numerical data (Aldred and Rohalu, 2011; Osei-Tutu and Campagna, 2005; Tully et al., 2005; Tully et al., 2007) or clarifications regarding the study protocol (Aldred and Rohalu, 2011; Baker et al., 2008; Stensel et al., 1994; Stensel et al., 1993) that were not detailed in the published paper. Previously unpublished numerical data was obtained from the original researchers of three articles (Osei-Tutu and Campagna, 2005; Tully et al., 2005; Tully et al., 2007).

The previous meta-analysis extracted data on:

1) Participant characteristics (age, sex, number of men and women)
2) Intervention characteristics (duration, frequency, intensity of walking, duration of the intervention)
3) Outcome measures (aerobic fitness, body weight, body fat percentage, body mass index, systolic blood pressure and diastolic blood pressure).
4) Study design

In addition to the above items, the following outcome measures were extracted from all included studies: total cholesterol, HDL cholesterol, LDL cholesterol, waist circumference, waist-to-hip ratio.

The Cochrane Collaboration 'risk of bias' assessment tool was employed. Two authors, with adequate reliability, evaluated studies for sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting and other potential threats to validity (Higgins et al., 2011).

Data synthesis and statistical analysis

Treatment effect was calculated by subtracting pre-intervention mean from the post-intervention mean (post – pre) for both exercise (delta 1) and control (delta 2) groups.

Treatment effect was then obtained as delta 1 – delta 2 for each study. Six studies reported data on standard deviation of change between pre- and post-intervention measurements (Butcher et al., 2008; Murphy and Hardman, 1998; Murphy et al., 2006; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011). If not reported, standard deviation of the individual delta values were calculated using pre- and post- standard deviations and the mean pre/post correlation from studies which reported sufficient detail to calculate correlation (Higgins JPT et al., 2011). To assess the effect of this assumption, sensitivity analyses were performed using minimum and maximum available pre-post correlations. In trials that had more than two intervention arms the description of the interventions were checked to ensure they only varied in the level of exercise undertaken and if so all intervention arms were collapsed into a single treatment arm (Higgins JPT and Deeks JJ, 2011).

Seven studies reported weight and height as outcomes but did not report body mass index (Braith et al., 1994; Duncan et al., 1991; Hinkleman and Nieman, 1993; Moreau et al., 2001; Osei-Tutu and Campagna, 2005; Santiago et al., 1995; Woolf-May et al., 2011). For these studies, an approximation for the mean and standard deviation of body mass index was derived using formulae for the product and ratio of random variables (Stuart and Ord, 1987). A sensitivity analysis was performed on the body mass index outcome by including and excluding these approximated data. Similarly, waist-to-hip ratio was approximated using separately reported waist and hip circumference data from the three studies (Anderson et al., 2006; Murtagh et al., 2005; Serwe et al., 2011).

Pooled results were reported as weighted mean treatment effects and 95% confidence intervals using a random effects model (DerSimonian and Laird method(DerSimonian and Laird, 1986)). Statistical heterogeneity was evaluated using the I^2 statistic. Publication bias was appraised by visual inspection of the funnel plots of treatment effect against standard error (to identify asymmetry, which can indicate evidence of non-publication of small trials with negative results) and also by Egger's test (Egger et al., 1997). To investigate possible sources of heterogeneity across studies we performed a meta-regression analysis to investigate the effects of the following study specific characteristics on treatment effect: mean age of participants, mean pre-intervention weight, gender (proportion of male participants) and duration of intervention. A p-value <0.05 was considered statistically significant. All analyses were conducted using Stata, Version 12 (StataCorp, College Station, TX).

RESULTS

Study selection

A total of 210 articles were identified by electronic searches and 16 articles from hand-searching. Thirty one duplicates were then excluded. After reviewing the title and abstract of the 195 articles identified, 150 were excluded as they did not meet the inclusion criteria. The full text versions of 45 articles were then reviewed. Fifteen studies were deemed eligible for inclusion in the study and combined with studies reported in our previous meta-analysis (Murphy et al., 2007) (n=17). Therefore in total 32 articles are included in this systemic review and updated meta-analysis. See figure 1 for further information. Two articles reported different outcomes measures from the same subjects in a larger study (Stensel et al., 1994; Stensel et al., 1993) and so the results from these two articles were combined to represent one study in the meta-analysis.

Study characteristics

All studies selected for this review are randomised controlled trials published in English. Subject and intervention characteristics are summarised in table 1. Participates ranged in age from 30 to 83 years. Sixteen studies include females only, 14 included both males and females and three included males only. The mean length of the walking interventions was 18.7 weeks (range: 8 – 52 weeks). Duration of walking per day was 20 – 60 minutes on 2 – 7 days per week. Twenty one studies reported exercise intensity as either percentage of maximum heart rate (range: 56-86 % HR_{max}), percentage of VO_{2max} or VO_{2peak} (45-62%), or percentage heart rate reserve (54-85 %). Using the generally accepted definition of moderate intensity exercise as 64-76% HR_{max} / 46-63% VO_{2max} / 40-59% HRR (Ewing Garber et al., 2011), 19 of these studies included a moderate intensity walking group (Aldred et al., 1995; Aldred and Rohalu, 2011; Anderson et al., 2006; Asikainen et al., 2002a; Asikainen et al., 2002b; Duncan et al., 1991; Hamdorf and Penhall, 1999; Hinkleman and Nieman, 1993; Jette et al., 1988; Murphy and Hardman, 1998; Murtagh et al., 2005; Osei-Tutu and Campagna, 2005; Probart et al., 1991; Ready et al., 1995; Ready et al., 1996; Santiago et al., 1995; Stensel et al., 1994; Stensel et al., 1993; Woolf-May et al., 1999). Three studies incorporated a vigorous intensity (Ewing Garber et al., 2011) walking group (Braith et al., 1994; Duncan et al., 1991; Serwe et al., 2011) and three studies included a light intensity group (Asikainen et al., 2002a; Duncan et al., 1991; Murphy et al., 2006). Additionally, five studies reported that walking was self-paced (Bell et al., 2010; Butcher et al., 2008; Moreau et al., 2001; Morgan

et al., 2010; Simons and Andel, 2006) and four noted that walking intensity was at a brisk pace (Baker et al., 2008; Brandon and Elliott-Lloyd, 2006; Tully et al., 2005; Tully et al., 2007). It was a criterion for inclusion that studies included a no-exercise control group. All authors were contacted to confirm the data extracted in the study characteristics table and responses were received from the authors of 21 articles.

Table 2 describes the number of studies and participants and summary baseline values for all outcome measurements. Also shown in this table are the weighted mean treatment effect and its 95% confidence interval, % change from baseline, I^2 and Egger's test bias coefficients. For each outcome there is a separate appendix containing a table of results from the individual studies pooled, a forest plot and a funnel plot (appendices 1 – 11). Appendix 12 details the results of meta-regression analyses of treatment effect against mean age of participants, mean pre-intervention weight, proportion of male participants and duration of intervention. A summary of the effect of the walking intervention on each outcome variable is given below.

