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DOSE-RESPONSE RELATIONSHIP BETWEEN EXERCISE AND CVD RISK FACTORS: A META-ANALYSIS OF RANDOMIZED CONTROLLED TRIALS

by

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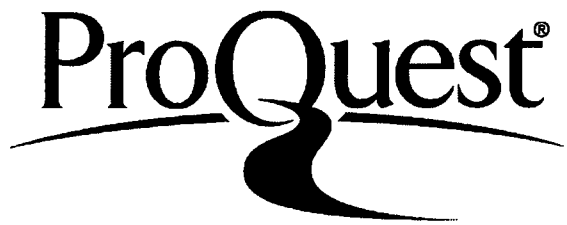

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DOSE-RESPONSE RELATIONSHIP BETWEEN EXERCISE AND CVD RISK FACTORS: A META-ANALYSIS OF RANDOMIZED CONTROLLED TRIALS

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Very strong scientific evidence shows that physically active people have better health, lower risk profiles for developing a number of disabling medical conditions, and lower rates of various chronic diseases than people who are inactive. However, due to the many variables associated with volume of physical activity and exercise, the dose-response relationship between exercise and cardiovascular disease (CVD) risk factors is not completely understood. The purpose of this investigation was to review and quantify the dose-response relationship between exercise and CVD risk factors using a meta-analytical review of randomized controlled trials. Studies that included adults and contained at least three CVD risk factor variables were identified using computer searches of the PubMed database restricting the search to randomized controlled trials studies published in English and for the period between January 1990 and December 2009. The search keywords were "exercise," "physical activity," "control," "cardiovascular," "CVD," "intervention," and "adults". Studies were classified in 12 possible categories based on the intensity and duration of exercise performed during the intervention. A total of 14 different variables representing CVD risk factors were investigated and the dose-response analysis was conducted for 12 of those variables. A total of 74 studies provided sufficient data to compute an Effect sizes (ES) expressed as Hedges adjusted *g* and were included in the analysis. VO2max had all positive ESs and a large positive effect. All other CVD risk factors had overall small effects. No significant differences were found among the ESs for different dose categories for any of the

variables indicating the lack of a dose-response relationship. This study makes clear that CVD risk factors do not have the same response to exercise and the current recommendations for duration and intensity of exercise do not guarantee positive and effective results to all CVD risk factors. Some risk factors respond to a lower combination of duration and intensity and others might require much higher duration and intensity than the current recommended amount of exercise to achieve better health.

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CHAPTER I

INTRODUCTION

Cardiovascular disease (CVD) is a broad term referring to numerous abnormal conditions that are characterized by dysfunction of the myocardium and blood vessels. An estimated 80,000,000 American adults (approximately 1 in 3) have 1 or more types of CVD (Lloyd-Jones et al., 2009). Mortality data show that CVD as the underlying cause of death (includes congenital cardiovascular defects) accounted for 35.3% (864,480) of all 2,448,017 deaths in 2005 or 1 of every 2.8 deaths in the United States. The estimated direct and indirect cost of CVD for 2009 is $475.3 billion (Lloyd-Jones et al., 2009). CVD is also a major cause of disability and premature death throughout the world, and contributes substantially to the escalating costs of health care.

There are seven commonly recognized risk factors for CVD: family history, cigarette smoking, hypertension, dyslipidemia, impaired fasting glucose, obesity, and sedentary life. High-serum HDL-C counts as a positive component and can offset one of the risk factors (American College of Sports Medicine [ACSM], 2006). Hypertension was perhaps the first well-established cardiovascular risk factor (Stampfer, Ridker, & Dzau, 2004). Approximately 73,600,000 people in the US are hypertensive (Lloyd-Jones et al., 2009). Cholesterol levels are well established as strong independent predictors of CVD (Stampfer et al., 2004). Large cohort studies have identified HDL-C as a strong, independent, inverse predictor of risk of CVD (deGoma, Leeper, & Heidenreich, 2008).

Type 2 diabetes accounts for ~90–95% of those with diabetes (American Diabetes Association [ADA], 2004). The CVD mortality rate is 3 times greater in people with diabetes than in those without diabetes (Evangelista & McLaughlin, 2009). In a study by Faeh and colleagues (Faeh, William, Yerly, Paccaud, & Bovet, 2007) a graded relationship between impaired glucose regulation (IGR) categories and major CVD risk factors was found. This relationship was only partly accounted for by BMI, waist circumference, and insulin. More than one-third of U.S. adults were obese in 2005–2006. This includes 33.3% of men and 35.3% of women. Obesity rates have increased since the 1976–1980 survey period. There was however, no significant change in obesity prevalence between 2003-2004 and 2005-2006 for either men or women (Ogden, Carroll, McDowell, & Flegal, 2007). The association between abdominal obesity, metabolic syndrome and CVD is well characterized (Ritchie & Connell, 2007). Physical inactivity is an established independent risk factor for CVD (Wang, Pratt, Macera, Zheng, & Heath, 2004), and medical costs due to inactivity and its consequences were estimated at $76 billion dollars in 2000 (Brownson, Boehmer, & Luke, 2005). In a cross sectional study, it was found that physical activity and physical fitness are independently associated with lower CVD risk and compared with physical activity, physical fitness exerts greater effects on each of these individual CVD risk factors and its combination (Ekblom-Bak, Hellénius, Ekblom, Engström, & Ekblom, 2009; Sassen et al., 2009).

Being physically active is one of the most important things that Americans of all ages can do to improve their health (United States Department of Health & Human Services [USDHHS], 2008). Very strong scientific evidence shows that physically active

people have higher levels of health-related fitness, lower risk profiles for developing a number of disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive (Physical Activity Guidelines Advisory Committee [PAGAC], 2008). Disease outcomes inversely related to regular physical activity in prospective observational studies include CVD, thromboembolic stroke, hypertension, type 2 diabetes mellitus, osteoporosis, obesity, colon cancer, breast cancer, anxiety and depression (Kesaniemi, Danforth, & Jensen, 2001).

Physical activity plays a role in the reduction of many CVD risk factors. In the meta-analysis by Cornelissen and Fagard (2005) mean reductions in resting systolic blood pressure (SBP) ranged from 2 to 5 mmHg (2% to 4%) and 2 to 3 mmHg (2% to 3%) for resting diastolic blood pressure (DBP) for all studies. Reductions were greater in hypertensive participants than in prehypertensive, and normotensive participants. In general, both HDL-C and serum TG reproducibly and favorably respond to changes in habitual physical activity, with increases in HDL cholesterol and decreases in serum TG (PAGAC, 2008). People who regularly engage in at least moderate-intensity aerobic activity have a significantly lower risk of developing type 2 diabetes than do inactive people. Lower rates of this condition are seen with 120 to 150 minutes (2 hours to 2 hours and 30 minutes) a week of at least moderate-intensity aerobic activity. As with cardiovascular health, additional levels of physical activity seem to lower risk even further. In addition, physical activity helps control blood glucose levels in persons who already have type 2 diabetes (USDHHS, 2008). Review studies have also found positive

effects of exercise in the reduction of BMI, weight, and body composition (Murphy, Nevill, Murtagh, & Holder, 2007; USDHHS, 2008).

The Surgeon General's report (USDHHS, 1996) clearly shows that physical activity for better health and well-being has been an important theme throughout much of western history. And the emphasis of public health recommendations changed from vigorous activity for cardiorespiratory fitness to the more conservative and attainable moderate levels of activity for numerous health benefits. In 1995, a group of experts was brought together by the CDC and the ACSM to review the pertinent scientific evidence and to develop a clear, concise "public health message" regarding physical activity (Pate et al., 1995). This was the recommendation that shifted the focus from physical activity for physical fitness to one of health-related benefits. The 1995 recommendations were for US adults to perform 30 min or more of physical activity on most, preferably all days of the week.

An expert panel was formed once again in 2007, to update and clarify the previous recommendations. The conclusion was that adults need moderate-intensity aerobic physical activity for a minimum of 30 min on five days each week, or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week, and can use a combination of the two to achieve health benefits. In addition, physical activity should be performed in bouts of at least 10 min. Additional benefits can be gained by engaging in more physical activity and 60-90 min of moderate activity might be necessary to lose and maintain body weight. Muscle strengthening exercises were also recommended (Haskell et al., 2007).

In the most recent recommendations (USDHHS, 2008), only minor changes were made to the previous recommendations. Instead of daily recommendations, weekly recommendations were presented, and the total time for vigorous intensity decreased 5 minutes. The recommendations now are as follows: (1) Adults should do 2 hours and 30 minutes a week of moderate-intensity, or 1 hour and 15 minutes (75 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic physical activity. (2) Aerobic activity should be performed in episodes of at least 10 minutes, preferably spread throughout the week. (3) Additional health benefits are provided by increasing to 5 hours (300 minutes) a week of moderate-intensity aerobic physical activity, or 2 hours and 30 minutes a week of vigorous-intensity physical activity, or an equivalent combination of both. (4) Adults should also do muscle-strengthening activities that involve all major muscle groups performed on 2 or more days per week (United States Department of Health & Human Services).

The PAGAC (2008) also made recommendations for future research. The committee notes that aerobic exercise exposures can be characterized by an interaction between bout intensity, frequency, duration, and longevity of the exercise program, and the most common way to represent those characteristics is the volume of exercise represented as energy expenditure (EE). Because relatively few interventional experimental studies examine exercise intensity while controlling for EE and even fewer studies examine frequency or duration effects while controlling for EE, this makes the construction of a precise exercise dose for any given response problematic (PAGAC). The committee identifies the gaps in the knowledge of the dose-response relationship

between exercise and health outcomes and makes specific recommendations for future research. They recommend that researchers should review the nature and volume of recent publications relating physical activity and health outcomes and conduct quantitative reviews when appropriate with the intent to contribute to the current knowledge and help formulate guidelines and policy statements and guide future research.

In summary, CVD is a major cause of disability and premature death throughout the world, and contributes substantially to the escalating costs of health care. CVD accounts for a large number of deaths and causes a financial burden to Americans. Very strong scientific evidence shows that physically active people have higher levels of health-related fitness, lower risk profiles for developing a number of disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive. More specifically, higher levels of physical activity and physical fitness are independently associated with lower CVD risk. However, due to the many variables associated with volume of physical activity and exercise, the dose-response relationship between exercise and CVD risk factors is not completely understood.

Purpose Statement

The purpose of this investigation was to review and quantify the dose-response relationship between exercise and CVD risk factors using a meta-analytical review of randomized, controlled trials.

Hypotheses

It was hypothesized that:

Higher durations and/or intensity levels of exercise have larger positive effects on the CVD risk factors.

Operational Definitions

1. Body composition: Measures of weight, body mass index (BMI), body fat percentage, waist circumference, and waist-to-hip ratio.
2. Blood pressure: Measures of systolic blood pressure (SBP) and diastolic blood pressure (DBP).
3. Cholesterol: Measures of total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and cholesterol ratio (TC/HDL-C).
4. The HbA1c test: Measures the percentage of red blood cells with glucose bound to the hemoglobin.
5. Fasting blood glucose: Blood glucose levels measured with at least 6 h of fasting.
6. Physical fitness: Measure of VO_2max.
7. Maximal oxygen uptake (VO_2max): The maximal capacity for oxygen consumption by the body during maximal exertion. It is also known as aerobic power, maximal oxygen consumption, and cardiorespiratory endurance capacity.
8. Heart rate reserve (HRR): The difference between exercise heart rate and resting heart rate.

9. Maximal heart rate (HRmax): The highest heart rate value attainable during an all-out effort to the point of exhaustion.
10. Metabolic equivalent (MET): A unit used to estimate the metabolic cost (oxygen consumption) of physical activity. One MET equals the resting metabolic rate of approximately 3.5 ml O_2/kg/ min.
11. Physical activity: Bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure.
12. Exercise: Planned, structured and repetitive bodily movement to improve or maintain one or more of the components of physical fitness.

Basic Assumptions

For the purposes of this investigation, it was assumed that:

1. The information contained in the published articles was accurate and complete.

Delimitations

1. Only published articles were included in this meta-analysis.

Significance of the Study

Although a number of meta-analyses have been conducted to try to establish the dose-response relationship between exercise and CVD risk factors, they are limited on the analysis of duration and intensity of the exercise. The common practice of using total EE combines exercises done in high intensity and short duration with exercises done at low intensity and long duration. This type of practice could lead to wrong conclusions, because the effects cannot be correctly attributed to intensity or duration of exercise. The first goal of this study was to overcome this limitation. Another goal of this study was to

provide quantitative evidence to support the recommendations presented in the 2008 Physical Activity Guidelines for Americans, which recommends 150 min or more of moderate physical activity, 75 min of vigorous intensity, or a combination of the two each week (USDHHS, 2008). Completing those two goals can help researchers and practitioners to better understand the level of exercise needed to obtain desirable health outcomes.

CHAPTER II

LITERATURE REVIEW

This chapter will present relevant literature concerning (1) the risk factors for cardiovascular disease (CVD), (2) the possible improvement that exercise and physical activity can bring to those risk factors, (3) a brief history of the physical activity recommendations, and (4) the conclusions of the expert panels involved in the construction of the recommendation.

Cardiovascular Disease

CVD is a broad term referring to numerous abnormal conditions that are characterized by dysfunction of the myocardium and blood vessels. The underlying pathology is atherosclerosis, which develops over many years and is usually advanced by the time symptoms occur, generally in middle age. Acute coronary and cerebrovascular events frequently occur suddenly, and are often fatal before medical care can be given. Modification of risk factors has been shown to reduce mortality and morbidity in people with diagnosed or undiagnosed cardiovascular disease (World Health Organization [WHO], 2007). An estimated 80,000,000 American adults (approximately 1 in 3) have 1 or more types of CVD (Lloyd-Jones et al., 2009). Mortality data show that CVD as the underlying cause of death (includes congenital cardiovascular defects) accounted for 35.3% (864,480) of all 2,448,017 deaths in 2005 or 1 of every 2.8 deaths in the United States. The estimated direct and indirect cost of CVD for 2009 is $475.3 billion in the

United States alone (Lloyd-Jones et al.). CVD is also a major cause of disability and premature death throughout the world, and contributes substantially to the escalating costs of health care. Of an estimated 58 million deaths globally from all causes in 2005, CVD accounted for 30%. This proportion is equal to that due to infectious diseases, nutritional deficiencies, and maternal and perinatal conditions combined (WHO, 2005). Between 2006 and 2015, deaths due to noncommunicable diseases (half of which will be due to CVD) are expected to increase by 17%, while deaths from infectious diseases, nutritional deficiencies, and maternal and perinatal conditions combined are projected to decline by 3% (WHO, 2005).

Cardiovascular Disease Risk Factors

There are seven commonly recognized risk factors for CVD: family history, cigarette smoking, hypertension, dyslipidemia, impaired fasting glucose, obesity, and sedentary life. High-serum HDL-C counts as a positive component and can offset one of the risk factors (ACSM, 2006). Family history cannot be changed and will not be discussed further; smoking will also not be discussed because it is not directly affected by exercise. The other risk factors will be discussed in detail, in addition the positive effects of exercise in the reduction of CVD risk factors will be examined (Haskell et al., 2007).

Sedentary life. Physical inactivity is an established independent risk factor for CVD, the leading cause of death and disability among U.S. adults (Wang et al., 2004), and medical costs due to inactivity and its consequences were estimated at $76 billion dollars in 2000 (Brownson et al., 2005). The prevalence of leisure-time (non-work related) physical inactivity among Americans remained fairly constant through 1996, but

more recently has declined. In 2005 23.7% of adults reported no leisure-time activity (Haskell et al., 2007).

Atherogenic dyslipidemia. Dyslipidemia is defined as having levels of low density lipoprotein cholesterol (LDL-C) > 130 mg/dL, high density lipoprotein cholesterol (HDL-C) < 40 mg/dL, or taking lipid-lowering medication. A total cholesterol (TC) > 200 mg/dL can also be used for dyslipidemia classification (ACSM, 2006). In addition, raised triglycerides (TG) generally correspond to the "high normal" range (150 to 250 mg/dL) for middle-aged adults (Grundy, 1997). Cholesterol levels are well established as strong independent predictors of CVD (Stampfer et al., 2004). Large cohort studies have identified HDL-C as a strong, independent, inverse predictor of risk of CVD. The inverse relationship between HDL-C and coronary risk persists even among patients with LDL-C below 60 mg/dL (deGoma et al., 2008). Hypertriglyceridemia can be an independent risk factor for major coronary events after controlling for LDL-C and HDL-C (Cullen, 2000). A meta-analysis of randomized trials of lipid modifying interventions found a 7% relative risk reduction in coronary heart disease events for every 10 mg/dL reduction in LDL-C, which is equivalent to a 10% relative reduction in coronary heart disease events for every 10% decrease in LDL-C (Briel et al., 2009).

Impaired fasting glucose. Impaired fasting glucose is determined by the measurements on at least two separate occasions of fasting blood glucose ≥ 100 mg/dL (ACSM, 2006). A fasting blood glucose level ≥126 mg/dl leads to a provisional diagnosis of Type 2 diabetes, which will require further testing for the diagnosis to be confirmed (American Diabetes Association [ADA], 2004). Type 2 diabetes accounts for

~90–95% of those with diabetes (ADA). The CVD mortality rate is 3 times greater in people with diabetes than in those without diabetes. Among diabetic individuals, CVD mortality is slightly higher in women compared with men (Evangelista & McLaughlin, 2009). In one study, a graded relationship between impaired glucose regulation (IGR) categories and major CVD risk factors was found (Faeh et al., 2007). This relationship was only partly accounted for by BMI, waist circumference, and insulin. This finding suggests that increased CVD-risk associated with IGR is also mediated by factors other than the considered markers of adiposity and insulin resistance. Despite controversies, evidence is mounting from a number of randomized controlled trials in recent years that blood-glucose-lowering therapy (as an integral part of multifactorial therapy) reduces CVD long-term, both in type 1 and type 2 diabetes. In particular, cardiovascular events are reduced by approximately 10-15% per 1% absolute reduction of HbA1c, on top of other CVD-risk-reducing therapies (Eberhard, Martin, & Oliver, 2009). However, hypoglycemia and weight gain, especially in patients with prior CVD, may also impact unfavorably on (cardiovascular) mortality. Therefore, blood glucose lowering is a highly individualized therapy (Eberhard et al.).