Table 1: Characteristics of included studies examining the effect of walking interventions on risk factors for cardiovascular disease

	Participants				Details of Intervention				
	Groups	**n**	**Age (mean ± SD)**	**Sex**	**No. of weeks**	**Duration (min/session)**	**Freq (days/wk)**	**Intensity**	**Notes**
Jette et al. (1988)	walk con	13 13		14m 12f		30	3	60% VO_{2max}	
Duncan et al. (1991)	stroll brisk aerobic con	18 12 16 13	20-40	f	24	60 45 36	5 5 5	56% HRmax 67% HRmax 86% HRmax	
Probart et al. (1991)	walk con	10 6	72.0 ± 1.9 72.0 ± 1.7	f	26	20	3	70% HRmax	
Hinkleman and Nieman (1993)	walk con	18 18	36.0 ± 6.8 32.4 ± 6.4	f	15	45	5	62 ± 2 % VO_{2max}	
Braith et al. (1994)	mod high con	19 14 11	66.0 ± 5.0 65.0 ± 4.0 66.0 ± 5.0	mf	26	45 35	3 3	70HRR 80-85HRR	Duration increased by 5 mins every 2 weeks until 40 minutes. Weeks 14 – 26: 45 mins for mod and 35 for high intensity group. Both groups progressed to 70% HRR by week 8. Mod group continued at 70% for last 13 weeks. The high group progressed to 80-85HRR for last 13 weeks.
Stensel et al. (1994); Stensel et al. (1993)	walk con	42 23	50.3 ± 5.2 51.6 ± 4.8	m	52	28	7	68% HRmax	
Aldred et al. (1995)	walk con	11 13	49.6 ± 4.7 49.1 ± 4.7	f f	12	33	5.6	74% HRmax	Duration of sessions progressed from 24 ± 1 to 33 ± 1 by week12. Number of sessions progressed from 3.5 ± 0.3 to 5.6 ± 0.3 by week 12. Mean age for walk group is for the 13 subject who began the study.
Ready et al. (1995)	walk con	15 10	60.9 ± 4.6 (group mean)	f	24	54.3 ± 7.7	4.9	54% HRR	
Santiago et al. (1995)	walk con	16 11	30.1 ± 5.3 31.5 ± 6.1	f	40		4	72% HRmax	4.8 km x 4 times per week. Progressive programme: wk 3-10: 5.1 kph walk at 5% grade (68% HR_{max}); wk 11-25: 5.4 kph walk at 6% grade (71% HR_{max}); wk 26-40: 5.8 kph walk at 7% grade (76% HR_{max}).
Ready et al. (1996)	3 day 5 day con	19 17 20	61.3 ± 5.8 (group mean)	f	24	60 60	3 5	60% VO_{2peak}	
Murphy and Hardman (1998)	short long con	12 12 10	44.8 ± 8.4 48.0 ± 5.5 47.3 ± 4.1	f	10	3x10 30	5 5	73% HRmax 75% HRmax	

	Participants				Details of Intervention				
	Groups	**n**	**Age (mean ± SD)**	**Sex**	**No. of weeks**	**Duration (min/session)**	**Freq (days/wk)**	**Intensity**	**Notes**
Hamdorf and Penhall (1999)	walk con	18 20	82.4 ± 2.8 83.1 ± 3.1	f	26	25	2	73% HRmax	Duration increased progressively (1 min/week) from 5 minutes during the first week to 25 minutes by week 22
Woolf-May et al. (1999)	LW IW SW con	19 10 14 13	50.1 ± 6.3 57.7 ± 6.1 54.3 ± 7.4 54.7 ± 7.0	mf	18	34.8 ± 1.0 14.5 ± 0.8 9.9 ± 0.3	4.4 ± 0.3 10.6 ± 1.2 15.4 ± 1.2	73.4 ± 4.8 % HRmax 74.8 ± 3.8 % HRmax 74.6 ± 4.1 % HRmax	Frequency of session noted is number of sessions per week
Moreau et al. (2001)	walk con	15 9	53.0 ± 7.8 55.0 ± 3.0	f	24		7	self-paced	Goal to increase activity by 3km every day of the week
Asikainen et al. (2002a)	walk 1 walk 2 walk 3 walk 4 con	20 21 16 21 38	57.0 ± 3.8 55.0 ± 3.7 54.0 ± 3.5 55.0 ± 4.2 56.0 ± 3.8	f	24	54.0 ± 5.6 65.0 ± 7.8 38.0 ± 3.9 46.0 ± 6.2	5 5 5 5	55% VO_{2max} 45% VO_{2max} 55% VO_{2max} 45% VO_{2max}	Mean (SD) age is for subjects numbers at pre-test: W1=21, W2=21, W3=18 and W4= 21, Control = 40
Asikainen et al. (2002b)	single bout accum bout con	44 43 43	57.8 ± 4.4 57.6 ± 4.2 56.5 ± 4.2	f	15	47.9 ± 14.2 25.0 ± 3.2	5 5	65% HRmax	Daily sessions for accumulated bout groups were divided into two equally long sessions with at least a 5 hour interval
Murtagh et al. (2005)	single bout accum bout con	16 9 7	45.7 ± 9.4	15m 17f	12	20 2 x10	3	73.1 ± 8.7 % HRmax 72.1 ± 7.7 % HRmax	Mean age is for the 48 subjects who began the study.
Osei-Tutu and Campagna (2005)	long bout short bout con	15 15 10	35.1 ± 4.6 35.4 ± 8.3 31.6 ± 4.8	8m 7f 8m 7f 5m 5f	8	1x30 3x10	5	60-79 % HRmax	Progressive programme: wk 1: 30 mins x 3 days; wk2: 30 mins x 4 days; wk 3-8: 30 mins x 5 days wk
Tully et al. (2005)	walk con	21 10	55.5 ± 4.0 57.8 ± 4.6	9m 12f 4m 6f	12	30	5	brisk	Mean age is for baseline subject numbers.
Anderson et al. (2006)	walk con	10 9	38.1 ± 9.3 (all groups, n=37)	f	8	30	5	74% HRmax	Additional group not included in meta-analysis.
Brandon and Elliott-Lloyd (2006)	walk AA walk W con AA con W	15 13 12 12	34.0 ± 7.2 40.5 ± 7.1 36.0 ± 8.4 42.0 ± 9.7	f	18		3	brisk	Instruction to walk as briskly as possible for 3 miles with goal of 3.5 mph

	Participants				Details of Intervention				
	Groups	**n**	**Age (mean ± SD)**	**Sex**	**No. of weeks**	**Duration (min/session)**	**Freq (days/wk)**	**Intensity**	**Notes**
Murphy et al. (2006)	walk con	21 12	41.4 ± 7.5 40.8 ± 10.0	mf	8	45	2	62 ± 7.1 % HRmax	Progressive programme: wk 1: 25 min x 2 days; wk 2: 35 min x 2 days; wk 3 – 8: 45 min x 2 days
Simons and Andel (2006)	walk con	18 21	81.6 ± 3.3 84.0 ± 3.3	7m 11f 3m 18f	16		2	self-paced	The initial walk length and pace were determined at the beginning of the study based on a pre-assessment performance during a timed, 880-yard walk. Participants encouraged to gradually increase the distance of their walks and reduce the elapsed time.
Tully et al. (2007)	3 day 5 day con	44 42 20	47.8 ± 6.0 46.4 ± 4.8 49.1 ± 6.3	21m 23f 16m 26f 5m 15f	12	30 30	3 5	brisk	Participants could choose to complete their walking in a single bout, or in multiple bouts of at least 10 minutes. Intention-to-treat analysis performed, substituting baseline data for those at 12 weeks for the participants who withdrew during the study.
Baker et al. (2008)	walk con	39 40	47.3 ± 9.3 51.2 ± 7.9	8m 31f 8m 32f	12			Brisk	Goal to increase steps by 3,000 on at least 5 days/wk. Intention to treat analysis conducted.
Butcher et al. (2008)	walk con	17 17	44.9 ± 10.0 46.1 ± 12.2	9m 8f 9m 8f	8		3	self-paced	10,000 steps 3 times a week on treadmill
Bell et al. (2010)	walk con	43 45	m: 49 ± 11; f: 50 ± 9	mf	24		7	self-paced	Progressive increase to 9221 ± 1429 steps per day by wk 17
Morgan et al. (2010)	walk con	14 15	57.4 ± 6.5 62.1 ± 4.0	3m 11f 4m 11f	15		7	self-paced	Progressive increase to 10,000 steps per day by wk 3 and maintained for additional 12 weeks
Aldred and Rohalu (2011)	walk con	12 9	68.1 ± 2.6 67.7 ± 2.9	6m 6f 4m 5f	8	30	3	50% Wmax	
Serwe et al. (2011)	SB LB con	20 20 20	38.2 ± 7.3 37.1 ± 7.2 36.3 ± 8.1	f	8	30 10 x 3	5	60-70 HRR	
Woolf-May et al. (2011)	walk con	29 19	54.9 ± 8.0 52.4 ± 8.0	m m	24	25.1 ± 10.3	7.2 ± 2.9	65.2 ± 6.9 % HRmax	Frequency of session noted is number of sessions per week

Abbreviations: Accum = accumulated, AA=African American, Con = control group, f = female, HRmax = maximum heart rate, HRR = heart rate reserve, IW = intermediate walkers, LW = long walkers, m = males, mins = minutes, mod = moderate, SW = short walkers, VO_{2max} = maximal oxygen consumption, VO_{2peak} = peak oxygen consumption, W = White, walk = walk group, Wmax = maximal performance

Databases were searched for articles published between Jan 1971 and June 2012.

Note: Subject numbers are those included in the analysis unless otherwise stated.

Table 2: Pre-intervention mean (SD) and weighted mean treatment effect by outcome

				Pooled analysis				Heterogeneity		Egger's test	
Outcome	**No. of studies**	**No. of participants**	**Mean (SD)**	**Weighted mean TE**	**(95% CI)**	**p**	**% change**	**I^2 (%)**	**p**	**Bias coefficient**	**p**
VO_{2max} (ml/kg/min)	18	894	29.02 (5.19)	3.04	(2.48 to 3.60)	<0.001	10.5	71	<0.001	0.47	0.45
BMI (kg/m^2)	23	1,201	27.15 (5.01)	-0.53	(-0.72 to -0.35)	<0.001	-2.0	70	<0.001	-1.56	0.005
Systolic BP (mm Hg)	16	816	124.66 (14.50)	-3.58	(-5.19 to -1.97)	<0.001	-2.9	39	0.05	-0.91	0.29
Diastolic BP (mm Hg)	16	806	77.54 (9.52)	-1.54	(-2.83 to -0.26)	0.02	-2.0	29	0.13	-0.60	0.63
Total cholesterol (mmol/L)	16	758	5.58 (1.07)	-0.12	(-0.27 to 0.04)	0.14	-2.2	42	0.04	-0.09	0.94
HDL cholesterol (mmol/L)	15	725	1.35 (0.47)	0.01	(-0.04 to 0.07)	0.65	0.7	0	0.47	0.05	0.95
LDL cholesterol (mmol/L)	14	664	3.72 (1.00)	-0.05	(-0.17 to 0.07)	0.39	1.3	0	0.59	0.22	0.79
Waist circumference (cm)	11	574	90.56 (14.15)	-1.51	(-2.34 to -0.68)	<0.001	-1.7	38	0.10	2.27	0.02
Waist-to-hip ratio	14	706	0.85 (0.10)	-0.01	(-0.02 to 0.00)	0.07	-1.2	60	0.001	1.04	0.28
Body weight (kg)	25	1,275	75.40 (14.75)	-1.37	(-1.75 to -1.00)	<0.001	-1.8	66	<0.001	-1.75	0.001
Body fat (%)	14	719	34.29 (6.07)	-1.22	(-1.70 to -0.73)	<0.001	-3.5	68	<0.001	-0.78	0.38

VO_{2max} = maximal oxygen consumption, BMI = body mass index

Databases were searched for articles published between Jan 1971 and June 2012.

Aerobic fitness

Observed VO_{2max}, predicted VO_{2max} and VO_{2peak} were utilised as the outcome measure of aerobic fitness. Twelve studies reported VO_{2max} (Aldred and Rohalu, 2011; Asikainen et al., 2002a; Asikainen et al., 2002b; Braith et al., 1994; Duncan et al., 1991; Hinkleman and Nieman, 1993; Jette et al., 1988; Murphy and Hardman, 1998; Osei-Tutu and Campagna, 2005; Probart et al., 1991; Ready et al., 1995; Santiago et al., 1995), four reported predicted VO_{2max} (Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Woolf-May et al., 1999; Woolf-May et al., 2011) and two reported VO_{2peak} (Bell et al., 2010; Ready et al., 1996). There was a statistically significant improvement in VO_{2max} of 3.04 mL/kg/min (95% CI 2.48 to 3.60) in the participants who followed the walking intervention. There was, however, evidence of significant heterogeneity between the results (I^2=71%, p<0.001).

Anthropometric measures

Sixteen trials examined the effect of walking on body mass index (Aldred and Rohalu, 2011; Anderson et al., 2006; Asikainen et al., 2002a; Asikainen et al., 2002b; Baker et al., 2008; Bell et al., 2010; Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Murphy et al., 2006; Probart et al., 1991; Ready et al., 1995; Ready et al., 1996; Serwe et al., 2011; Stensel et al., 1994; Tully et al., 2005; Tully et al., 2007) and a further seven trials reported height and weight, allowing body mass index to be approximated (Braith et al., 1994; Duncan et al., 1991; Hinkleman and Nieman, 1993; Moreau et al., 2001; Osei-Tutu and Campagna, 2005; Santiago et al., 1995; Woolf-May et al., 2011). The pooled effect of the walking intervention was a statistically significant reduction in body mass index of 0.53 kg/m^2 (95% CI -0.72 to -0.35). A sensitivity analysis considering only those studies which reported body mass index directly as an outcome found a similar estimate of effect (0.49 kg/m^2 reduction (95% CI -0.70 to -0.27)). There was substantial heterogeneity between the studies (I^2=70%, p<0.001). The funnel plot showed some asymmetry indicating that smaller studies which found an increase in body mass index in the intervention group appeared to be absent (Egger's test, p=0.005).