Obesity. Obesity is a disorder, that results from a complex interplay of environmental and genetic factors and is associated with significant morbidity and mortality. The multiple social, economic, and hereditary factors that contribute to obesity make treatment of the condition difficult (Aronne, 2002). The first step in evaluation of obesity is calculation of BMI. BMI is calculated by dividing weight (in kilograms) by square height (in meters). In 1998(32), the WHO, recommended a standard classification

of adult overweight and obesity based on the following BMI classifications: a BMI of 25.0 to 29.9 kg per m^2 is defined as overweight; a BMI of 30.0 kg per m^2 or more is defined as obesity. Additional classifications for obesity are waist circumferences > 102 cm for men and > 88 cm for women, waist/hip ratio ≥ 0.95 for men and ≥ 0.86 for women, and body fat percentage ≥ 20 and 32% for men and women, respectively (ACSM, 2006).

More than one-third of U.S. adults were obese in 2005–2006. This includes 33.3% of men and 35.3% of women. Obesity rates have increased since the 1976–1980 survey period. There was no significant change in obesity prevalence, however, between 2003–2004 and 2005–2006 for either men or women. (Ogden et al., 2007). The association between abdominal obesity, metabolic syndrome and CVD is well characterized (Ritchie & Connell, 2007).

Hypertension. Hypertension was perhaps the first well-established cardiovascular risk factor (Stampfer et al., 2004). Normal levels of blood pressure are SBP less than 120 mm Hg and DBP less than 80 mm Hg. Hypertension is diagnosed by measurements of SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg on at least two separate occasions, or the use of antihypertensive medication (ACSM, 2006). Approximately 73,600,000 people are hypertensive in the US (Lloyd-Jones et al., 2009).

It is common knowledge that high blood pressure is a risk factor for CVD. It has been estimated that a small 2 mm Hg reduction in average resting SBP can reduce mortality from CVD by 4%, while a reduction of 5 mm Hg can reduce mortality risk by 9%. The potential numbers of annual lives saved in adults 45-64 years old in the United

States as a result of these reductions has been estimated to be 11,800 for a 2 mm Hg reduction and 27,600 for a 5 mm Hg reduction (Stamler et al., 1989).

Physical Activity and Cardiovascular Risk

Being physically active is one of the most important things that Americans of all ages can do to improve their health (United States Department of Health & Human Services, 2008). Physical activity is defined as "any bodily movement, planned or unplanned, produced by skeletal muscles that results in energy expenditure" (ACSM, 2006 p. 3). Very strong scientific evidence shows that physically active people have higher levels of health-related fitness, lower risk profiles for developing a number of disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive (Physical Activity Guidelines Advisory Committee, 2008). Disease outcomes inversely related to regular physical activity in prospective observational studies include CVD, thromboembolic stroke, hypertension, type 2 diabetes mellitus, osteoporosis, obesity, colon cancer, breast cancer, anxiety, and depression (Kesaniemi et al., 2001). This section will examine the impact of physical activity on selected CVD risk factors.

Obesity. The effect of exercise on measures of obesity is somewhat controversial. A recent review study (Hansen, Dendale, Berger, van Loon, & Meeusen, 2007), concluded that, in general an addition of exercise to interventions with a dietary restriction does not induce a greater fat-mass loss than dietary restriction alone. The authors attributed this to a compensatory reduction in daily physical activity following the implementation of exercise training. In a meta-analysis of pedometer-based walking

interventions only a modest amount of weight loss –1.27 kg (95% confidence interval, –1.85 to –0.70 kg) was found (Richardson et al., 2008). However, in a meta-analysis of randomized controlled trials, significant decreases in body weight, BMI, and percent body fat were found (Murphy et al., 2007). In addition, in the review by the PAGAC (2008) 24 cross-sectional studies that examined the association between physical activity and body weight were identified, and of these studies, 23 reported results suggesting an inverse relationship between physical activity and body weight and/or BMI.

Artherogenic dyslipidemia. The responses of serum lipoproteins to changes in habitual physical activity have been well studied. In general, both HDL-C and serum TG reproducibly and favorably respond to changes in habitual physical activity, with increases in HDL cholesterol and decreases in serum TG (PAGAC, 2008). The relationship between physical activity and the levels of lipoproteins and triglycerides has been studied at length, leading to a large number of meta-analyses in the subject. This has been studied in such great lengths that meta-analyses have been conducted for specific groups. In the study by Kelley and Kelley (2007), the effects of aerobic exercise on lipids and lipoproteins was studied only on adults with Type 2 diabetes, and it was found that aerobic exercise lowers LDL-C. In another meta-analysis (G. A. Kelley, Kelley, & Franklin, 2006), chronic aerobic exercise increases HDL-C and decreases TG in adults CVD patients. In addition, more general meta-analyses have been conducted and benefits were also found (G. A. Kelley & Kelley, 2008; G. A. Kelley, Kelley, & Tran, 2004; G. A. Kelley, Kelley, & Tran, 2005).

Impaired fasting glucose. People who regularly engage in at least moderate-intensity aerobic activity have a significantly lower risk of developing type 2 diabetes than do people who are inactive. Lower rates of this condition are seen with 120 to 150 minutes (2 hours to 2 hours and 30 minutes) a week of at least moderate-intensity aerobic activity. As with cardiovascular health, additional levels of physical activity seem to lower risk even further. In addition, physical activity helps control blood glucose levels in persons who already have type 2 diabetes (USDHHS, 2008). Large prospective cohort and cross-sectional observational studies that assessed physical activity through the use of questionnaires all show that increased physical activity levels are associated with reduced risk for developing type 2 (PAGAC, 2008). In a study comparing the effects of medication with lifestyle modifications, which included exercise, found that the lifestyle component reduced incident diabetes by 58% and had a more powerful effect than the metformin (by 39%) medication (Diabetes Prevention Program Research Group, 2002). In a meta-analysis (D. E. Kelley & Goodpaster, 2001), that analyzed the effects of exercise on glucose homeostasis in type 2 diabetes found that higher levels of physical activity were clearly associated with a lower incidence of type 2 diabetes, but a dose-response relationship was not evident.

Hypertension. Physical activity can be a potent factor in the reduction of blood pressure. Due to the large number of exercise intervention and prospective studies that measure blood pressure as an outcome, there are a number of meta-analyses investigating the effects of physical activity and blood pressure (Cornelissen & Fagard, 2005; Hamer, Taylor, & Steptoe, 2006; Murphy et al., 2007). In the meta-analysis by Cornelissen and

Fagard, mean reductions for resting SBP and DBP due to exercise interventions ranged from 2 to 5 mm Hg and 2 to 3 mm Hg respectively. Reductions were greater in hypertensive participants than in prehypertensive and normotensive participants.

Physical Activity Recommendations

In the 1996 Surgeon General's report (USDHHS) a comprehensive overview of the historical background and evolution of the physical activity recommendations is presented. Information is provided from ancient history to modern times, with detailed information about recommendations from 1965 to 1996, which was the publication date of the report. The report clearly shows that physical activity for better health and well-being has been an important theme throughout much of western history. The emphasis of public health recommendations changed from vigorous activity for cardiorespiratory fitness to the more conservative and attainable moderate levels of activity for numerous health benefits. Some of the more recent recommendations will the discussed next.

In 1995, a group of experts was brought together by the CDC and the ACSM to review the pertinent scientific evidence and to develop a clear, concise "public health message" regarding physical activity (Pate et al., 1995). This was the recommendation that shifted the focus from physical activity for physical fitness to one of health-related benefits. The recommendations were for US adults to perform 30 min or more of physical activity on most, preferably all days of the week. Moderate physical activity was defined as activity performed at an intensity of 3 to 6 METs (work metabolic rate/resting metabolic rate), the equivalent of brisk walking at 3 to 4 mph for most healthy adults. This was an important step in getting people to understand the benefits of physical

activity for health, but a few questions were left unanswered. An update on those recommendations was presented a few years later.

An expert panel was formed once again in 2007, to update and clarify the previous recommendations. Very precise and specific recommendations emerged from this expert panel. The conclusion was that adults need moderate-intensity aerobic physical activity for a minimum of 30 min on five days each week, or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week, or can use a combination of the two to achieve health benefits. In addition, physical activity should be performed in bouts of at least 10min. Additional benefits can be gained by engaging in more physical activity and 60-90 min of moderate activity and might be necessary to lose and maintain body weight. Muscle strengthening exercises were also recommended (Haskell et al., 2007).

In the most recent 2008 PA guidelines, minor changes were made to the previous recommendations. Instead of daily recommendations, weekly recommendations were presented, and the total time for vigorous intensity decreased 5 minutes. The recommendations now are as follows: (1) Adults should do 2 hours and 30 minutes a week of moderate-intensity, or 1 hour and 15 minutes (75 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic physical activity. (2) Aerobic activity should be performed in episodes of at least 10 minutes, preferably spread throughout the week. (3) Additional health benefits are provided by increasing to 5 hours (300 minutes) a week of moderate-intensity aerobic physical activity, or 2 hours and 30 minutes a week of vigorous-

intensity physical activity, or an equivalent combination of both. (4) Adults should also do muscle-strengthening activities that involve all major muscle groups performed on 2 or more days per week (USDHHS, 2008).

Along with the publication of the guidelines, a report from the PAGAC (2008) was published. To create the recommendations, the panel of experts involved in this committee reviewed and took into consideration the available literature between January 1996 and June 2007. The benefits of physical activity for all-cause mortality, cardio respiratory health, metabolic health, energy balance, musculoskeletal health, functional health, cancer, and mental health were taken into consideration to arrive at the recommendations. The PAGAC also made some observations and recommendations for future research.

The committee notes that aerobic exercise exposures can be characterized by an interaction between bout intensity, frequency, duration, and longevity of the exercise program, and the most common way to represent those characteristics is the volume of exercise represented as energy expenditure (EE). Most of the data from experimental studies reviewed by the committee are limited. Regarding the dose-response associations, the studies address the issue of varying intensities of exercise and do not control for bout duration, frequency, or total volume of the exercise exposure. In most observational studies, the major variable used as an exposure is activity amount (e.g., minutes, MET-min per day, miles per week) with the other exposure frequently being activity intensity. This can lead to the aggregation of different combinations of intensity and duration that cause the same volume of exercise. Relatively few interventional experimental studies

examine exercise intensity while controlling for EE and even fewer study frequency or duration effects while controlling for EE. This makes the construction of a precise exercise dose for any given response problematic (PAGAC, 2008).

The committee identifies the gaps in the knowledge of the dose-response relationship between exercise and health outcomes and makes specific recommendations for future research. Some of the recommendations are: investigate the benefits of lower intensity exercise, examine the upper limits of intensity and duration and the health effects, and use of bouts of different lengths to determine the effects on musculoskeletal health. In addition, the committee notes that between 1995 and 2007 a large number of studies have been published for selected health outcomes in various populations, however meta-analyses covering those studies have not been published. The committee recommends that researchers should review the nature and volume of recent publications relating physical activity and health outcomes and conduct quantitative reviews when appropriate with the intent to contribute to the current knowledge and help formulate guidelines and policy statements, and help guide future research (PAGAC, 2008).

Summary

CVD is a major cause of disability and premature death throughout the world, and contributes substantially to the escalating costs of health care. An estimated 80,000,000 American adults (approximately 1 in 3) have 1 or more types of CVD. Mortality data show that CVD as the underlying cause of death of 1 of every 2.8 deaths in the United States with an estimated direct and indirect cost of CVD for 2009 of $475.3 billion. Very strong scientific evidence shows that physically active people have higher levels of

health-related fitness, lower risk profiles for developing a number of disabling medical conditions, and lower rates of various chronic diseases than do people who are inactive. More specifically, higher levels of physical activity and physical fitness are independently associated with lower CVD risk. However, due to the many variables associated with volume of physical activity and exercise, the dose-response relationship between exercise and CVD risk factors is not completely understood. Therefore, the purpose of this investigation was to review and quantify the dose-response relationship between exercise and CVD risk factors using a meta-analytical review of randomized, controlled trials.

CHAPTER III

METHODOLOGY

In this chapter, the data sources, study selection, data extraction, and data analysis methods will be explained in detail.

Data Sources

Studies were identified using computer searches of the PubMed database restricting the search to randomized controlled trials studies using adults, published in English and for the period between January 1990 and December 2009 because prior to the 1990's reduction in CVD risk factors was mainly done with drugs not exercise. The search keywords were "exercise," "physical activity," "control," "cardiovascular," "CVD," "intervention," and "adults". Additionally, searches of the references of the CDC/ACSM (Pate et al., 1995) and ACSM/AHA (Haskell et al., 2007) recommendations, and the 2008 Physical Activity Guidelines for Americans (United States Department of Health & Human Services, 2008) were conducted. Hand-searches and cross-referencing were also conducted using the reference lists of retrieved articles.

Study Selection

The inclusion criteria used in this study were: (1) the study design was pretest and posttest randomized control, (2) the average age of participants was between 18-65 years, this was done to included adults and exclude teenagers and older adults, (3) at least one group participated in an exercise intervention, (4) exercise or physical activity was

aerobic in nature, this was done to exclude resistance training (5) duration and intensity of exercise was reported, (6) the control group was not advised to participate in exercise, (7) intervention and control groups diets were not controlled to achieve a pre-determined weight loss goal, (8) if diet alteration was a main component of the intervention, the control group should also have diet alteration, this was necessary to eliminate the effects of a controlled diet, (9) the intervention lasted for a minimum of 8 weeks, this was done to eliminate studies which investigated acute effects of exercise, and (10) the study assessed at least three variables related to CVD risk (e.g., BMI, cholesterol), this done to eliminate interventions that did not focus on reduction of CVD risk factors.

The exclusion criteria used in this study were: (1) the intervention included resistance training exercises, (2) lack of a true control group, and (3) lack of information.

Data Extraction

Extracted variable included demographics, aspects of exercise or physical activity intervention, cardiovascular disease risk factors, and statistical data.

Participant characteristics. Demographic variables included the age, ethnicity, sex, and if the participants were part of any special population (e.g., diabetics, heart transplant, heart failure patients).

Intervention characteristics. Aspects of exercise or physical activity intervention included whether the activity was supervised, monitored, or done at participant discretion, the mode of activity (e.g., cycling, walking), the intensity of the activity (e.g., 60-70% of VO_2max, 50-80% of HRR), the duration of the activity bout, the weekly

frequency of activity, the duration of the intervention, what type of intervention (e.g., exercise only, exercise and nutrition), and intervention setting (e.g., laboratory, home).

Dose-response analysis. To determine the dose-response relationship between exercise and CVD risk factors, intervention groups were classified according to the intensity and duration of the exercise or physical activity. Because of the variety of intensity classifications (e.g., HRmax, HHR, VO_2max, METs, RPE), intensity was classified according to the guidelines found in the ACSM's Guidelines for Exercise Testing and Prescription book (ACSM, 2006, see Figure 1) and the ACSM/AHA (Haskell et al., 2007) recommendations. Based on the ACSM book, "very light" and "light" were combined into the "light" category and "hard" and "very hard" were combined into the "vigorous" intensity. Duration was classified according to the 2008 physical activity guidelines for Americans (USDHHS, 2008). There were a total of 12 possible combinations between intensity and duration (see Table 1).

	Endurance-Type Activity											
	Relative Intensity			Intensity (METs and $\%\dot{V}O_{2max}$) in Healthy Adults Differing in $\dot{V}O_{2max}$								
				$\dot{V}O_{2max}$ = 12 METs		$\dot{V}O_{2max}$ = 10 METs		$\dot{V}O_{2max}$ = 8 METs		$\dot{V}O_{2max}$ = 5 METs	
Intensity	$\%\dot{V}O_2R$[a]/%HRR	$\%HR_{max}$[b]	RPE[c]	METs	$\%\dot{V}O_{2max}$[d]	METs	$\%\dot{V}O_{2max}$	METs	$\%\dot{V}O_{2max}$	METs	$\%\dot{V}O_{2max}$
Very light	<20	<50	<10	<3.2	<27	<2.8	<28	<2.4	<30	<1.8	<36
Light	20–39	50–63	10–11	3.2–5.3	27–44	2.8–4.5	28–45	2.4–3.7	30–47	1.8–2.5	36–51
Moderate	40–59	64–76	12–13	5.4–7.5	45–62	4.6–6.3	46–63	3.8–5.1	48–64	2.6–3.3	52–67
Hard	60–84	77–93	14–16	7.6–10.2	63–85	6.4–8.6	64–86	5.2–6.9	65–86	3.4–4.3	68–87
Very Hard	≥85	≥94	17–19	≥10.3	≥86	≥8.7	≥87	≥7.0	≥87	≥4.4	≥88
Maximal	100	100	20	12	100	10	100	8	100	5	100

Modified from Table 1 of ACSM Position Stand (ref. 5).
[a] $\%\dot{V}O_2R$ - percent of oxygen uptake reserve; %HRR - percent of heart rate reserve.
[b] $\%HR_{max} = 0.7305\ (\%\dot{V}O_{2max}) + 29.95$ (reference #20); values based on 10-MET group.
[c] Borg Rating of Perceived Exertion 6–20 scale (reference #8).
[d] $\%\dot{V}O_{2max} = [(100\% - \%\dot{V}O_2R)\ MET_{max}^{-1}] + \%\dot{V}O_2R$; personal communication.

Figure 1. Exercise intensity categories (ACSM, 2006 p. 4).

Table 1.

Possible groupings for the combination of intensity x duration.