Eleven studies measured waist circumference (Anderson et al., 2006; Baker et al., 2008; Bell et al., 2010; Murphy and Hardman, 1998; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1996; Serwe et al., 2011; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011). Overall a significant reduction of 1.51 cm (95% CI -2.34 to -0.68) was found when the studies were pooled. The funnel plot showed some asymmetry indicating an absence of smaller studies (Egger's test, p=0.02).

Waist-to-hip ratio was an outcome in eleven trials (Aldred et al., 1995; Baker et al., 2008; Bell et al., 2010; Brandon and Elliott-Lloyd, 2006; Murphy et al., 2006; Ready et al., 1995; Ready et al., 1996; Stensel et al., 1994; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011) and a further three trials gave enough information for this outcome to be approximated (Anderson et al., 2006; Murtagh et al., 2005; Serwe et al., 2011). A small non-significant reduction in waist-to-hip ratio of 0.01 (95% CI -0.02 to 0.00) was found. A sensitivity analysis of only those trials directly reporting waist-to-hip ratio found a similar estimate of effect (-0.01 (95% CI -0.02 to 0.00)). There was substantial heterogeneity between studies (I^2=60%, p<0.001).

Twenty-five studies presented data on body weight (Aldred et al., 1995; Aldred and Rohalu, 2011; Anderson et al., 2006; Asikainen et al., 2002a; Asikainen et al., 2002b; Baker et al., 2008; Bell et al., 2010; Braith et al., 1994; Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Duncan et al., 1991; Hinkleman and Nieman, 1993; Moreau et al., 2001; Murphy and Hardman, 1998; Murphy et al., 2006; Murtagh et al., 2005; Osei-Tutu and Campagna, 2005; Ready et al., 1995; Ready et al., 1996; Santiago et al., 1995; Serwe et al., 2011; Stensel et al., 1994; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011). With the exception of one study (Baker et al., 2008), all reported a negative treatment effect (intervention group lost more or gained less weight than the control group). Pooling of the data resulted in an overall reduction in body weight of 1.37 kg (95% CI -1.75 to -1.00) in those participating in a walking intervention. There was significant heterogeneity between studies (I^2=66%, p<0.001). Meta-regression analyses found that studies of only female participants had a greater overall treatment effect (-1.96 kg, (95% CI -2.52 to -1.37)) than those studies including some male participants (-0.71 kg (95% CI -1.04 to -0.37)), although substantial heterogeneity remained for the female only studies. There was also evidence of publication bias indicating that studies reporting a positive treatment effect (greater weight gain in the treatment group) may be less likely to reach publication.

Data for the effect of walking on body fat percentage was available from fourteen trials (Anderson et al., 2006; Asikainen et al., 2002a; Asikainen et al., 2002b; Baker et al., 2008; Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Duncan et al., 1991; Hinkleman and Nieman, 1993; Moreau et al., 2001; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1995; Santiago et al., 1995; Stensel et al., 1994). Pooling of these data found an overall

reduction in body fat of 1.22% (95% CI -1.70 to -0.73). There was substantial heterogeneity between studies (I^2=68%, p<0.001).

Blood pressure

The weighted mean treatment effect of the sixteen trials which measured systolic blood pressure (Baker et al., 2008; Bell et al., 2010; Braith et al., 1994; Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Duncan et al., 1991; Hamdorf and Penhall, 1999; Murphy and Hardman, 1998; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1996; Serwe et al., 2011; Simons and Andel, 2006; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011) was -3.58 mmHg (95% CI -5.19 to -1.97) indicating a reduction in systolic blood pressure in those who followed a program of walking. Diastolic blood pressure was also reported by sixteen studies (Baker et al., 2008; Bell et al., 2010; Braith et al., 1994; Brandon and Elliott-Lloyd, 2006; Butcher et al., 2008; Duncan et al., 1991; Hamdorf and Penhall, 1999; Moreau et al., 2001; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1996; Serwe et al., 2011; Simons and Andel, 2006; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 2011) and the weighted mean treatment effect of the walking intervention was a significant reduction of 1.54 mmHg (95% CI -2.83 to -0.26).

Lipids

Data on the effect of walking on total cholesterol were available from sixteen studies (Baker et al., 2008; Bell et al., 2010; Butcher et al., 2008; Duncan et al., 1991; Hinkleman and Nieman, 1993; Morgan et al., 2010; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1995; Ready et al., 1996; Santiago et al., 1995; Stensel et al., 1993; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 1999; Woolf-May et al., 2011), HDL cholesterol from fifteen studies (Baker et al., 2008; Bell et al., 2010; Butcher et al., 2008; Duncan et al., 1991; Morgan et al., 2010; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1995; Ready et al., 1996; Santiago et al., 1995; Stensel et al., 1993; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 1999; Woolf-May et al., 2011), and LDL cholesterol from fourteen studies (Bell et al., 2010; Butcher et al., 2008; Duncan et al., 1991; Hinkleman and Nieman, 1993; Murphy et al., 2006; Murtagh et al., 2005; Ready et al., 1995; Ready et al., 1996; Santiago et al., 1995; Stensel et al., 1993; Tully et al., 2005; Tully et al., 2007; Woolf-May et al., 1999; Woolf-May et al., 2011). None of the pooled treatment effects for blood lipid outcomes were statistically significant. There was no evidence of publication bias, nor was any between-study heterogeneity found.

For all outcomes, sensitivity analyses to assess the impact of the correlation coefficient used for imputing standard deviation of change score did not result in any variation in significance of the pooled treatment effect. Similarly, meta-regression analyses were conducted to assess whether heterogeneity could be explained by age, baseline weight, gender or duration of intervention. With the exception of body weight, where a gender effect was found to explain some of the heterogeneity, the majority of the slope parameters were found to be non-significant (see appendix 12).

Risk of bias of individual studies

Details of the risk-of-bias assessment appear in Table 3. Only two studies were judged to be at low risk of bias. Many studies did not provide sufficient information to make firm judgements about bias.

Table 3. Assessment of risk of bias

Trial	Adequate sequence generation?	Allocation concealment?	Blinding?	Incomplete outcome data addressed?	Free of selective reporting?	Free of other bias?
Jette et al. (1988)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Duncan et al. (1991)	Unclear	Unclear	Unclear	No	Yes	Yes
Probart et al. (1991)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Hinkleman and Nieman (1993)	Unclear	Unclear	Unclear	No	Yes	Yes
Braith et al. (1994)	Unclear	Unclear	Unclear	Unclear	Yes	Yes
Stensel et al. (1994); Stensel et al. (1993)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Aldred et al. (1995)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Ready et al. (1995)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Santiago et al. (1995)	Yes	Yes	Unclear	Yes	Yes	Yes
Ready et al. (1996)	Unclear	Unclear	Unclear	No	Yes	Yes
Murphy and Hardman (1998)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Hamdorf and Penhall (1999)	Yes	Yes	Unclear	Yes	Yes	Yes
Woolf-May et al. (1999)	Unclear	Unclear	No	Unclear	Yes	Yes
Moreau et al. (2001)	Unclear	Unclear	No	Yes	Yes	Yes
Asikainen et al. (2002a)	Yes	Yes	No	Yes	Yes	Yes
Asikainen et al. (2002b)	Unclear	Unclear	Unclear	Yes	Yes	No
Murtagh et al. (2005)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Osei-Tutu and Campagna (2005)	Unclear	Unclear	No	Yes	Yes	Yes
Tully et al. (2005)	Yes	Yes	Yes	Yes	Yes	Yes
Anderson et al. (2006)	Yes	Unclear	Unclear	Yes	Yes	Yes
Brandon and Elliott-Lloyd (2006)	Unclear	Unclear	Unclear	Unclear	Yes	Yes
Murphy et al. (2006)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Simons and Andel (2006)	Unclear	Unclear	Yes	Yes	Yes	Yes
Tully et al. (2007)	Yes	Yes	No	Yes	Yes	Yes
Baker et al. (2008)	Yes	Yes	Yes	Yes	Yes	Yes
Butcher et al. (2008)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Bell et al. (2010)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Morgan et al. (2010)	Unclear	Unclear	Unclear	Yes	Yes	Yes
Aldred and Rohalu (2011)	Unclear	Unclear	Unclear	Unclear	No	Yes
Serwe et al. (2011)	Unclear	Unclear	No	Yes	Yes	Yes
Woolf-May et al. (2011)	Yes	Yes	Unclear	Unclear	Yes	Yes