	Duration/week			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	1	4	7	10
Moderate	2	5	8	11
Vigorous	3	6	9	12

Outcome measures. The CVD risk factors that were extracted included: physical fitness (VO_2max, and resting HR), body composition (BMI, weight, body fat percentage, waist circumference, and waist-to-hip ratio), cholesterol (total cholesterol, cholesterol ratio, HDL-C, and LDL-C), triglycerides, fasting blood glucose, and blood pressure (SBP, and DBP). Each risk factors was broken down in more than one variable due to the possibility of different effects and the common practices, for example, cholesterol levels were analyzed as total cholesterol, cholesterol ratio, HDL-C, and LDL-C (Murphy et al., 2007). In case of insufficient information to compute an effect size (ES), the corresponding author from each study was contacted to obtain means and/or standard deviations to enable computation of an ES.

Data Analysis

ESs were computed using mean differences in the post test between intervention and control groups divided by pooled standard deviations (i.e., Hedges adjusted *g*). The Comprehensive Meta Analysis software version 2.0 (Borenstein, Hedges, Higgins, & Rothstein, 2005) was used to compute the individual ESs and inverse variance weight for each study. A funnel plot approach was used to remove studies that produced ESs that were considered outliers (Kodama et al., 2007). Because heterogeneity of ESs is expected (i.e., variability in the outcomes is greater than expected from sampling error), the mean weighted ES and 95% confidence interval (CI) were calculated using a random effects model and moderator analysis was performed using the dose categories. Effect sizes were considered "small = 0.2," "medium = 0.5," and "large = 0.8" based on Cohen's (1988)

definition. Confidence intervals help estimate the accuracy of the corrected effect size in representing the true population parameter (Marshall & Biddle, 2001).

To determine the dose-response relationship, the combination of intensity and duration was treated as a moderator and ESs were calculated using the methods described by Lipsey and Wilson (2001), using SPSS version 18. The dose-response analysis was only performed for the variables that had at least three studies in dose categories. This threshold was used to eliminate comparison between under represented categories (one or two studies only) and categories that had a large number of studies. For the CVD risk factors that had dose categories with three or more ESs, the moderator analysis was performed and the between Q statistics (Qb) was reviewed to determine if there was a significant difference in ESs among different dose categories. In addition, CI were analyzed to determine if overlapping did not occur, which also indicates significant differences. The determination of a dose-response relationship was made accordingly.

CHAPTER IV

RESULTS

Two main searches were conducted using the PubMed database. Both searches were limited to studies published in English between January 1990 and December 2009, and using the limits for age and randomized controlled trials. Using the key words "exercise" or "physical activity," "control," and "cardiovascular" returned 857 hits. Using the key words "exercise" or "physical activity," "control," and "cardiovascular" or "CVD," and "intervention" returned 913 hits. The titles and abstracts of those articles were examined to determine if further review was necessary for inclusion or exclusion from the analysis. This examination provided a total of 223 articles for further review. The references list of the physical activity guidelines provided another 38 articles for review. In addition, cross referencing of reviewed articles provided another 22 articles for review. A grand total of 283 full articles were reviewed for inclusion in the analysis. A total of 199 studies were eliminated due to duplication (i.e., same data presented in different articles) or not meeting the inclusion criteria. Of the remaining 84 studies, 10 studies did not provide sufficient information for the calculation of the ES (e.g., missing mean and standard deviation of the outcome variable). Thirteen authors were contacted via e-mail and two provided the necessary data for inclusion of the study in the analysis. A total of 74 studies provided sufficient data to compute an ES expressed as Hedges

adjusted *g*, did not classify as an outlier, and were included in this analysis. The number of ESs calculated for each CVD risk factor variable can be found in Table 2.

Table 2

Overall ESs and 95% CI for each CVD risk factor variable.

Variable	Number of ESs	ES	-95% CI	+95% CI
VO_2max	65	0.89	0.75	1.03
HR	26	0.33	0.14	0.53
BMI	59	0.25	0.16	0.33
Weight	72	0.20	0.11	0.28
BF%	40	0.29	0.18	0.39
Waist	26	0.26	0.14	0.37
W/H	13	0.37	0.19	0.55
Triglycerides	32	0.16	0.07	0.25
Fasting Glucose	26	0.23	0.12	0.34
HDL	33	0.21	0.07	0.34
LDL	28	0.18	0.06	0.30
TC	26	0.25	0.14	0.37
CR	9	0.29	0.11	0.46
SBP	47	0.28	0.17	0.39
DBP	46	0.21	0.10	0.32

Note. ES = effect size; CI = confidence interval; HR = heart rate; BMI = body mass index; BF% = body fat percentage; W/H = waist-to-hip ratio; HDL-C = high density lipoprotein cholesterol; LDL-C = low density lipoprotein cholesterol; BP = blood pressure.

VO_2max Effect Size

A total of 65 ESs were calculated for the VO_2max variable. Those effect sizes were based on 47 different studies and included 1,687 participants in the experimental groups. VO_2max was the only variable with only positive ESs. The quantitative synthesis of the effects yielded a large and positive mean ES (see Table 2). The summary information of the articles included in the VO_2max analysis can be found in Table 3 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 2. A dose-response analysis was performed for the VO_2max variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 4.

Table 3.

Characteristics of the studies in the VO_2max analysis.

Authors	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Albright et al. (1992)a	21	20	3	2	8	F	None	W/J	6 months	47 ± 5	No	Exercise only
Albright et al. (1992)aa	21	21	3	2	8	M	None	W/J	6 months	49 ± 6	No	Exercise only
Asikainen et al. (2002)a	43	44	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)aa	43	43	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)b1	38	20	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)b2	38	21	4	2	11	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)b3	38	16	3	2	8	F	Post menopausal	Walking	24 week	48-63	Yes	Exercise only
Asikainen et al. (2002)b4	38	21	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Balducci et al. (In Press)	20	20	2	3	6	B	Type II diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Beer at al. (2008)	11	11	3	3	9	B	Dilated cardiomyopathy	Cycling	8 months	57	No	Exercise only
Belardinelli et al. (1999)	49	50	2	3	6	B	Chronic heart failure	Cycling	14 months	59 ± 14	Yes	Exercise only
Blumenthal et al. (1991)	22	39	2	3	6	B	Mild hypertension	W/J	4 months	56 ± 8	Yes	Exercise only
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Courneya et al. (2009)	62	60	2	3	6	F	Lymphoma Patients	Cycling	12 weeks	53.2	Yes	Exercise only
Courneya et al. (2003)	28	24	2	3	6	F	Post menopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Deligiannis et al. (1999)a	12	16	3	2	8	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only

Table 3.

Authors	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Deligiannis et al. (1999)aa	12	10	3	1	7	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Donnelly et al. (2003)a	21	24	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Donnelly et al. (2003)aa	24	22	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Dubach et al. (1997)	13	12	2	3	6	M	Reduced left ventricular function	Cycling	8 weeks	56 ± 7	Yes	Exercise only
Giallauria et al. (2009)	30	30	2	3	6	B	Acute myocardial infarction	Cycling	6 months	59 ± 3	Yes	Exercise only
Hass et al. (2001)	9	17	2	3	6	B	Sedentary	Stepper	12 weeks	48 ± 6	Yes	Exercise only
Hautala et al. (2004)	6	18	3	2	8	M	None	W/J	8 weeks	41 ± 8	Yes	Exercise only
Irving et al. (2008)a	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Kim et al. (2006)	19	22	2	3	6	F	Breast cancer	Walk	8 weeks	40+	No	Exercise only
Kraemer et al. (2001)a	6	8	2	3	6	F	None	Bench stepping	12 weeks	32 ± 8	No	Exercise only
Krasnoff et al. (2006)	70	49	2	3	6	B	Liver transplantation patients	W/C	12 months	50 ± 11	Yes	Exercise and diet
Kukkonen-Harjula et al. (1998)a	26	25	3	3	9	M	None	Walking	15 weeks	30-55	Yes	Exercise only
Kukkonen-Harjula et al. (1998)aa	29	28	3	3	9	F	None	Walking	15 weeks	30-55	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
Meyer et al. (2007)a	13	13	3	2	8	B	None	W/J	12 weeks	44 ± 7	Yes	Exercise only
Meyer et al. (2007)aa	13	13	3	1	7	B	None	W/J	12 weeks	44 ± 7	Yes	Exercise only
Myers et al. (2002)	12	12	3	3	9	B	Heart failure patients	Cycling	8 weeks	55 ± 9	Yes	Exercise only
Naimark et al. (1996)a	20	19	3	3	9	F	Post menopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Naimark et al. (1996)aa	20	17	4	3	12	F	Post menopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Potteiger et al. (2003)a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-36	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	62 ± 6	Yes	Exercise only

Table 3.

Authors	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Rogers et al. (2009)	20	21	3	2	8	F	Breast cancer survivor	Walking	12 weeks	53 ± 9	Yes	Exercise and counseling
Roveda et al. (2003)	9	7	2	2	5	B	Chronic heart failure	Cycling	4 months	35-60	Yes	Exercise only
Salvetti et al. (2008)	20	19	2	2	5	B	Coronary disease	Walking	12 weeks	53 ± 8	No	Exercise only
Santa-Clara et al. (2003)a	16	17	3	3	9	F	Postmenopausal Caucasian	Variable	6 months	45-70	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Shin et al. (2008)	8	8	2	3	6	F	Overweight obese	W/J	6 months	47 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Smith et al. (2001)	29	18	2	3	6	B	HIV positive	Variable	12 weeks	37 ± 6	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Trapp et al. (2008)aa	15	8	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Trapp et al. (2008)aa	15	11	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Tsai et al. (2002)a	11	12	2	2	6	B	Mild hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Tsekouras et al. (2008)	8	7	2	3	6	M	None	Running	8 weeks	20-40	Yes	Exercise only
Vainionpaa et al. 2007	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Vigorito et al. (2003)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

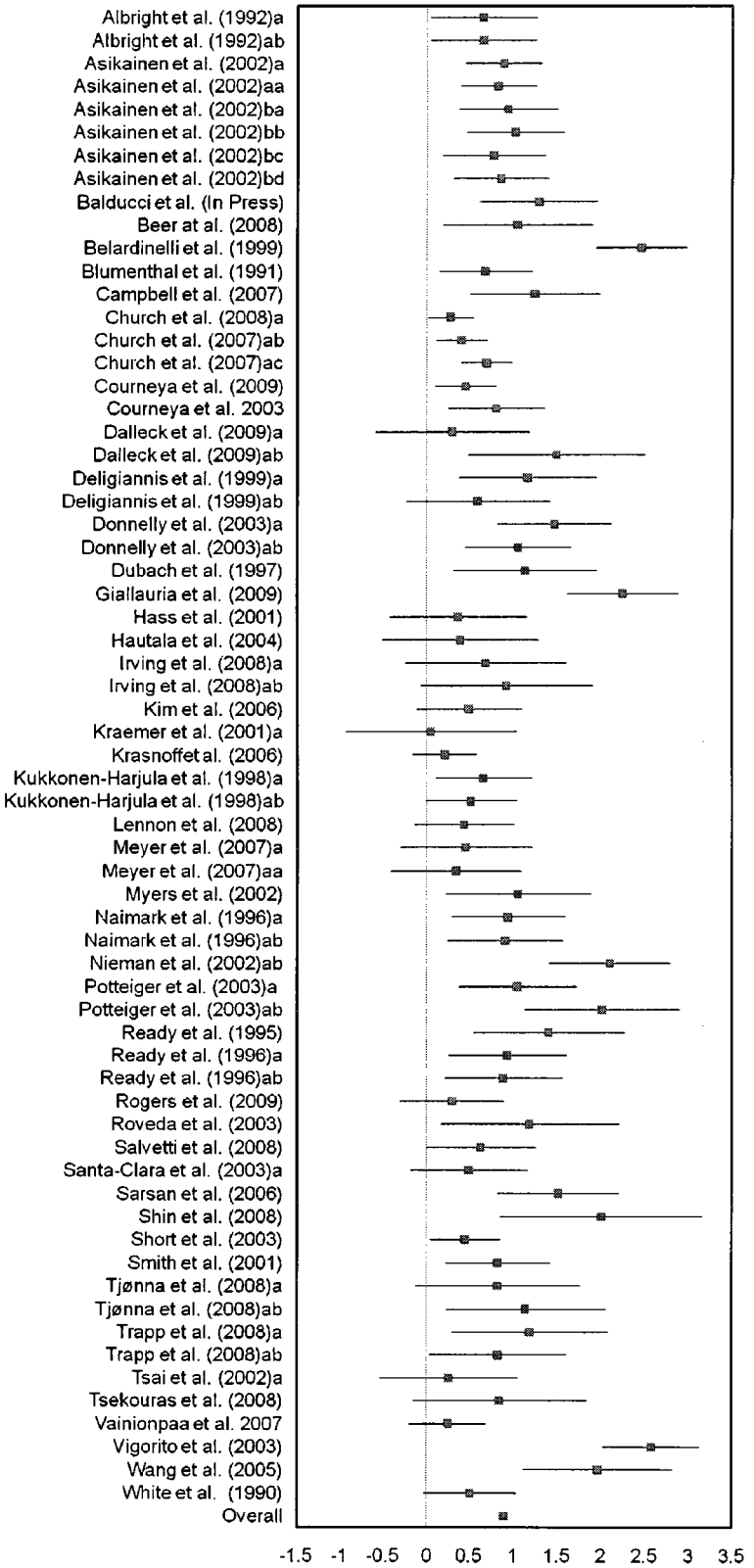

Figure 2. *Forrest plot with ESs and VO_2max studies.*

Table 4.

ESs for different dose categories of VO_2max studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.53 (-0.23,1.28) n = 3	-
Moderate	-	0.69 (0.07,1.31) n = 4	0.89 (0.63,1.15) n = 21	-
Vigorous	-	1.01 (0.75,1.28) n = 21	0.86 (0.47,1.25) n = 10	-

Heart Rate Effect Size

A total of 26 ESs were calculated for the HR variable. Those effect sizes were based on 23 different studies and included 559 participants in the experimental groups. HR is another variable that measures physical fitness but the results were more variable than VO_2max results. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the HR analysis can be found in Table 5 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 3. A dose-response analysis was performed for the HR. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 6.

Table 5.

Characteristics of the studies in the heart rate analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Albright et al. (1992)a	21	20	3	2	8	F	None	W/J	6 months	47 ± 5	No	Exercise only
Albright et al. (1992)aa	21	21	3	2	8	M	None	W/J	6 months	49 ± 6	No	Exercise only
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Beer at al. (2008)	11	11	3	3	9	B	Dilated cardiomyopathy	Cycling	8 months	57	No	Exercise only
Belardinelli et al. (1999)	49	50	2	3	6	B	Chronic heart failure	Cycling	14 months	59 ± 14	Yes	Exercise only
Blumenthal et al. (1991)	22	39	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Deligiannis et al. (1999)a	12	16	3	2	8	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Deligiannis et al. (1999)aa	12	10	3	1	7	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Dubach et al. (1997)	13	12	2	3	6	M	Reduced left ventricular function	Cycling	8 weeks	56 ± 7	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Giallauria et al. (2009)	30	30	2	3	6	B	Acute myocardial infarction	Cycling	6 months	59 ± 3	Yes	Exercise only
Hass et al. (2001)	9	17	2	3	6	B	Sedentary	Stepper	12 weeks	48 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Kim et al. (2006)	19	22	2	3	6	F	Breast cancer	Walking	8 weeks	40+	No	Exercise only
Kokkinos et a. (1995)	22	23	2	2	6	M	African American hypertensive	Cycling	16 weeks	36-76	Yes	Exercise and medication
Kraemer et al. (2001)a	6	8	2	3	6	F	None	Bench stepping	12 weeks	32 ± 8	No	Exercise only
Kraemer et al. (2001)aa	6	12	2	3	6	F	None	Bench stepping	12 weeks	37 ± 8	No	Exercise only

Table 5.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Laterza et al. (2007)	9	11	2	2	5	B	Hypertensive	Cycling	4 months	46 ± 2	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
Martin et al. (1990)	9	10	2	2	5	M	Hypertensive	Variable	10 weeks	18-60	Yes	Exercise only
Myers et al. (2002)	12	12	3	3	9	B	Heart failure patients	Cycling	8 weeks	55 ± 9	Yes	Exercise only
Tsai et al. (2002)a	11	12	2	2	6	B	Mild hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Tsai et al. (2002)b	20	22	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

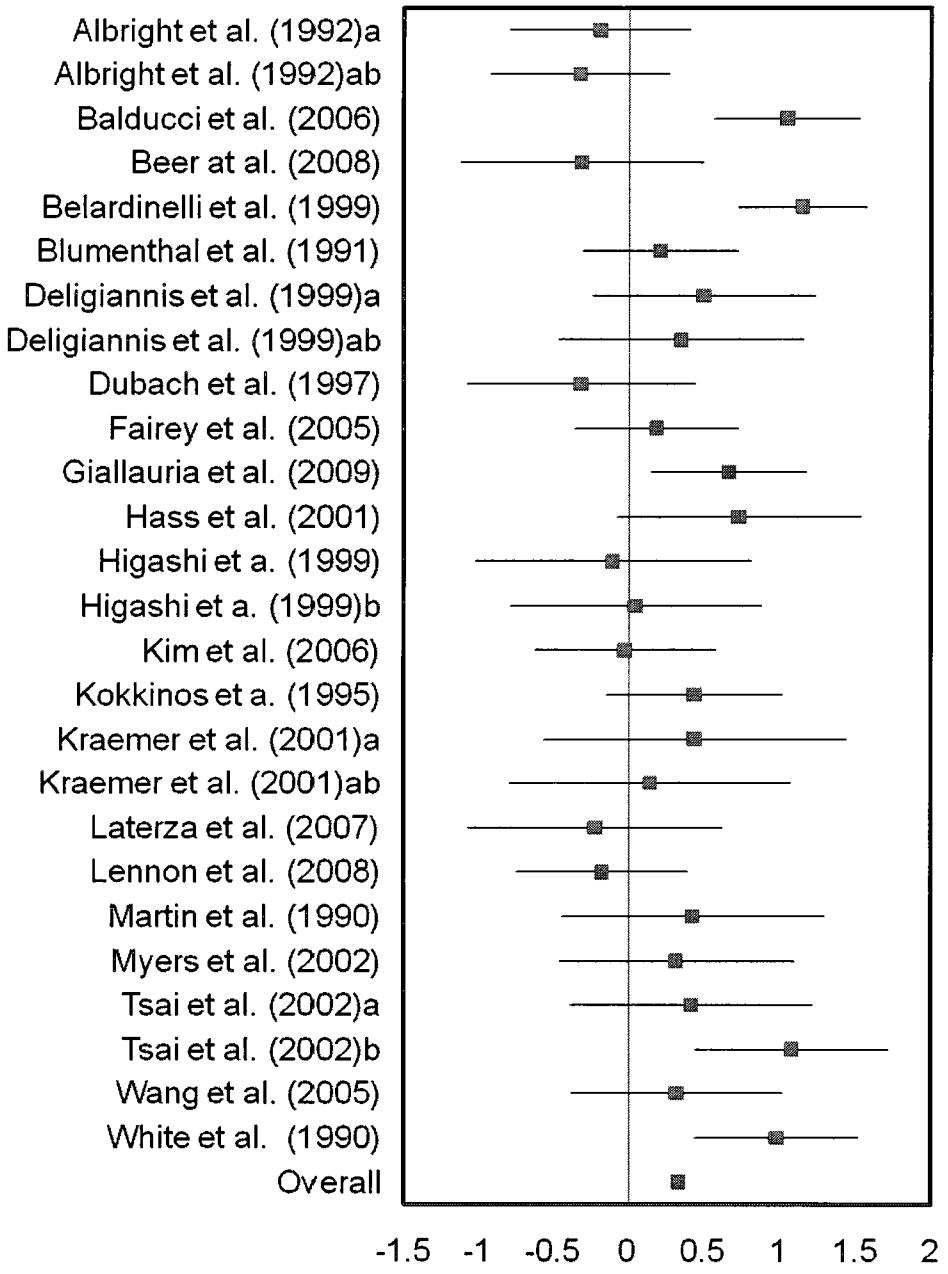

Figure 3. *Forrest plot with ESs and hear rate studies.*

Table 6.

ESs for different dose categories of heart rate studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	-	0.26 (0.03,0.50) n = 7	-
Vigorous	-	0.55 (0.36,0.74) n = 11	0.47 (0.13,0.81) n = 4	-

BMI Effect Size

A total of 60 ESs were calculated for the BMI variable. Those effect sizes were based on 44 different studies and included 1,800 participants in the experimental groups. BMI was one of the variables with the highest number of studies and participants, along with VO_2max and weight. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the BMI analysis can be found in Table 7 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 4. A dose-response analysis was performed for the BMI. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 8.

Table 7.

Characteristics of the studies in the BMI analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Asikainen et al. (2002)a	43	44	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)aa	43	43	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)b	38	20	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)bb	38	21	4	2	11	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)bc	38	16	3	2	8	F	Post menopausal	Walking	24 week	48-63	Yes	Exercise only
Asikainen et al. (2002)bd	38	21	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Balducci et al. (In press)	20	20	2	3	6	B	Type II diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Blumenthal et al. (1991)	22	39	2	3	6	B	Mild Hypertension	W/J	4 months	56 ± 8	Yes	Exercise only
Blumenthal et al. (2000)	22	44	2	3	6	B	Obese/Mild Hypertension	W/J	6 months	48 ± 1	Yes	Exercise only
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	45-65	No	Exercise only
Courneya, 2003	28	24	2	3	6	F	Post menopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dengel et al. (1994)	15	23	2	3	6	M	Obese	W/J	9 Months	57 ± 1	Yes	Exercise and diet
Donnelly et al. (2003)a	21	24	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only

Table 7.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Donnelly et al. (2003)aa	24	22	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Hautala et al. (2004)	6	18	3	2	8	M	None	W/J	8 weeks	41 ± 8	Yes	Exercise only
Higashi et a. (1999)a	7	10	3	2	8	B	Mild hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Houmard et al. (2004)a	40	41	3	1	7	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Houmard et al. (2004)ab	40	30	2	3	6	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Irving et al. (2008)a	9	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	11	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irwin et al. (2009)	38	37	3	2	8	F	Brest cancer survivors		6 months	56 ± 8	Yes	Exercise only
Kokkinos et a. (1995)	22	23	2	2	6	M	African American hypertensive	Cycling	16 weeks	36-76	Yes	Exercise and medication
Krasnoff et al. (2006)	70	49	2	2	5	F	Liver transplant	W/C	12 months	50 ± 11	Yes	Exercise and diet
Kukkonen-Harjula et al. (1998)a	26	25	3	3	9	M	None	Walking	15 weeks	30-55	Yes	Exercise only
Kukkonen-Harjula et al. (1998)aa	29	28	3	3	9	F	None	Walking	15 weeks	30-55	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
McTiernan et al. (2007)a	50	49	4	2	11	F	Sedentary	Variable	12 months	40-75	No	Exercise only
McTiernan et al. (2007)aa	51	51	4	2	11	M	Sedentary	Variable	12 months	40-75	No	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Miller et al. (2002)	20	20	2	1	4	B	Hypertensive, overweight adults on BP medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Myslivecek et al. (2002)a	8	8	3	2	8	F	Pre menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Myslivecek et al. (2002)aa	8	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Nieman et al. (2002)a	22	21	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise only
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant		11 months	40 ± 13	Yes	Exercise only

Table 7.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	62 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	62 ± 6	Yes	Exercise only
Rogers et al. (2009)	20	21	3	2	8	F	Breast cancer survivor	Walking	12 weeks	53 ± 9	Yes	Exercise and counseling
Santa-Clara et al. (2003)	16	17	3	3	9	F	Postmenopausal Caucasian	Variable	6 months	45-70	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Shin et al. (2008)	8	8	2	3	6	F	Overweight obese	W/J	6 months	47 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Smith et al. (2001)	29	18	2	3	6	B	HIV positive	Variable	12 weeks	37 ± 6	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tsai et al. (2002)a	11	12	2	2	6	B	Mild Hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Tsekouras et al. (2008)	8	8	2	3	6	M	None	Running	8 weeks	20-40	Yes	Exercise only
Vainionpaa et al. (2007)	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
van Rooijen et al. (2004)	74	80	4	2	11	F	African American type II diabetics	Walking	12 weeks	40-65	No	Exercise only
Vigorito et al. (2007)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

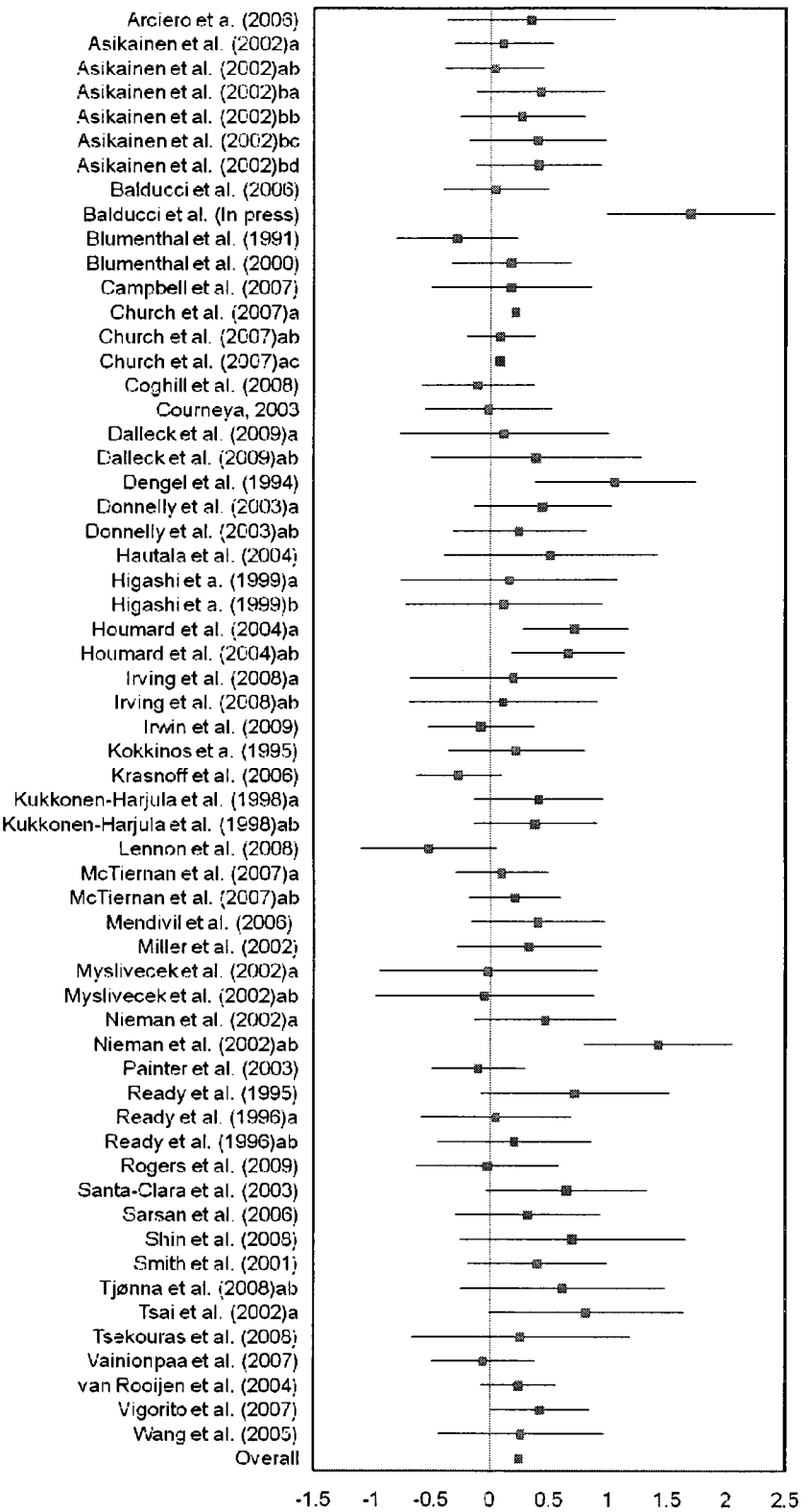

Figure 4. *Forrest plot with ESs and BMI studies.*

Table 8.

ESs for different dose categories of BMI studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.56 (0.13,0.99) n = 3	-
Moderate	-	0.15 (-0.23,0.53) n = 3	0.23 (0.08,0.38) n = 24	0.24 (-0.11,0.59) n = 3
Vigorous	-	0.32 (0.14,0.50) n = 15	0.22 (-0.04,0.48) n = 7	-

Weight Effect Size

A total of 73 ESs were calculated for the weight variable. Those effect sizes were based on 50 different studies and included 1,904 participants in the experimental groups. Weight was the variable with the largest number of ESs and participants in the experimental group. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the weight analysis can be found in Table 9 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 5. A dose-response analysis was performed for the weight variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 10.

Table 9.

Characteristics of the studies in the weight analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Asikainen et al. (2002)a	43	44	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)aa	43	43	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)b	38	20	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)bb	38	21	4	2	11	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)bc	38	16	3	2	8	F	Post menopausal	Walking	24 week	48-63	Yes	Exercise only
Asikainen et al. (2002)bd	38	21	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Balducci et al. (In press)	20	20	2	3	6	B	Type II diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Blumenthal et al. (1991)	22	39	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Blumenthal et al. (2000)	22	44	2	3	6	B	Obese/Mild Hypertension	W/J	6 months	48 ± 1	Yes	Exercise only
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	45-65	No	Exercise only
Courneya et al. (2009)	62	60	2	3	6	F	Lymphoma Patients	Cycling	12 weeks	53	Yes	Exercise only
Courneya et al. 2003	28	24	2	3	6	F	Post menopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	□□□□	Yes	Exercise only

Table 9.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Dengel et al. (1994)	15	23	2	3	6	M	Obese	W/J	9 Months	57 ± 1	Yes	Exercise and diet
Donnelly et al. (2003)a	21	24	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Donnelly et al. (2003)aa	24	22	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Hautala et al. (2004)	6	18	3	2	8	M	None	W/J	8 weeks	41 ± 8	Yes	Exercise only
Higashi et a. (1999)a	7	10	3	2	8	B	Mild hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Houmard et al. (2004)a	40	41	3	1	7	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Houmard et al. (2004)ab	40	30	2	3	6	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Houmard et al. (2004)ac	40	45	3	3	9	B	Sedentary, overweight/obese	W/J	6 months	51 ± 1	No	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irwin et al. (2009)	38	37	3	2	8	F	Brest cancer survivors	Walking	6 months	56 ± 8	Yes	Exercise only
Kokkinos et a. (1995)	22	23	2	2	6	M	African American hypertensive	Cycling	16 weeks	36-76	Yes	Exercise and medication
Kraemer et al. (2001)a	6	8	2	3	6	F	None	Bench stepping	12 weeks	32 ± 8	No	Exercise only
Kraemer et al. (2001)aa	6	12	2	3	6	F	None	Bench stepping	12 weeks	37 ± 8	No	Exercise only
Krasnoffet al. (2006)	70	49	2	3	6	B	Liver transplantation patients	W/C	12 months	50 ± 11	Yes	Exercise and diet
Kukkonen-Harjula et al. (1998)a	26	25	3	3	9	M	None	Walking	15 weeks	30-55	Yes	Exercise only
Kukkonen-Harjula et al. (1998)aa	29	28	3	3	9	F	None	Walking	15 weeks	30-55	Yes	Exercise only
Martin et al. (1990)	9	10	2	2	5	M	Hypertensive	Variable	10 weeks	18-60	Yes	Exercise only
McTiernan et al. (2007)a	50	49	4	2	11	F	Sedentary	Variable	12 months	40-75	No	Exercise only
McTiernan et al. (2007)aa	51	51	4	2	11	M	Sedentary	Variable	12 months	40-75	No	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Meyer et al. (2007)a	13	13	3	2	8	B	None	W/J	12 weeks	44 ± 7	Yes	Exercise only
Meyer et al. (2007)aa	13	13	3	1	7	B	None	W/J	12 weeks	44 ± 7	Yes	Exercise only

Table 9.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Miller et al. (2002)	23	20	2	1	4	B	Hypertensive, overweight adults on BP medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Myslivecek et al. (2002)a	8	8	3	2	8	F	Pre menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Myslivecek et al. (2002)aa	8	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Naimark et al. (1996)a	20	19	3	3	9	F	Post menopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Naimark et al. (1996)aa	20	17	4	3	12	F	Post menopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Nieman et al. (2002)a	22	21	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise only
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Potteiger et al. (2003)a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-36	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Santa-Clara et al. (2003)a	16	17	3	3	9	F	Postmenopausal Caucasian	Variable	6 months	45-70	Yes	Exercise only
Santa-Clara et al. (2003)aa	12	15	3	3	9	F	Postmenopausal African American	Variable	6 months	45-70	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Shin et al. (2008)	8	8	2	3	6	F	Overweight obese	W/J	6 months	47 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Smith et al. (2001)	29	18	2	3	6	B	HIV positive	Variable	12 weeks	37 ± 6	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Trapp et al. (2008)a	15	8	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Trapp et al. (2008)aa	15	11	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Tsekouras et al. (2008)	8	7	2	3	6	M	None	Running	8 weeks	20-40	Yes	Exercise only
Vainionpaa et al. 2007	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only

Weiss et al. (2006)	10	18	4	2	11	B	None	Walking	12 months	50-60	No	Exercise and diet

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

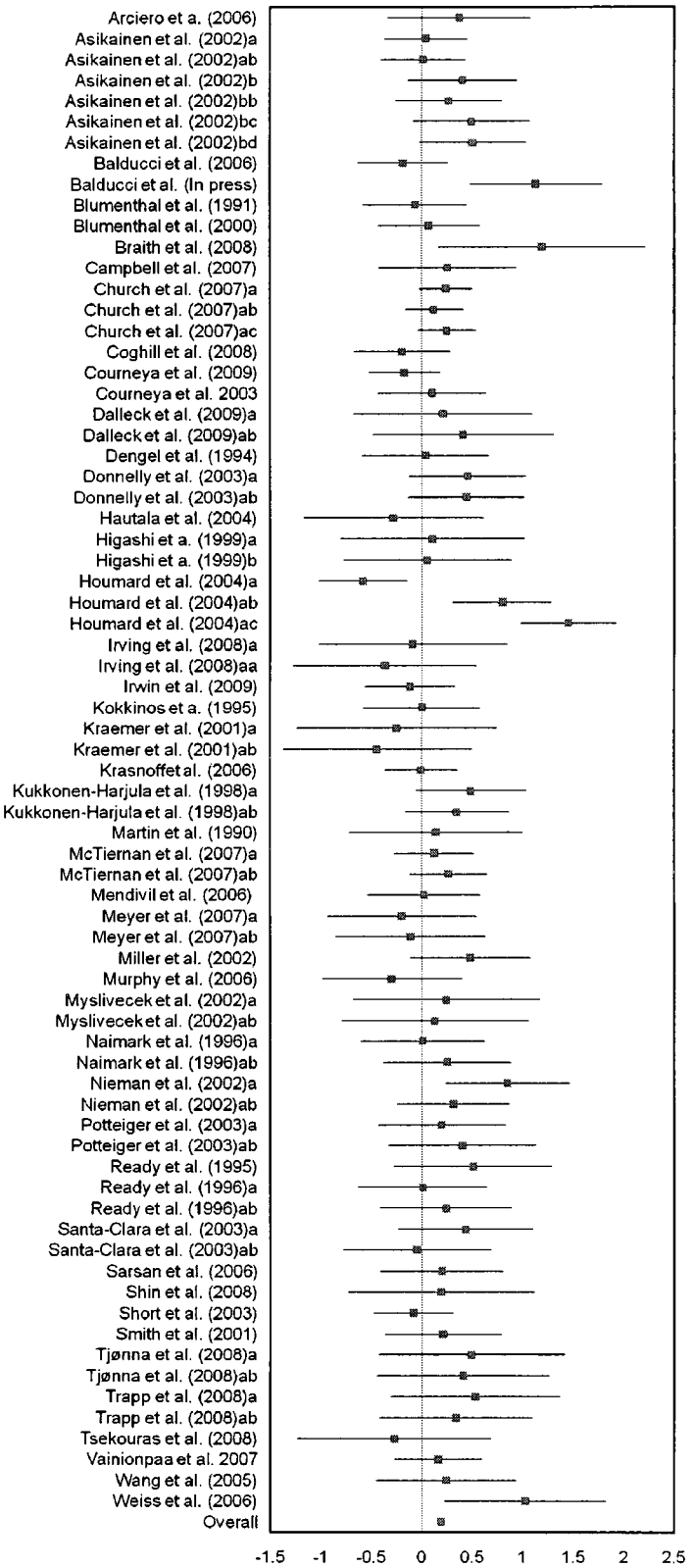

Figure 5. *Forrest plot with ESs and weight studies.*

Table 10.