Databases were searched for articles published between Jan 1971 and June 2012.

DISCUSSION

This updated systematic review and meta-analysis suggests that walking programmes improve several markers of cardiovascular risk, including aerobic capacity, systolic and diastolic blood pressure, and adiposity (waist circumference, body mass, percentage body fat and body mass index) in previously inactive but apparently healthy adults. However there was no evidence of changes in total cholesterol, HDL cholesterol, LDL cholesterol or waist-to-hip ratio. In this updated meta-analysis we analysed five additional outcome variables not included in our earlier publication (Murphy et al., 2007), namely total cholesterol, HDL cholesterol, LDL cholesterol, waist-to-hip ratio and waist circumference, and identified an additional 15 relevant studies. Overall, this body of evidence supports the role of walking as a central feature of individual and population health promoting strategies to ameliorate the escalating global burden of cardiovascular disease.

Aerobic fitness

Aerobic fitness is an independent risk factor for cardiovascular disease and a stronger risk factor than physical activity alone (Blair et al., 2001; Blair and Jackson, 2001). VO_{2max}, considered the "gold standard" for the assessment of aerobic fitness (Murphy et al., 2007), was measured or predicted in 18 of the studies included and showed a significant weighted mean treatment effect (TE) of 3.04 ml/kg/min. Consequences of improvement in aerobic capacity include greater ease of performance of everyday physical activities and improved quality of life for the individual (Murphy et al., 2007). From a population perspective an improvement of this magnitude (approx 10%) is likely to result in a 15% reduction in mortality (Dunn et al., 1999), irrespective of the baseline fitness level (Blair et al., 1995). Healthcare professionals should be mindful however that walking needs to be of at least moderate intensity (64-76% HR max) (American College of Sports Medicine, 2010) in order to improve aerobic fitness . Evidence has demonstrated that even greater fitness improvements can be attained from walking at vigorous intensity (Duncan et al., 1991; Nicklas et al., 2009).

Blood pressure

Hypertension is a major risk factor for cardiovascular disease (Egan et al., 2010). A significant reduction in systolic blood pressure of 3.58mm Hg and in diastolic blood pressure of 1.54 mm Hg was observed in this meta-analysis. This weighted mean treatment effect is similar to findings of an earlier meta-analysis focussing on walking and resting blood

pressure (Kelley et al., 2001). A previous prospective study reported that a 2mm Hg reduction in systolic blood pressure would result in 10% lower stroke mortality and 7% lower mortality from ischaemic heart disease or other vascular causes in middle age (Prospective Studies Collaboration, 2002), thus highlighting the clinical significance of even small changes in resting blood pressure. Given that hypertension has wide-scale population prevalence, affecting approximately 19 – 32% of men and women in UK (Maryon-Davis, 2005) and 29% of US adults (Egan et al., 2010), policy makers should consider the central role walking could play in population blood pressure control strategies.

Lipids

Elevated total cholesterol levels have been associated with coronary heart disease mortality (Menotti and Lanti, 2003) and also found to be independently predictive of ischemic heart disease (Yarnell et al., 2001). In the current review 16 studies reported total cholesterol and a non-significant weighted mean treatment effect of - 0.12 mmol/L was found. The weighted mean treatment effect for HDL cholesterol of 0.01 mmol/L did not reach statistical significance, which may be linked to the optimal mean pre-intervention values of these subjects (Expert Panel on Detection Evaluation and Treatment of High Blood Cholesterol in Adults, 2001). While HDL cholesterol levels are strongly, independently and inversely associated with coronary heart disease (Cooney et al., 2009), evidence from a systematic review and regression analysis suggests that simply increasing the amount of circulating HDL cholesterol does not reduce the risk of coronary heart disease events, coronary heart disease deaths, or total deaths (Briel et al., 2009). Existing evidence supports reduction in LDL cholesterol as the primary goal for lipid modifying interventions (Briel et al., 2009; Expert Panel on Detection Evaluation and Treatment of High Blood Cholesterol in Adults, 2001). LDL cholesterol was reported in 14 studies in this meta-analysis, however the mean TE of -0.05 mmol/L was not significant. Some authors have suggested that changes in apolipoprotiens A or B may reduce cardiovascular risk by increasing the LDL-C particle size without changing LDL levels and therefore monitoring apolipoproteins rather than just the cholesterol of lipoproteins might be a more sensitive measure of exercise induced changes in lipoprotein function (Holme et al., 2007).

Anthropometric measures

Obesity is a major influence on the development of cardiovascular diseases (Kumanyika et al., 2008). Several measures of overweight and obesity were utilised in the studies included in

this review and significant effects were observed for body mass, percentage body fat, body mass index and waist circumference. The mean decrease in body mass and percentage body fat of 1.37kg and 1.22% respectively was significant and reinforces the critical role that walking can play in the management of overweight. Body mass index, a strong predictor of overall mortality both above and below the apparent optimum of about 22.5–25 kg/m^2 (Prospective Studies Collaboration, 2009), demonstrated a TE of -0.53 km/m^2. Waist circumference, which may be the best single indicator of other individual and multiple cardiovascular risk factors (Dobbelsteyn et al., 2001), also demonstrated a significant TE of -1.51cm. Although the treatment effect observed in waist circumference may be small, a previous meta-regression analysis of prospective studies demonstrated that a 1cm increase in waist circumference was associated with a 2% increase in the relative risk of a cardiovascular disease event (de Koning et al., 2007). So even small improvements in waist circumference resulting from walking interventions may have substantial public health gains.