ESs for different dose categories of weight studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-0.24 (-0.62,0.13) n = 4	-
Moderate	-	0.16 (-0.15,0.47) n = 5	0.19 (0.05,0.32) n = 26	0.32 (0.01,0.62) n = 4
Vigorous	-	0.15 (-0.02,0.32) n = 18	0.41 (0.17,0.65) n = 9	-

Body Fat Percentage Effect Size

A total of 41 ESs were calculated for the body fat percentage (BF%) variable. Those effect sizes were based on 29 different studies and included 1,118 participants in the experimental groups. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the BF% analysis can be found in Table 11 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 6. A dose-response analysis was performed for the BF% variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 12.

Table 11.

Characteristics of the studies in the body fat percentage analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Asikainen et al. (2002)a	43	44	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)aa	43	43	3	3	9	F	Post menopausal	Walking	15 weeks	47-64	Yes	Exercise only
Asikainen et al. (2002)b1	38	20	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)b2	38	21	4	2	11	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Asikainen et al. (2002)b3	38	16	3	2	8	F	Post menopausal	Walking	24 week	48-63	Yes	Exercise only
Asikainen et al. (2002)b4	38	21	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	52 ± 14	Yes	Exercise only
Balducci et al. (In press)	20	20	2	3	6	B	Type II diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Blumenthal et al. (1991)	22	39	3	2	8	F	None	High impact exercise	6 months	35-40	Yes	Exercise only
Blumenthal et al. (2000)	22	44	2	3	6	B	Obese/Mild Hypertension	W/J	6 months	48 ± 1	Yes	Exercise only
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	45-65	No	Exercise only
Courneya et al. (2009)	62	60	2	3	6	F	Lymphoma Patients	Cycling	12 weeks	53.2	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Donnelly et al. (2003)a	21	24	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Donnelly et al. (2003)aa	24	22	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irwin et al. (2009)	38	37	3	2	8	F	Brest cancer survivors	Walking	6 months	56 ± 8	Yes	Exercise only
Kraemer et al. (2001)a	6	8	2	3	6	F	None	Bench stepping	12 weeks	32 ± 8	No	Exercise only

Table 11.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Krasnoffet al. (2006)	70	49	2	3	6	B	Liver transplantation patients	W/C	12 months	50 ± 11	Yes	Exercise and diet
Kukkonen-Harjula et al. (1998)a	26	25	3	3	9	M	None	Walking	15 weeks	30-55	Yes	Exercise only
Kukkonen-Harjula et al. (1998)aa	29	28	3	3	9	F	None	Walking	15 weeks	30-55	Yes	Exercise only
Martin et al. (1990)	9	10	2	2	5	M	Hypertensive	Variable	10 weeks	18-60	Yes	Exercise only
McTiernan et al. (2007)a	50	49	4	2	11	F	Sedentary	Variable	12 months	40-75	No	Exercise only
McTiernan et al. (2007)aa	51	51	4	2	11	M	Sedentary	Variable	12 months	40-75	No	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Nieman et al. (2002)a	22	21	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise only
Potteiger et al. (2003)a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Rogers et al. (2009)	20	21	3	2	8	F	Breast cancer survivor	Walking	12 weeks	53 ± 9	Yes	Exercise and counseling
Sabelis et al. (2004)	25	36	1	2	2	B	Chronic heart failure	Cycling	26 weeks	60 ± 9	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Trapp et al. (2008)a	15	8	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Trapp et al. (2008)aa	15	11	2	3	6	F	None	Cycling	15 weeks	20 ± 2	Yes	Exercise only
Tsekouras et al. (2008)	8	7	2	3	6	M	None	Running	8 weeks	20-40	Yes	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

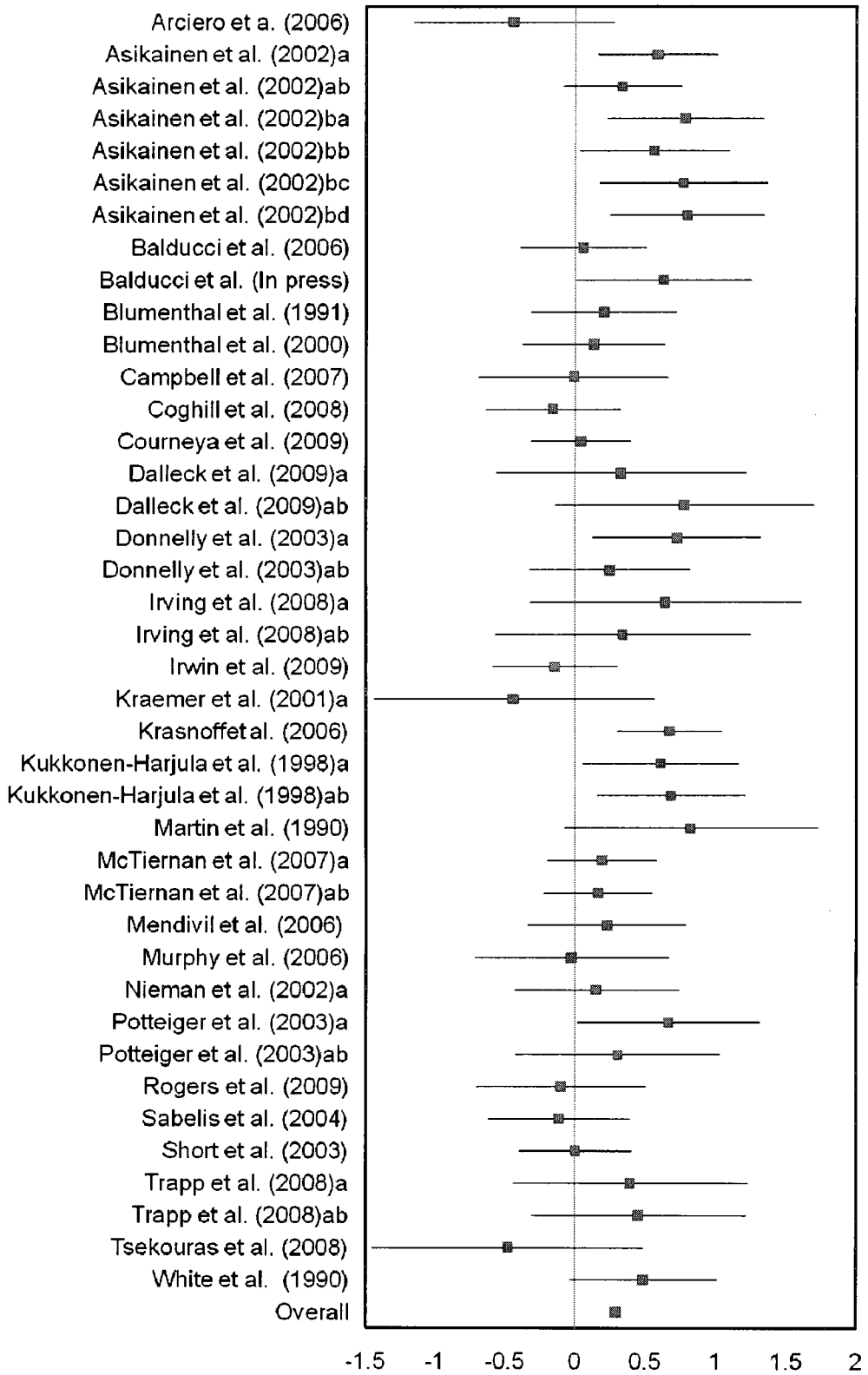

Figure 6. *Forrest plot with ESs and body fat percentage studies.*

Table 12.

ESs for different dose categories of body fat percentage studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	-	0.36 (0.21,0.52) n = 17	0.27 (-0.03,0.57) n = 3
Vigorous	-	0.21 (-0.01,0.43) n = 10	0.65 (0.25,1.05) n = 4	-

Waist Circumference Effect Size

A total of 28 ESs were calculated for the waist variable. Those effect sizes were based on 19 different studies and included 936 participants in the experimental groups. Waist circumference was one of the least used anthropometric variables. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the waist analysis can be found in Table 13 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 7. There were not enough studies to conduct a dose response analysis for waist circumference.

Table 13.

Characteristics of the studies in the waist circumference analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Balducci et al. (2006)	47	31	3	2	8	F	Post menopausal	Walking	24 weeks	48-63	Yes	Exercise only
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	45-65	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irwin et al. (2009)	38	37	3	2	8	F	Brest cancer survivors	Walking	6 months	56 ± 8	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
McTiernan et al. (2007)a	50	49	4	2	11	F	Sedentary	Variable	12 months	40-75	No	Exercise only
McTiernan et al. (2007)aa	51	51	4	2	11	M	Sedentary	Variable	12 months	40-75	No	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Potteiger et al. (2003)a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Sabelis et al. (2004)	25	36	1	2	2	B	Chronic heart failure	Cycling	26 weeks	60 ± 9	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Smith et al. (2001)	28	17	2	3	6	B	HIV positive	Variable	12 weeks	37 ± 6	Yes	Exercise only

Table 13.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Vainionpaa et al. (2007)	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Vigorito et al. (2007)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

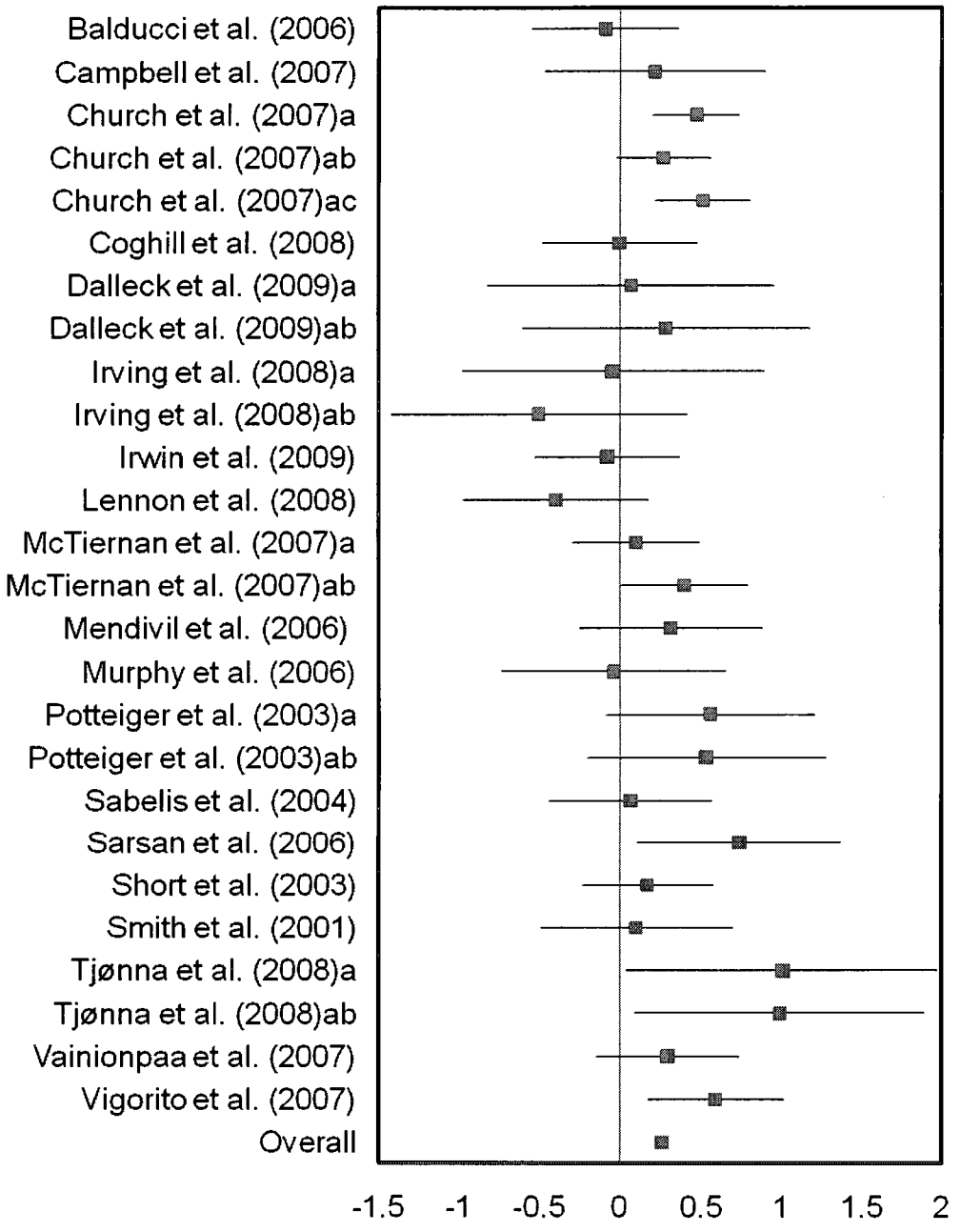

Figure 7. *Forrest plot with ESs and waist circumference studies.*

Waist-to-Hip Ratio Effect Size

A total of 13 ESs were calculated for the waist-to-hip ratio (WR) variable. Those effect sizes were based on 10 different studies and included 239 participants in the experimental groups. WR had the lowest number of ESs from the body composition variables, but it had the highest ES among them. The quantitative synthesis of the effects yielded a small to medium and positive mean ES (see Table 2). The summary information of the articles included in the WR analysis can be found in Table 14 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 8. There were not enough studies to conduct a dose response analysis for WR.

Table 14.

Characteristics of the studies in the waist-to-hip ratio analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Potteiger et al. (2003a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Campbell et al. (2007)	15	17	2	3	6	F	Sedentary	Cycling	12 weeks	20-35	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	45-65	No	Exercise only
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Rogers et al. (2009)	20	21	3	2	8	F	Breast cancer survivor	Walking	12 weeks	53 ± 9	Yes	Exercise and counseling
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Smith et al. (2001)	29	18	2	3	6	B	HIV positive	Variable	12 weeks	37 ± 6	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

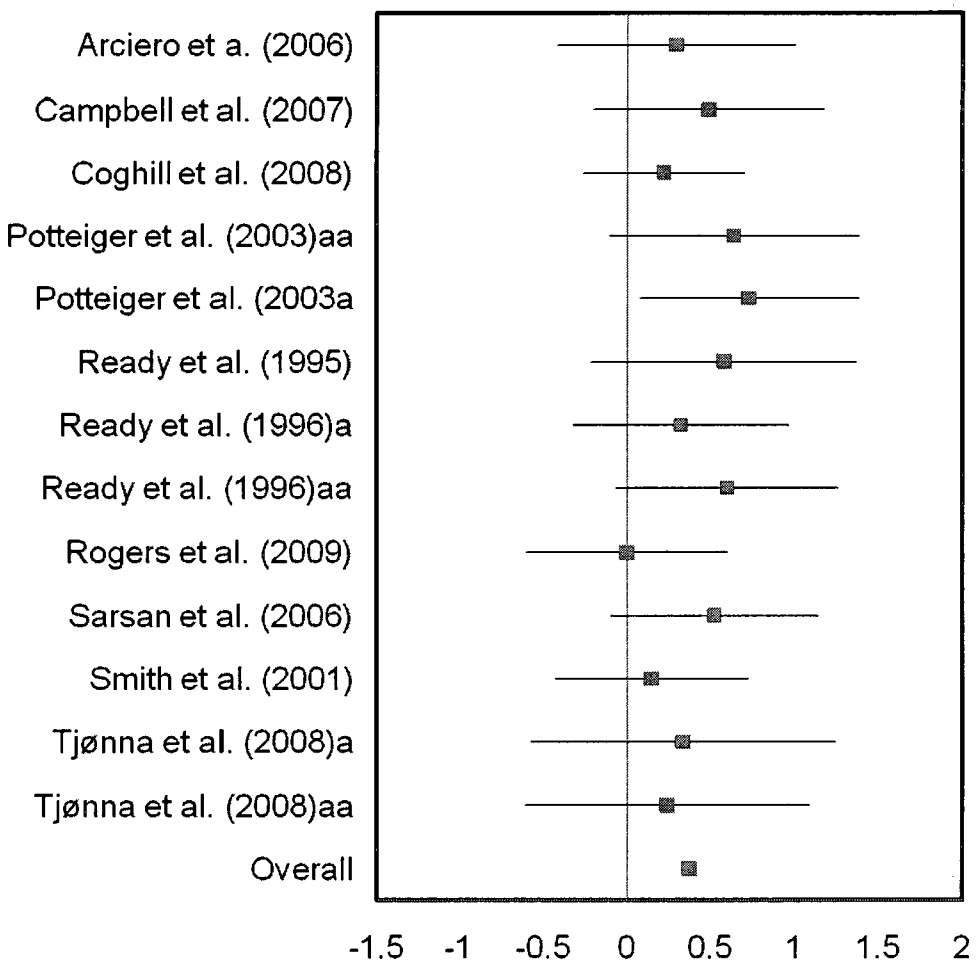

Figure 8. *Forrest plot with ESs and waist-to-hip ratio studies.*

Triglycerides Effect Size

A total of 32 ESs were calculated for the triglycerides variable. Those effect sizes were based on 24 different studies and included 1,044 participants in the experimental groups. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the triglycerides analysis can be found in Table 15 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 9. A dose-response analysis was performed for the triglycerides variable. No significant difference was found among the categories ($Qb >$ .05). The ES and CI for each category can be found in Table 16.

Table 15.

Characteristics of the studies in the triglycerides analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention Components
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Balducci et al. (In press)	20	20	2	3	6	B	Type II diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild Hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Irving et al. (2008)a	9	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	11	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Kraus et al. (2002)a	26	19	3	2	8	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ab	26	17	2	3	6	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ac	26	22	3	3	9	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Ligtenberg et al. (1997)	26	25	3	3	9	B	Type 2 diabetics	W/J	12 weeks	62 ± 5	Yes	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Nieman et al. (2002)a	22	21	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise only

Table 15.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention Components
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II diabetics	W/C	6 months	39-70	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tsai et al. (2002)b	22	20	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Vainionpaa et al. (2007)	38	41	3	2	8	F	None	High impact exercise	6 months	35-40	Yes	Exercise only
Vigorito et al. (2007)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

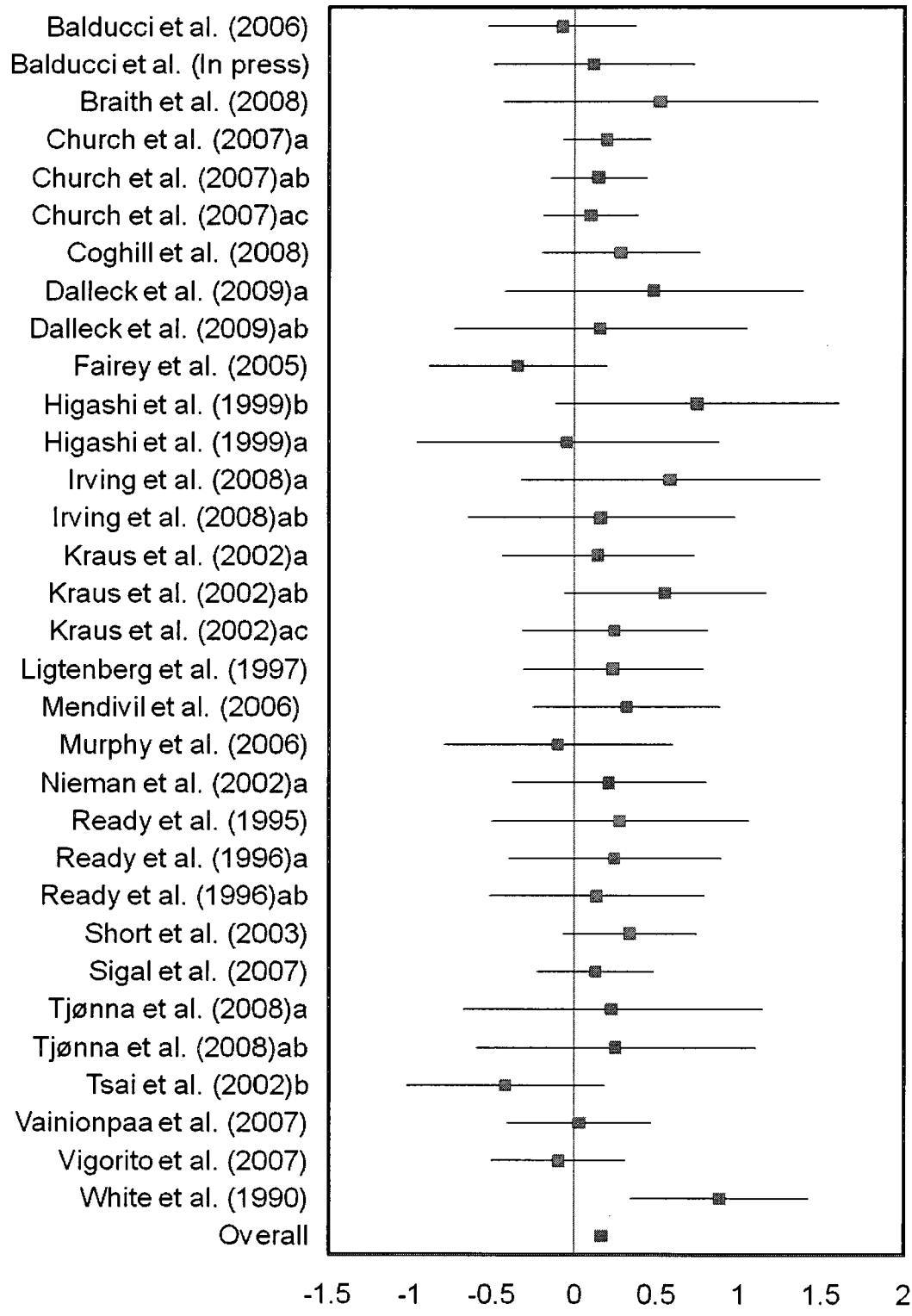

Figure 9. *Forrest plot with ESs and triglycerides studies.*

Table 16.

ESs for different dose categories of triglycerides studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	0.18 (-0.02,0.37) n = 5	0.08 (-0.04,0.30) n = 10	-
Vigorous	-	0.05 (-0.15,0.25) n = 7	0.43 (0.16,0.70) n = 5	-

Fasting Glucose Effect Size

A total of 26 ESs were calculated for the fasting glucose variable. Those effect sizes were based on 18 different studies and included 837 participants in the experimental groups. Only two studies were conducted with males only, all other studies included females or both. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the fasting glucose analysis can be found in Table 17 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 10. A dose-response analysis was performed for the fasting glucose variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 18.

Table 17.

Characteristics of the studies in the fasting glucose analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Blumenthal et al. (2000)	22	44	2	3	6	B	Obese/Mild Hypertension	W/J	6 months	48 ± 1	Yes	Exercise only
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild Hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Houmard et al. (2004)a	40	41	3	1	7	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Houmard et al. (2004)ab	40	30	2	3	6	B	Sedentary, overweight/obese	W/J	6 months	53 ± 1	No	Exercise only
Houmard et al. (2004)ac	40	45	3	3	9	B	Sedentary, overweight/obese	W/J	6 months	51 ± 1	No	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Potteiger et al. (2003)a	16	22	3	2	8	F	Overweight	Walking	16 months	17-35	Yes	Exercise only

Table 17.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Potteiger et al. (2003)aa	13	15	3	2	8	M	Overweight	Walking	16 months	17-35	Yes	Exercise only
Sabelis et al. (2004)	25	36	1	2	2	B	Chronic heart failure	Cycling	26 weeks	60 ± 9	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Vainionpaa et al. (2007)	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Weiss et al. (2006)	10	18	4	2	11	B	None	Walking	12 months	50-60	No	Exercise and diet

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

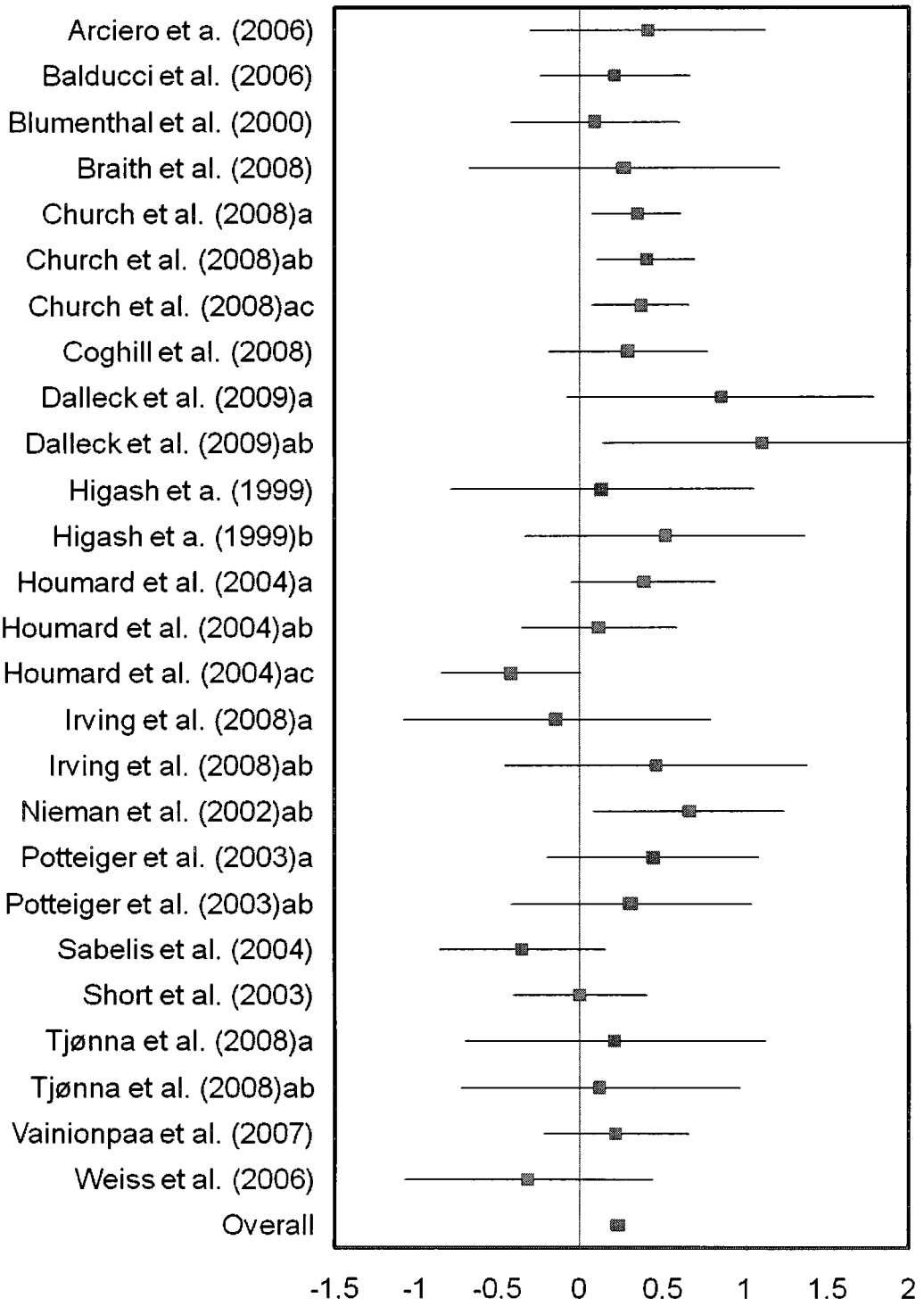

Figure 10. *Forrest plot with ESs and fasting glucose studies.*

Table 18.

ESs for different dose categories of fasting glucose studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.40 (0.05,0.74) n = 3	-
Moderate	-	0.35 (0.12,0.59) n = 4	0.39 (0.21,0.66) n = 10	-
Vigorous	-	0.07 (-0.18,0.32) n = 4	-	-

HDL-C Effect Size

A total of 33 ESs were calculated for the HDL-C variable. Those effect sizes were based on 25 different studies and included 1,027 participants in the experimental groups. HDL-C was the cholesterol variable with the largest number of ESs computed. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the HDL-C analysis can be found in Table 19 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 11. A dose-response analysis was performed for the HDL-C. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 20.

Table 19.

Characteristics of the studies in the high density lipoprotein cholesterol analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/Obese	W/J	12 weeks	26-60	No	Exercise and diet
Balducci et al. (In Press)	20	20	2	3	6	B	Type II Diabetics with MS	Walking	12 months	40-75	Yes	Exercise and counseling
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	37	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild Hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Kraus et al. (2002)a	26	19	3	2	8	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ab	26	17	2	3	6	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ac	26	22	3	3	9	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Ligtenberg et al. (1997)	26	25	3	3	9	B	Type 2 diabetics	W/J	12 weeks	62 ± 5	Yes	Exercise only
Miller et al. (2002)	20	20	2	1	4	B	Hypertensive, overweight on blood pressure medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and

diet

Table 19.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant		11 months	40 ± 12	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II Diabetics	W/C	6 months	39-70	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tsai et al. (2002)b	20	22	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Vainionpaa et al. (2007)	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Vigorito et al. (2003)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised

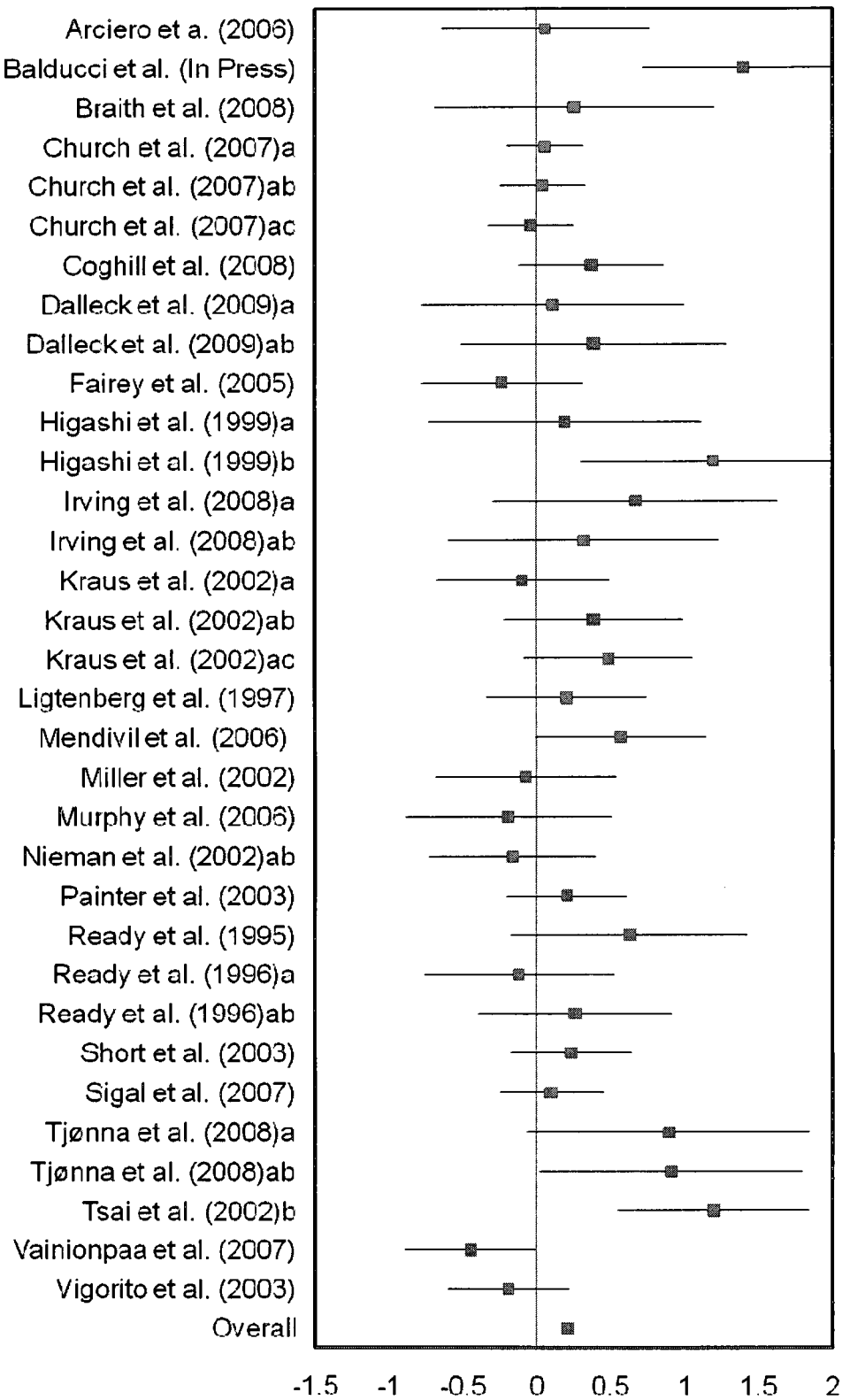

Figure 11. *Forrest plot with ESs and high density lipoprotein cholesterol studies.*

Table 20.

ESs for different dose categories of high density lipoprotein cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	0.24 (-0.13,0.61) n = 5	0.11 (-0.18,0.41) n = 9	-
Vigorous	-	0.39 (0.10,0.68) n = 8	0.27 (-0.18,0.72) n = 4	-

LDL-C Effect Size

A total of 28 ESs were calculated for the LDL-C variable. Those effect sizes were based on 21 different studies and included 996 participants in the experimental groups. From the cholesterol measures LDL-C was the one with the lowest overall ES. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the LDL-C analysis can be found in Table 21 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 11. A dose-response analysis was performed for the LDL-C variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 22.

Table 21.