Limitations

While this meta-analysis provides useful updated information for healthcare providers and policy-makers, the results should be interpreted with the following limitations in mind. First, this meta-analysis pooled data from several studies in order to calculate mean weighted treatment effects. However the walking intervention employed, in terms of dose of exercise and support provided, is not the same across studies. Second, risk of bias, assessed using the Cochrane Collaboration assessment tool (Higgins et al., 2011), revealed that many studies did not provide sufficient information to make firm judgements about bias. Third, observed changes in cardiovascular risk factors may be mediated by a change in another risk factor. For example change in VO_{2max} measured per unit of body mass may be affected by change in body mass therefore the impact of the intervention on a single outcome measure is difficult to isolate. Fourth, the search strategy was restricted to English-language publications. Fifth, several studies did not fully report outcomes of interest and not all authors who were contacted for further information provided missing data. Additionally, for many of the studies standard deviation of change from baseline was not reported and these data were imputed using the mean correlation coefficient from the available data. Sensitivity analyses were performed using a range of correlation coefficients which did not show any changes to the pooled effect sizes. Sixth, publication bias was evident for some outcomes including body mass index, weight and waist circumference. Asymmetrical funnel plots suggested that there was an absence of small studies with negative findings (favouring the control group). Finally

the majority of subjects in the studies were middle-aged and female. While this may reflects the appeal that this form of physical activity has for women (Murphy et al., 2007), the applicability of these findings to a male populations may therefore be limited.

Conclusions

Our findings confirm the important role that regular walking can play in the prevention of cardiovascular disease. The meta-analysis revealed positive changes for multiple cardiovascular disease risk factors, including aerobic fitness, systolic and diastolic blood pressure, and several measures of adiposity in previously inactive adults who walked as part of a randomised controlled trial. Clinicians and health-care providers can prescribe walking with confidence that it will evoke health benefit. As in our previous meta-analysis, few studies have investigated the effects of walking interventions on non-traditional cardiovascular disease risk factors, such as markers of inflammation, oxidative stress and coagulation (Murphy et al., 2007). Future research should incorporate these measures and further examine the effect of walking in specific populations including ethnic minorities and older adults. The results and recommendations of this meta-analysis are of relevance for health professionals involved in the primary prevention of cardiovascular disease and should underscore the central role of walking as a cornerstone in physical activity for health promotion.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest

Acknowledgements

Funding was received from the Mary Immaculate College Research Directorate Seed-funding scheme for assistance with data extraction. This funder had no role in the study.

References

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., O'Brien, W.L., Bassett JR, D.R., Schmitz, K.H., et al., 2000. Compendium of Physical Activities: an update of activity codes and MET intensities. Med. Sci. Sports Exerc. 32:498-516.

Aldred, H.E., Hardman, A.E., Taylor, S., 1995. Influence of 12 Weeks of Training by Brisk Walking on Postprandial Lipemia and Insulinemia in Sedentary Middle-Aged Women. Metabolism-Clinical and Experimental 44:390-97.

Aldred, S., Rohalu, M., 2011. A moderate intensity exercise program did not increase the oxidative stress in older adults. Arch. Gerontol. Geriatr. 53:350-53.

American College of Sports Medicine, 2010. ACSM's Guidelines for Exercise Testing and Prescription, 8th ed. Lippincott Williams & Wilkins, Philadelphia.

Anderson, A.G., Murphy, M.H., Murtagh, E., Nevill, A., 2006. An 8-week randomized controlled trial on the effects of brisk walking, and brisk walking with abdominal electrical muscle stimulation on anthropometric, body composition, and self-perception measures in sedentary adult women. Psychology of Sport & Exercise 7:437-51.

Asikainen, T.M., Miilunpalo, S., Oja, P., Rinne, M., Pasanen, M., Uusi-Rasi, K., Vuori, I., 2002a. Randomised, controlled walking trials in postmenopausal women: the minimum dose to improve aerobic fitness? Br. J. Sports Med. 36:189-94.

Asikainen, T.M., Miilunpalo, S., Oja, P., Rinne, M., Pasanen, M., Vuori, I., 2002b. Walking trials in postmenopausal women: effect of one vs two daily bouts on aerobic fitness. Scand. J. Med. Sci. Sports 12:99-105.

Baker, G., Gray, S., Wright, A., Fitzsimons, C., Nimmo, M., Lowry, R., Mutrie, N., 2008. The effect of a pedometer-based community walking intervention" Walking for Wellbeing in the West" on physical activity levels and health outcomes: a 12-week randomized controlled trial. The International Journal of Behavioral Nutrition and Physical Activity 5:44.

Bell, G.J., Harber, V., Murray, T., Courneya, K.S., Rodgers, W., 2010. A Comparison of Fitness Training to a Pedometer-Based Walking Program Matched for Total Energy Cost. J. Phys. Act. Health 7:203-13.

Blair, S.N., Cheng, Y., Holder, J.S., 2001. Is physical activity or physical fitness more important in defining health benefits? Med. Sci. Sports Exerc. 33:S379-S99.

Blair, S.N., Jackson, A.S., 2001. Editorial: Physical fitness and activity as separate heart disease risk factors: a meta-analysis. Med. Sci. Sports Exerc. 33:762-64.

Blair, S.N., Kohl, H.W., Barlow, C.E., Paffenbarger, R.S., Gibbons, L.W., Macera, C.A., 1995. Changes in Physical-Fitness and All-Cause Mortality - a Prospective-Study of Healthy and Unhealthy Men. Jama-Journal of the American Medical Association 273:1093-98.

Braith, R.W., Pollock, M.L., Lowenthal, D.T., Graves, J.E., Limacher, M.C., 1994. Moderate and High-Intensity Exercise Lowers Blood-Pressure in Normotensive Subjects 60 to 79 Years of Age. Am. J. Cardiol. 73:1124-28.

Brandon, L.J., Elliott-Lloyd, M.B., 2006. Walking, body composition, and blood pressure dose-response in African American and white women. Ethn. Dis. 16:675.

Briel, M., Ferreira-Gonzalez, I., You, J.J., Karanicolas, P.J., Akl, E.A., Wu, P., Blechacz, B., Bassler, D., Wei, X., et al., 2009. Association between change in high density lipoprotein cholesterol and cardiovascular disease morbidity and mortality: systematic review and meta-regression analysis. BMJ 338.

Butcher, L.R., Thomas, A., Backx, K., Roberts, A., Webb, R., Morris, K., 2008. Low-Intensity Exercise Exerts Beneficial Effects on Plasma Lipids via PPAR [gamma]. Med. Sci. Sports Exerc. 40:1263-70.

Cooney, M., Dudina, A., De Bacquer, D., Wilhelmsen, L., Sans, S., Menotti, A., De Backer, G., Jousilahti, P., Keil, U., et al., 2009. HDL cholesterol protects against cardiovascular disease in both genders, at all ages and at all levels of risk. Atherosclerosis 206:611-16.

de Koning, L., Merchant, A.T., Pogue, J., Anand, S.S., 2007. Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur. Heart J. 28:850-56.

DerSimonian, R., Laird, N., 1986. Meta-analysis in clinical trials. Control. Clin. Trials 7:177-88.

Dobbelsteyn, C., Joffres, M., MacLean, D., Flowerdew, G., 2001. A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian Heart Health Surveys. Int. J. Obes. 25:652-61.

Duncan, J.J., Gordon, N.F., Scott, C.B., 1991. Women Walking for Health and Fitness - How Much Is Enough. Jama-Journal of the American Medical Association 266:3295-99.

Dunn, A.L., Marcus, B.H., Kampert, J.B., Garcia, M.E., Kohl, H.W., Blair, S.N., 1999. Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness - A randomized trial. Jama-Journal of the American Medical Association 281:327-34.

Egan, B.M., Zhao, Y., Axon, R.N., 2010. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA: the journal of the American Medical Association 303:2043-50.