Characteristics of the studies in the low density lipoprotein cholesterol analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Kraus et al. (2002)a	26	19	3	2	8	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ab	26	17	2	3	6	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ac	26	22	3	3	9	B	Overweight/Obese	W/J	8 months	52 ± 8	Yes	Exercise only
Ligtenberg et al. (1997)	26	25	3	3	9	B	Type 2 diabetics	W/J	12 weeks	62 ± 5	Yes	Exercise only
Miller et al. (2002)	20	20	2	1	4	B	Hypertensive, overweight adults on a single blood pressure medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet

Table 21.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II Diabetics	W/C	6 months	39-70	Yes	Exercise only
Tsai et al. (2002)b	20	22	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Vainionpaa et al. 2007	38	41	3	2	8	F	None	High impact exercise	6 months	35-40	Yes	Exercise only
Vigorito et al. (2003)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

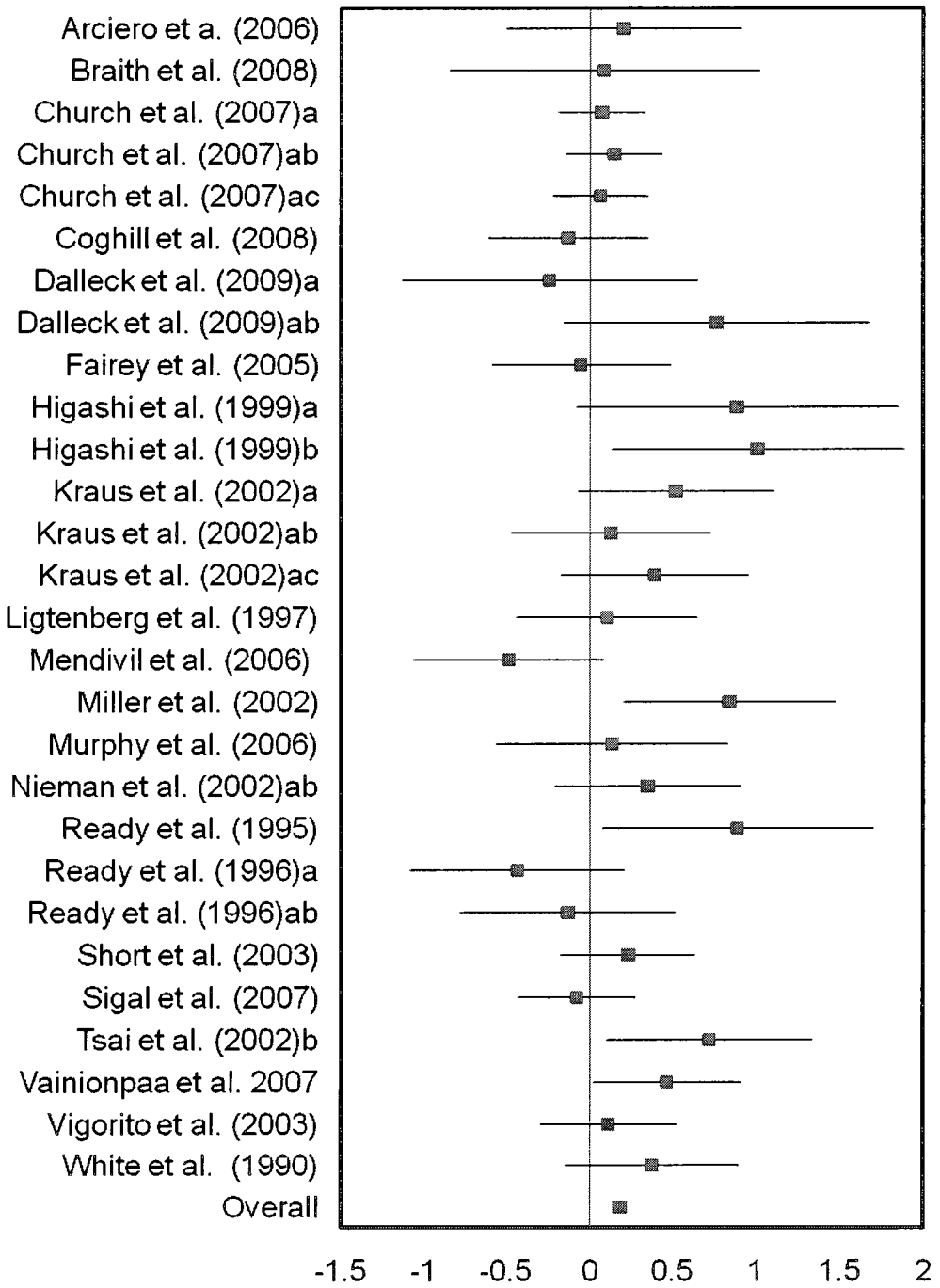

Figure 12. *Forrest plot with ESs and low density lipoprotein cholesterol studies.*

Table 22.

ESs for different dose categories of low density lipoprotein cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	0.00 (-0.28,0.29) n = 4	0.27 (0.04,0.50) n = 9	-
Vigorous	-	0.20 (-0.07,0.48) n = 5	0.14 (-0.20,0.47) n = 4	-

Total Cholesterol Effect Size

A total of 27 ESs were calculated for the total cholesterol variable. Those effect sizes were based on 22 different studies and included 715 participants in the experimental groups. Only relatively small studies were included in this analysis, the study with the highest number os participants had 90 participants. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the total cholesterol analysis can be found in Table 23 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 12. A dose-response analysis was performed for the total cholesterol variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 24.

Table 23.

Characteristics of the studies in the total cholesterol analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild Hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Kraus et al. (2002)a	26	19	3	2	8	B	Overweight/obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ab	26	17	2	3	6	B	Overweight/obese	W/J	8 months	52 ± 8	Yes	Exercise only
Kraus et al. (2002)ac	26	22	3	3	9	B	Overweight/obese	W/J	8 months	52 ± 8	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
Ligtenberg et al. (1997)	26	25	3	3	9	B	Type 2 diabetics	W/J	12 weeks	62 ± 5	Yes	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Miller et al. (2002)	20	20	2	1	4	B	hypertensive, overweight on BP medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant	Walking	11 months	40 ± 12	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only

Table 23.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Short et al. (2003)	37	65	2	3	6	B	Sedentary	Cycling	16 weeks	21-84	Yes	Exercise only
Tsai et al. (2002)b	20	22	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Vainionpaa et al. 2007	38	41	3	2	8	F	None	High impact	6 months	35-40	Yes	Exercise only
Vigorito et al. (2003)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	22 ± 2	Yes	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised

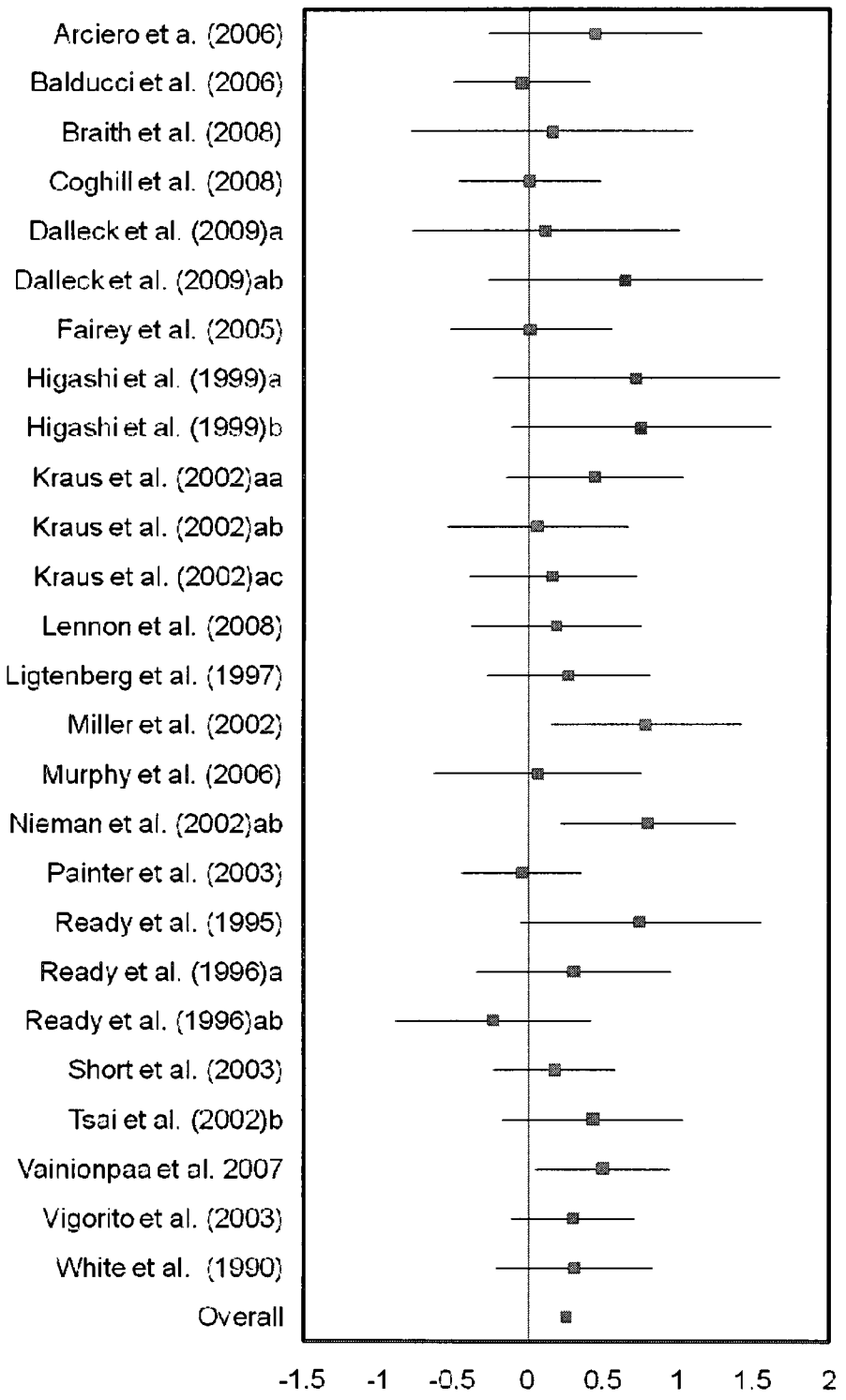

Figure 13. *Forrest plot with ESs and total cholesterol studies.*

Table 24.

ESs for different dose categories of total cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	-	-
Moderate	-	-	0.15 (-0.03,0.34) n = 8	-
Vigorous	-	0.26 (0.03,0.49) n = 6	0.26 (-0.10,0.62) n = 4	-

Cholesterol Ratio Effect Size

A total of nine ESs were calculated for the cholesterol ratio (CR) variable. Those effect sizes were based on nine different studies and included 315 participants in the experimental groups. CR had the highest ES from all the cholesterol variables due to a combination of the reduction of LDL-C and increase in HDL-C. The quantitative synthesis of the effects yielded a small to medium and positive mean ES (see Table 2). The summary information of the articles included in the CR analysis can be found in Table 25 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 13. There were not enough studies to conduct a dose-response analysis for CR.

Table 25.

Characteristics of the studies in the cholesterol ratio analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Braith et al. (2008)	7	9	2	2	5	B	Heart transplant recipient	Walking	12 weeks	54 ± 13	Yes	Exercise only
Coghill et al. (2008)	29	37	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Nieman et al. (2002)aa	26	22	3	2	8	F	Moderately obese	Walking	12 weeks	25-75	Yes	Exercise and diet
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant	Walking	11 months	40 ± 13	Yes	Exercise only
Ready et al. (1995)	10	15	4	1	10	F	Postmenopausal	Walking	6 months	62 ± 6	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II Diabetics	W/C	6 months	39-70	Yes	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

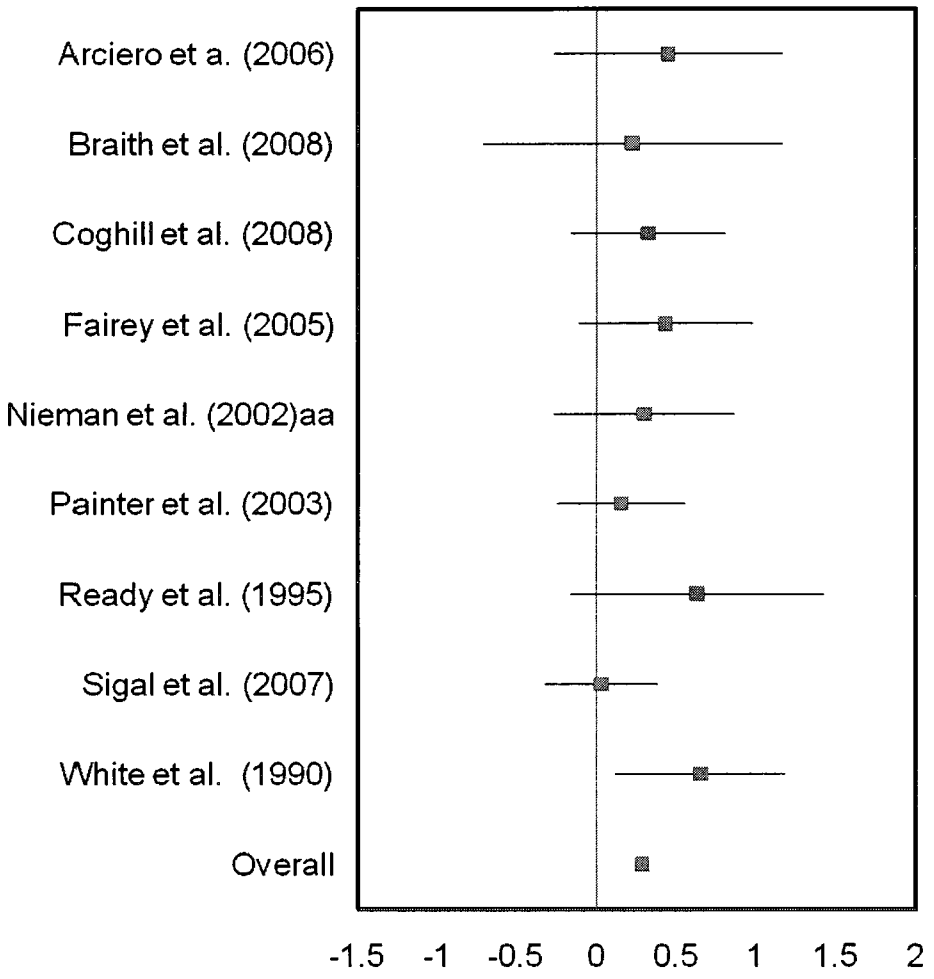

Figure 14. *Forrest plot with ESs and cholesterol ratio studies.*

Systolic Blood Pressure Effect Size

A total of 49 ESs were calculated for the SBP variable. Those effect sizes were based on 38 different studies and included 1,322 participants in the experimental groups. A slightly higher ES for SBP was found compared to DBP. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the SBP analysis can be found in Table 26 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 14. A dose-response analysis was performed for the SBP variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 27.

Table 26.

Characteristics of the studies in the systolic blood pressure analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Albright et al. (1992)a	21	20	3	2	8	F	None	W/J	6 months	47 ± 5	No	Exercise only
Albright et al. (1992)aa	21	21	3	2	8	M	None	W/J	6 months	49 ± 6	No	Exercise only
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Balducci et al. (2006)	47	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Beer at al. (2008)	11	11	3	3	9	B	Dilated cardiomyopathy	Cycling	8 months	57	No	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Deligiannis et al. (1999)a	12	16	3	2	8	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Deligiannis et al. (1999)aa	12	10	3	1	7	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Dubach et al. (1997)	13	12	2	3	6	M	Reduced left ventricular function	Cycling	8 weeks	56 ± 7	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Giallauria et al. (2009)	30	30	2	3	6	B	Acute myocardial infarction	Cycling	6 months	59 ± 3	Yes	Exercise only
Hass et al. (2001)	9	17	2	3	6	B	Sedentary	Stepper	12 weeks	48 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only

Table 26.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Kim et al. (2006)	19	22	2	3	6	F	Breast cancer	Walking	8 weeks	40+	No	Exercise only
Kokkinos et a. (1995)	22	23	2	2	6	M	African American hypertensive	Cycling	16 weeks	36-76	Yes	Exercise and medication
Kraemer et al. (2001)a	6	8	2	3	6	F	None	Bench stepping	12 weeks	32 ± 8	No	Exercise only
Kraemer et al. (2001)aa	6	12	2	3	6	F	None	Bench stepping	12 weeks	37 ± 8	No	Exercise only
Laterza et al. (2007)	9	11	2	2	5	B	Hypertensive	Cycling	4 months	46 ± 2	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
Martin et al. (1990)	9	10	2	2	5	M	Hypertensive	Variable	10 weeks	18-60	Yes	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Miller et al. (2002)	23	20	2	1	4	B	hypertensive, overweight on BP medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Myers et al. (2002)	12	12	3	3	9	B	Heart failure patients	Cycling	8 weeks	55 ± 9	Yes	Exercise only
Myslivecek et al. (2002)a	8	8	3	2	8	F	Pre menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Myslivecek et al. (2002)aa	8	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant	Walking	11 months	40 ± 13	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Salvetti et al. (2008)	20	19	2	2	6	B	Coronary disease	Walking	12 weeks	53 ± 8	No	Exercise only
Santa-Clara et al. (2003)a	12	15	3	3	9	F	Postmenopausal Caucasian	Variable	6 months	45-70	Yes	Exercise only
Santa-Clara et al. (2003)aa	16	17	3	3	9	F	Postmenopausal African American	Variable	6 months	45-70	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II Diabetics	W/C	6 months	39-70	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only

Table 26.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Tsai et al. (2002)b	20	22	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
van Rooijen et al. (2004)	74	80	4	2	11	F	African American type II diabetics	Walking	12 weeks	40-65	No	Exercise only
Vigorito et al. (2007)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	21 ± 2	Yes	Exercise only
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