Egger, M., Smith, G.D., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. BMJ 315:629-34.

Ewing Garber, C., Blissmer, B., Deschenes, M.R., Franklin, B., Lamonte, M.J., Lee, I.-M., Nieman, D.C., Swain, D.P., 2011. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med. Sci. Sports Exerc. 43:1334-59.

Expert Panel on Detection Evaluation and Treatment of High Blood Cholesterol in Adults, 2001. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 285:2486-97.

Hamdorf, P.A., Penhall, R.K., 1999. Walking with its training effects on the fitness and activity patterns of 79-91 year old females. Aust. N. Z. J. Med. 29:22-28.

Higgins, J., Altman, D., Sterne, J., 2011. Assessing risk of bias in included studies, in: Higgins, J., Green, S. (Eds.), Cochrane Handbook for Systematic Reviews of Interventions. The Cochrane Collaboration.

Higgins JPT, Deeks JJ, 2011. Selecting studies and collecting data, in: Higgins JPT, Green S (Eds.), Cochrane Handbook for Systematic Reviews of Interventions. The Cochrane Collaboration.

Higgins JPT, Deeks JJ, Altman DG, 2011. Special topics in statistics, in: Higgins JPT, Green S (Eds.), Cochrane Handbook for Systematic Reviews of Interventions. The Cochrane Collaboration.

Hinkleman, L.L., Nieman, D.C., 1993. The Effects of a Walking Program on Body-Composition and Serum- Lipids and Lipoproteins in Overweight Women. J. Sports Med. Phys. Fitness 33:49-58.

Holme, I., Høstmark, A., Anderssen, S., 2007. ApoB but not LDL-cholesterol is reduced by exercise training in overweight healthy men. Results from the 1-year randomized Oslo Diet and Exercise Study. J. Intern. Med. 262:235-43.

Hootman, J.M., Macera, C.A., Ainsworth, B.E., Martin, M., Addy, C.L., Blair, S.N., 2001. Association among physical activity level, cardiorespiratory fitness, and risk of musculoskeletal injury. Am. J. Epidemiol. 154:251-58.

Jette, M., Sidney, K., Campbell, J., 1988. Effects of a 12-Week Walking Program on Maximal and Submaximal Work Output Indexes in Sedentary Middle-Aged Men and Women. J. Sports Med. Phys. Fitness 28:59-66.

Kelley, G.A., Kelley, K.S., Tran, Z.V., 2001. Walking and resting blood pressure in adults: a meta-analysis. Prev. Med. 33:120-27.

Kelly, P., Murphy, M., Oja, P., Murtagh, E.M., Foster, C., 2011. Estimates of the number of people in England who attain or exceed vigorous intensity exercise by walking at 3 mph. J. Sports Sci. 29:1629-34.

Kumanyika, S.K., Obarzanek, E., Stettler, N., Bell, R., Field, A.E., Fortmann, S.P., Franklin, B.A., Gillman, M.W., Lewis, C.E., et al., 2008. Population-Based Prevention of Obesity: The Need for Comprehensive Promotion of Healthful Eating, Physical Activity, and Energy Balance: A Scientific Statement From American Heart Association Council on Epidemiology and Prevention, Interdisciplinary Committee for Prevention (Formerly the Expert Panel on Population and Prevention Science). Circulation 118:428-64.

Lee, I.-M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N., Katzmarzyk, P.T., 2012. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. The Lancet 380:219-29.

Maryon-Davis, A., 2005. Hypertension – the 'Silent Killer'. Faculty of Public Health of the Royal Colleges of Physicians of the United Kingdom, London.

Menotti, A., Lanti, M., 2003. Coronary risk factors predicting early and late coronary deaths. Heart 89:19-24.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Br. Med. J. 339:332-36.

Moreau, K.L., Degarmo, R., Langley, J., McMahon, C., Howley, E.T., Bassett, D.R., Thompson, D.L., 2001. Increasing daily walking lowers blood pressure in postmenopausal women. Med. Sci. Sports Exerc. 33:1825-31.

Morgan, A.L., Tobar, D.A., Snyder, L., 2010. Walking toward a new me: the impact of prescribed walking 10,000 steps/day on physical and psychological well-being. J. Phys. Act. Health 7:299.

Murphy, M.H., Hardman, A.E., 1998. Training effects of short and long bouts of brisk walking in sedentary women. Med. Sci. Sports Exerc. 30:152-57.

Murphy, M.H., Murtagh, E.M., Boreham, C.A.G., Hare, L.G., Nevill, A.M., 2006. The effect of a worksite based walking programme on cardiovascular risk in previously sedentary civil servants. BMC Public Health 6:136.

Murphy, M.H., Nevill, A.M., Murtagh, E.M., Holder, R.L., 2007. The effect of walking on fitness, fatness and resting blood pressure: A meta-analysis of randomised, controlled trials. Prev. Med. 44:377-85.

Murtagh, E.M., Boreham, C.A.G., Murphy, M.H., 2002. Speed and exercise intensity of recreational walkers. Prev. Med. 35:397-400.

Murtagh, E.M., Boreham, C.A.G., Nevill, A., Hare, L.G., Murphy, M.H., 2005. The effects of 60 minutes of brisk walking per week, accumulated in two different patterns, on cardiovascular risk. Prev. Med. 41:92-97.

National institute for Health and Clinical Excellence, 2012. Walking and cycling: local measures to promote walking and cycling as forms of travel or recreation. NICE Public Health Guidance 41.

Nicklas, B., Wang, X., You, T., Lyles, M., Demons, J., Easter, L., Berry, M., Lenchik, L., Carr, J., 2009. Effect of exercise intensity on abdominal fat loss during calorie restriction in overweight and obese postmenopausal women: a randomized, controlled trial. Am. J. Clin. Nutr. 89:1043-52.

Ogilvie, D., Foster, C.E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C.F., Mutrie, N., 2007. Interventions to promote walking: systematic review. Br. Med. J. 334:1204-07.

Osei-Tutu, K.B., Campagna, P.D., 2005. The effects of short-vs. long-bout exercise on mood, VO2max., and percent body fat. Prev. Med. 40:92-98.

Physical Activity Guidelines Advisory Committee, 2008. Physical Activity Guidelines Advisory Committee Report, Washington, DC.

Probart, C.K., Notelovitz, M., Martin, D., Khan, F.Y., Fields, C., 1991. The Effect of Moderate Aerobic Exercise on Physical-Fitness among Women 70 Years and Older. Maturitas 14:49-56.

Prospective Studies Collaboration, 2002. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet (London, England) 360:1903-13.

Prospective Studies Collaboration, 2009. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. The Lancet 373:1083-96.

Ready, A.E., Drinkwater, D.T., Ducas, J., Fitzpatrick, D.W., Brereton, D.G., Oades, S.C., 1995. Walking Program Reduces Elevated Cholesterol in Women Postmenopause. Can. J. Cardiol. 11:905-12.

Ready, A.E., Naimark, B., Ducas, J., Sawatzky, J.A.V., Boreskie, S.L., Drinkwater, D.T., Oosterveen, S., 1996. Influence of walking volume on health benefits in women post-menopause. Med. Sci. Sports Exerc. 28:1097-105.

Santiago, M.C., Leon, A.S., Serfass, R., 1995. Failure of 40 Weeks of Brisk Walking to Alter Blood Lipids in Normolipemic Women. Can. J. Appl. Physiol. 20:417-28.

Serwe, K.M., Swartz, A.M., Hart, T.L., Strath, S.J., 2011. Effectiveness of Long and Short Bout Walking on Increasing Physical Activity in Women. J. Womens Health 20:247-53.

Simons, R., Andel, R., 2006. The effects of resistance training and walking on functional fitness in advanced old age. J. Aging Health 18:91-105.

Stensel, D.J., Brookewavell, K., Hardman, A.E., Jones, P.R.M., Norgan, N.G., 1994. The Influence of a 1-Year Program of Brisk Walking on Endurance Fitness and Body-Composition in Previously Sedentary Men Aged 42-59 Years. Eur. J. Appl. Physiol. 68:531-37.

Stensel, D.J., Hardman, A.E., Brookewavell, K., Vallance, D., Jones, P.R.M., Norgan, N.G., Winder, A.F., 1993. Brisk Walking and Serum-Lipoprotein Variables in Formerly Sedentary Men Aged 42-59 Years. Clin. Sci. 85:701-08.

Stuart, A., Ord, J., 1987. Kendall's Advanced Theory of Statistics, Volume 1: Distribution Theory, 5th ed. Griffin, London.

Tully, M.A., Cupples, M.E., Chan, W.S., McGlade, K., Young, I.S., 2005. Brisk walking, fitness, and cardiovascular risk: a randomized controlled trial in primary care. Prev. Med. 41:622-28.

Tully, M.A., Cupples, M.E., Hart, N.D., McEneny, J., McGlade, K.J., Chan, W.S., Young, I.S., 2007. Randomised controlled trial of home-based walking programmes at and below current recommended levels of exercise in sedentary adults. J. Epidemiol. Community Health 61:778-83.

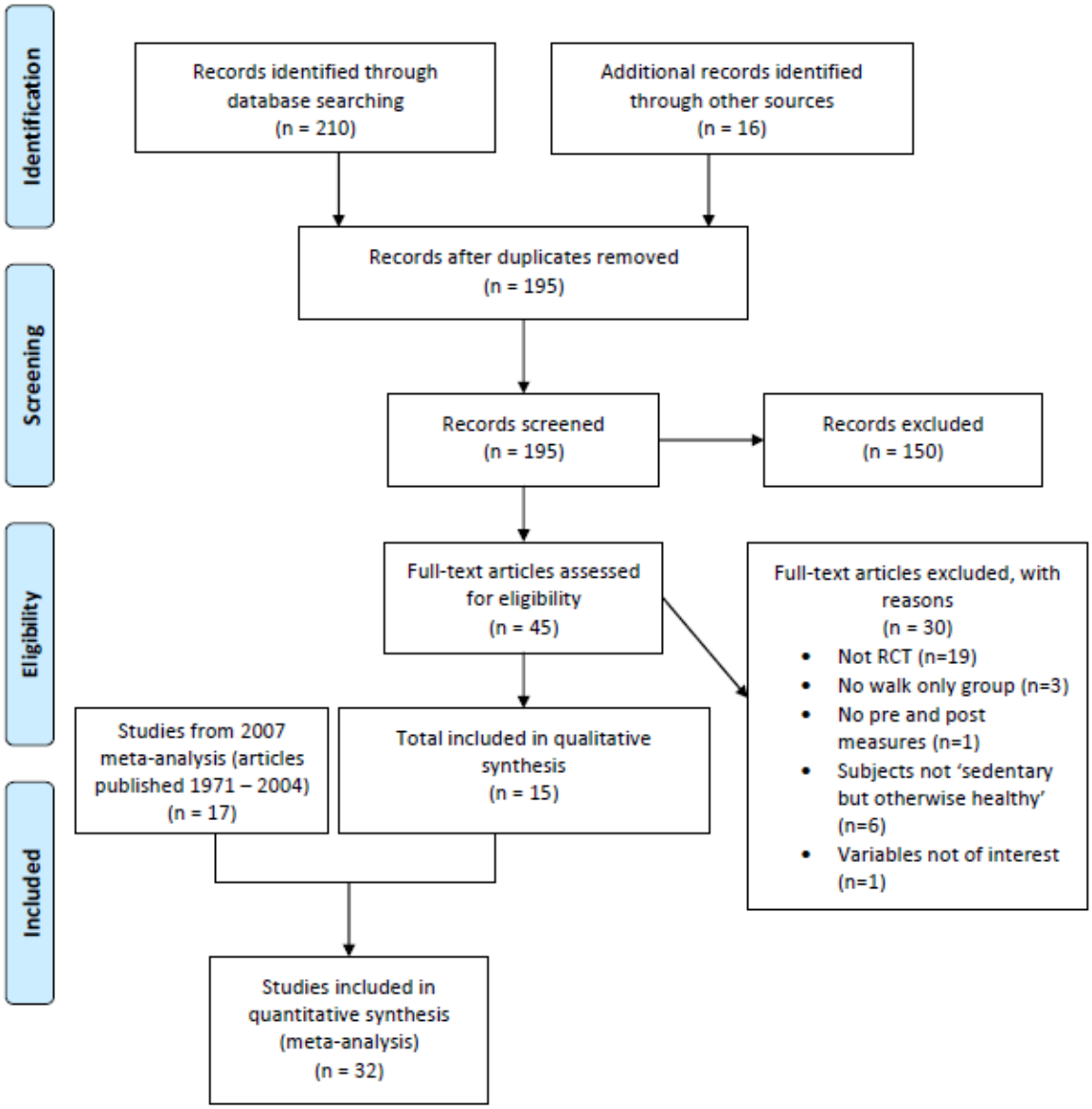
Woolf-May, K., Kearney, E.M., Owen, A., Jones, D.W., Bird, S.R., 1999. The efficacy of accumulated short bouts versus single daily bouts of brisk walking in improving aerobic fitness and blood lipid profiles. Health Educ. Res. 14:803-15.

Woolf-May, K., Scott, A., Kearney, E., Jones, D., 2011. The effect of 24 weeks of moderate intensity walking upon metabolic syndrome risk factors in previously sedentary/low active men. Journal of Exercise Physiology 14.

World Health Organisation, 2009. Global health risks: mortality and burden of disease attributable to selected major risks. WHO Press, Geneva.

Yarnell, J.W.G., Patterson, C.C., Sweetnam, P.M., Thomas, H.F., Bainton, D., Elwood, P.C., Bolton, C.H., Miller, N.E., 2001. Do total and high density lipoprotein cholesterol and triglycerides act independently in the prediction of ischemic heart disease? Ten-year follow-up of caerphilly and speedwell cohorts. Arteriosclerosis Thrombosis and Vascular Biology 21:1340-45.

Figure 1: Study selection process



Databases were searched for articles published between Jan 1971 and June 2012.

Highlights

- 32 RCTs examining the effect of walking on risk factors for cardiovascular disease were included.
- Walking improved aerobic fitness (10.5%), systolic (-3%) and diastolic blood pressure (-2%).
- Walking improved several measures of adiposity but did not alter blood lipids significantly.