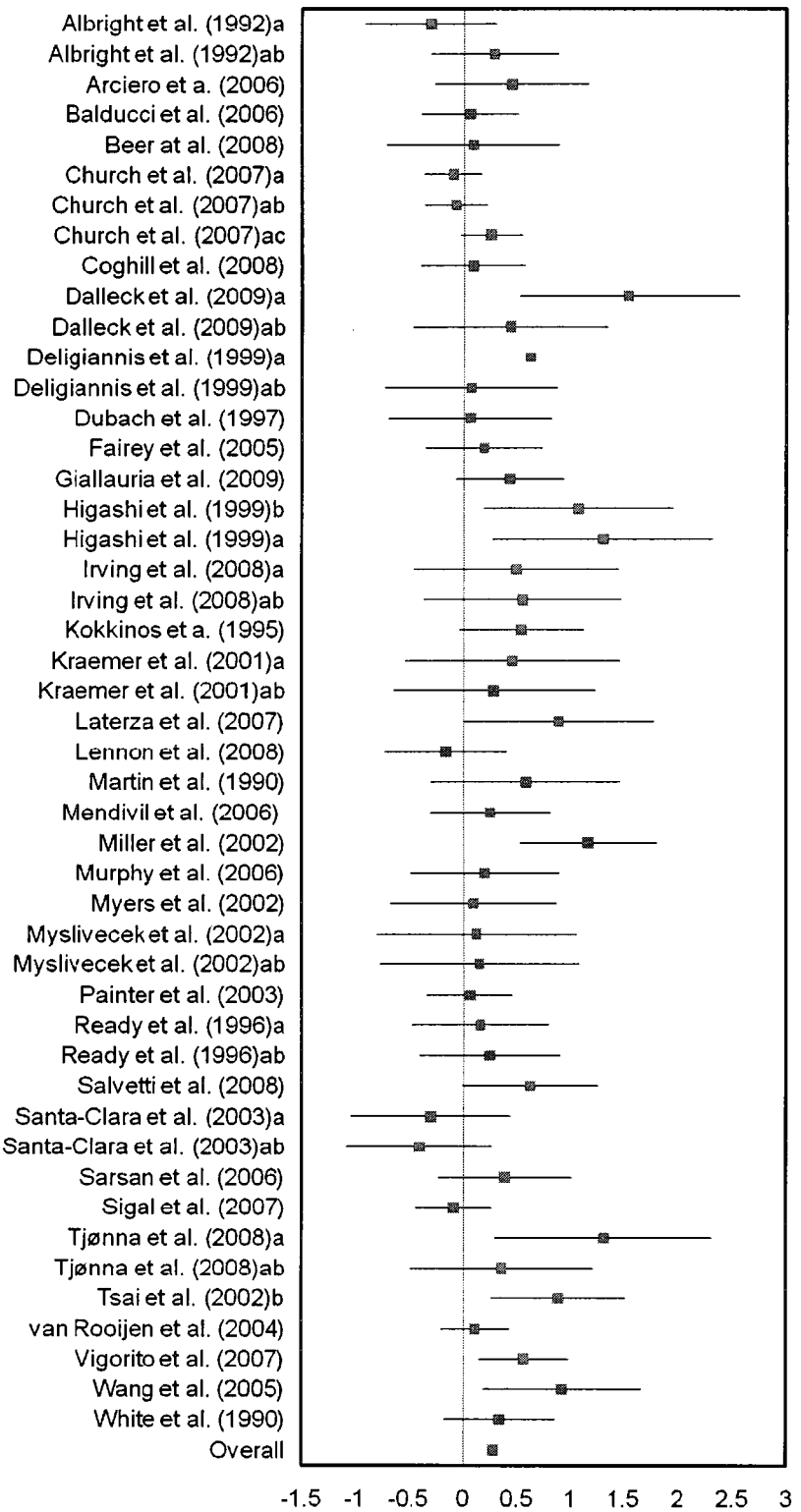

Figure 15. *Forrest plot with ESs and systolic blood pressure studies.*

Table 27.

ESs for different dose categories of systolic blood pressure studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.42 (0.03,0.81) n = 4	-
Moderate	-	0.07 (-0.12,0.26) n = 6	0.28 (0.12,0.81) n = 13	-
Vigorous	-	0.39 (0.22,0.56) n = 11	0.18 (-0.09,0.44) n = 7	-

Diastolic Blood Pressure Effect Size

A total of 46 ESs were calculated for the DBP variable. Those effect sizes were based on 37 different studies and included 1,295 participants in the experimental groups. The quantitative synthesis of the effects yielded a small and positive mean ES (see Table 2). The summary information of the articles included in the DBP analysis can be found in Table 28 and the Forrest plot with the ES and the 95% CI for each study can be found in Figure 15. A dose-response analysis was performed for the DBP variable. No significant difference was found among the categories ($Qb > .05$). The ES and CI for each category can be found in Table 29.

Table 28.

Characteristics of the studies in the diastolic blood pressure analysis.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Albright et al. (1992)a	21	20	3	2	8	F	None	W/J	6 months	47 ± 5	No	Exercise only
Albright et al. (1992)aa	21	21	3	2	8	M	None	W/J	6 months	49 ± 6	No	Exercise only
Arciero et a. (2006)	12	19	3	1	7	B	Overweight/obese	W/J	12 weeks	26-60	No	Exercise and diet
Balducci et al. (2006)	31	31	3	2	8	B	Diabetics	Walking	4 years	51 ± 14	Yes	Exercise only
Beer at al. (2008)	11	11	3	3	9	B	Dilated cardiomyopathy	Cycling	8 months	57	No	Exercise only
Blumenthal et al. (1991)	22	39	2	3	6	B	Mild hypertension	W/J	4 months	56 ± 8	Yes	Exercise only
Coghill et al. (2008)	29	38	2	2	5	M	High cholesterol	Walking	12 weeks	55 ± 5	No	Exercise only
Church et al. (2007)a	92	142	1	2	2	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ab	92	89	2	2	5	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Church et al. (2007)ac	92	95	3	2	8	F`	Postmenopausal, sedentary, high BP	W/C	6 months	45-75	Yes	Exercise only
Dalleck et al. (2009)a	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Dalleck et al. (2009)aa	10	8	3	2	8	F	Post menopausal sedentary	Walking	12 weeks	45-75	Yes	Exercise only
Deligiannis et al. (1999)a	12	16	3	2	8	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Deligiannis et al. (1999)aa	12	10	3	1	7	B	Renal disease	W/C	6 months	21-65	Yes	Exercise only
Dubach et al. (1997)	13	12	2	3	6	M	Reduced left ventricular function	Cycling	8 weeks	56 ± 7	Yes	Exercise only
Fairey et al. (2005)	28	24	2	3	6	F	Postmenopausal breast cancer survivors	Cycling	15 weeks	59 ± 6	Yes	Exercise only
Hass et al. (2001)	9	17	2	3	6	B	Sedentary	Stepper	12 weeks	48 ± 6	Yes	Exercise only
Higashi et al. (1999)a	7	10	3	2	8	B	Mild Hypertension	Walking	12 weeks	47 ± 10	Yes	Exercise only
Higashi et al. (1999)b	7	20	3	2	8	B	Hypertensive	Walking	12 weeks	59 ± 9	Yes	Exercise only
Irving et al. (2008)a	7	9	3	3	9	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only
Irving et al. (2008)aa	7	11	3	1	7	F	Obese	W/J	16 weeks	51 ± 9	Yes	Exercise only

Table 28.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Kokkinos et a. (1995)	22	23	2	2	6	M	African American hypertensive	Cycling	16 weeks	36-76	Yes	Exercise and medication
Kraemer et al. (2001)aa	6	12	2	3	6	F	None	Bench stepping	12 weeks	37 ± 8	No	Exercise only
Laterza et al. (2007)	9	11	2	2	5	B	Hypertensive	Cycling	4 months	46 ± 2	Yes	Exercise only
Lennon et al. (2008)	23	23	1	2	2	B	Ischaemic stroke	Cycling	10 weeks	59 ± 10	Yes	Exercise only
Martin et al. (1990)	9	10	2	2	5	M	Hypertensive	Variable	10 weeks	18-60	Yes	Exercise only
Mendivil et al. (2006)	21	27	3	2	8	B	None	Variable	16 weeks	40-70	Yes	Exercise and diet
Miller et al. (2002)	23	20	2	1	4	B	Hypertensive, overweight adults on a single blood pressure medication	W/C	9 weeks	53 ± 11	Yes	Exercise and diet
Murphy et al. (2006)	12	21	2	1	4	B	Sedentary	Walking	8 weeks	42 ± 9	Yes	Exercise and diet
Myers et al. (2002)	12	12	3	3	9	B	Heart failure patients	Cycling	8 weeks	55 ± 9	Yes	Exercise only
Painter et al. (2003)	45	51	2	3	6	B	Renal transplant		11 months	40 ± 13	Yes	Exercise only
Ready et al. (1996)a	18	18	3	3	9	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Ready et al. (1996)aa	18	17	4	3	12	F	Postmenopausal	Walking	24 weeks	61 ± 6	Yes	Exercise only
Salvetti et al. (2008)	20	19	2	2	6	B	Coronary disease	Walking	12 weeks	53 ± 8	No	Exercise only
Santa-Clara et al. (2003)a	16	17	3	3	9	F	Postmenopausal Caucasian	Variable	6 months	45-70	Yes	Exercise only
Santa-Clara et al. (2003)aa	12	15	3	3	9	F	Postmenopausal African American	Variable	6 months	45-70	Yes	Exercise only
Sarsan et al. (2006)	20	20	3	2	8	F	Obese	W/C	12 weeks	20-60	Yes	Exercise only
Sigal et al. (2007)	63	60	2	2	5	B	Type II diabetics	W/C	6 months	39-70	Yes	Exercise only
Tjønna et al. (2008)a	9	8	2	2	5	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tjønna et al. (2008)aa	9	11	2	3	6	B	Metabolic Syndrome	W/J	16 weeks	52 ± 4	Yes	Exercise only
Tsai et al. (2002)a	11	12	2	2	6	B	Mild Hypertension	Walking	12 weeks	20-60	Yes	Exercise only
Tsai et al. (2002)b	22	20	2	2	6	B	White coat hypertension	Walking	12 weeks	20-60	Yes	Exercise only
van Rooijen et al. (2004)	74	80	4	2	11	F	African American type II diabetics	Walking	12 weeks	40-65	No	Exercise only
Vigorito et al. (2007)	45	45	2	3	6	F	Overweight/Obese polycystic ovary syndrome	Cycling	3 months	21 ± 2	Yes	Exercise only

Table 28.

Author	CG n	EG n	Duration Category	Intensity Category	Dose Category	Sex	Special Population	Exercise Mode	Duration of Intervention	Age	S	Intervention components
Wang et al. (2005)	15	15	3	3	9	M	Sedentary	Cycling	8 weeks	24 ± 2	No	Exercise only
White et al. (1990)	17	78	3	3	9	M	None	Variable	9 Months	57 ± 8	Yes	Exercise only

Note. CG = control group; EG = experimental group; Duration Category, 1 = Inactive, 2 = Low, 3 = Medium, and 4 = High; Intensity Category, 1 = Light, 2 = Moderate, and 3 = Vigorous; F = Female; M = Male; B = Both; W/J = Walking and/or jogging, W/C = Walking and/or cycling; S = Supervised?

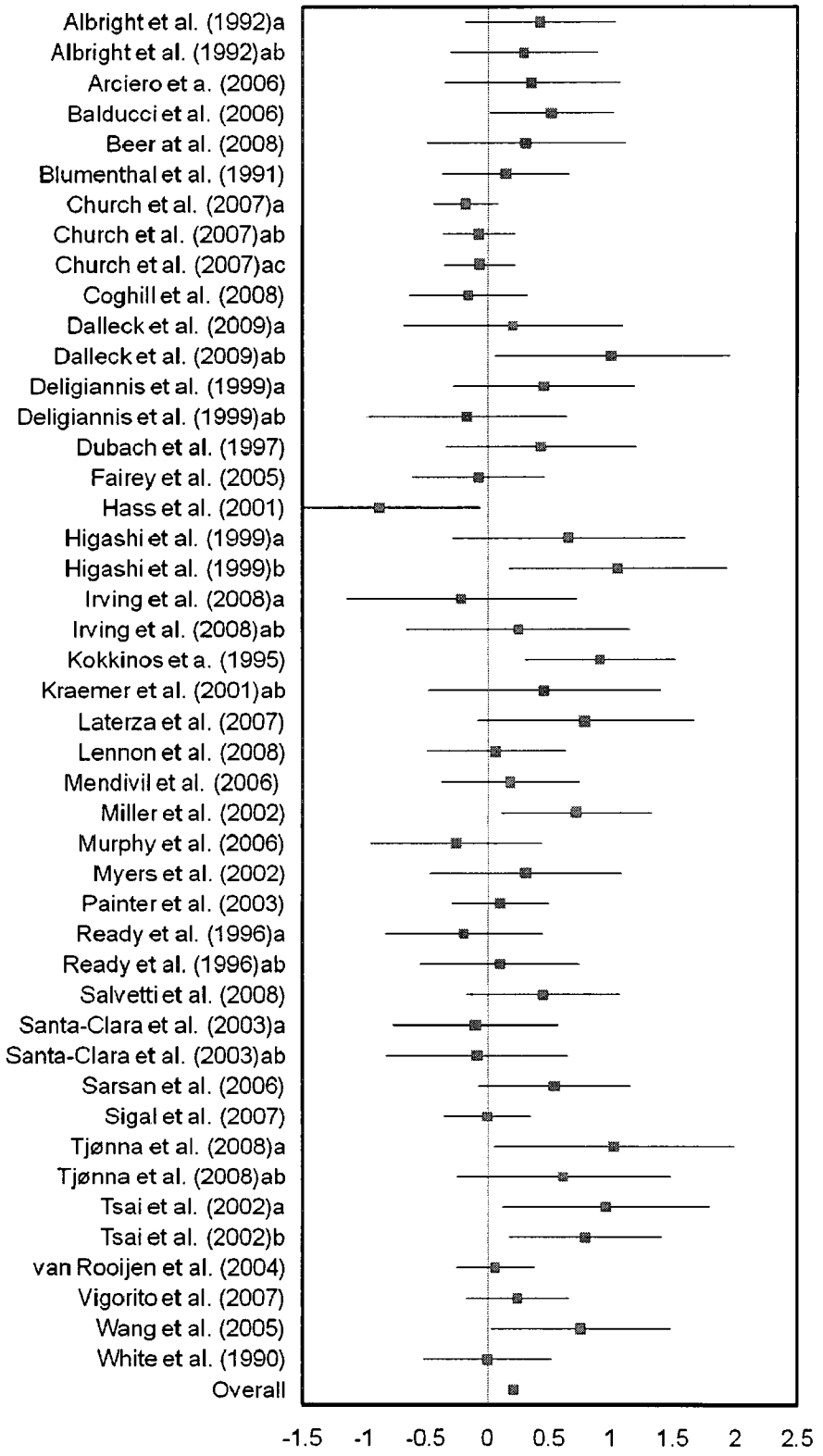

Figure 15. *Forrest plot with ESs and 95% CI for diastolic blood pressure studies.*

Table 29.

ESs for different dose categories of diastolic blood pressure studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.37 (-0.13,0.87) n = 3	-
Moderate	-	0.09 (-0.20,0.37) n = 5	0.33 (0.11,0.56) n = 11	-
Vigorous	-	0.32 (0.10,0.53) n = 12	0.09 (-0.20,0.37) n = 8	-

CHAPTER V

DISCUSSION

The purpose of this investigation was to review and quantify the dose-response relationship between exercise and CVD risk factors using a meta-analytical review of randomized, controlled trials. A total of 16 different outcome variables representing five CVD risk factors were reviewed. Due to insufficient number of studies for waist circumference, waist-to-hip ratio, cholesterol ratio, and VLDL-C variables, the dose-response analyses were not performed for these variables. To determine the dose-response relationship, studies were assigned into one of 12 possible dose categories (i.e., combination of 3 duration levels and 4 intensity levels of the exercise performed by the experimental group). Once the dose category was determined, ESs were calculated based on the mean differences in the post-test between intervention and control groups divided by pooled standard deviations. The moderator analyses were conducted to determine if there were significant differences in ESs among the dose categories.

The overall ESs were ranged from 0.14 to 0.95 (see Table 2). No significant differences in ESs were found among dose categories for any of the outcome variables investigated; however, some important observations can be made.

Physical Fitness

Physical fitness measure includes two variables: VO_2max, and resting HR. Physical fitness is inversely associated with the clustering of metabolic abnormalities. In

cross sectional studies it was found that physical fitness is independently associated with lower CVD risk and compared with physical activity, physical fitness exerts greater effects on each of these individual CVD risk factors and their combination (Ekblom-Bak et al., 2009; Sassen et al., 2009).

For the analysis of VO_2max enough studies were found for dose categories 5, 6, 8, and 9. ESs were positive and large for all dose categories, but there was no significant difference in ESs among dose categories. The changes with increase in duration or intensity were not consistent. On a positive note. Those findings indicate that even at a lower dose (75 - 149 min a week at moderate intensity) than the current recommended by the 2008 physical activity guidelines for Americans (USDHHS, 2008) can bring benefits to the physical fitness level of exercisers.

Similar to the results found in other meta analyses (Kim, Kang, & Park, 2009; Murphy et al., 2007). VO_2max was unique in a sense that almost all the studies provided large positive ESs, while in other CVD risk factors, negative ESs were observed.

Resting HR can also be considered an indicator of fitness level, however it is much more variable than VO_2max. The dose-response analysis did not show significant differences in ESs among the categories, but at the same duration the vigorous intensity had higher ES than the moderate category and both categories that included vigorous exercise had higher ESs than the moderate category. The low duration with vigorous intensity category had the highest number of ESs (nine), and an overall medium positive effect. This is a category that falls in line with the current recommendations. The intensity of the exercise might be a key for improvements in HR.

Obesity

Obesity measures include five variables: BMI, weight, body fat percentage, waist circumference, and waist-to-hip ratio. A variety of variables related to obesity were investigated because each one can have a unique relationship with CVD (Murphy et al., 2007). Enough studies were found for dose categories 5-9 for BMI. The ESs ranged from no effect to a moderate effect. There was no difference in ESs among dose categories. For a medium duration, doing more intense exercise did not result in higher ES and for vigorous intensity, adding more time also did not improve the ES. In general, the dose categories with vigorous exercise provided larger ESs. This implies that intensity might be an important factor in weight loss. The ESs for BMI ranged from -0.5 to 1.5. This wide range of ESs is not surprising because BMI is dependent on weight and nutrition has a large influence on the outcome of weight loss. Exercise can influence the amount of calories consumed during the day, and it plays a small role in the overall energy expenditure of an individual. Diet is what influences the energy in and it is fairly easy to consume more than the calories necessary to maintain or lose weight.

The largest number of studies was found for the weight variable. Similar to BMI, enough studies were found for categories 5-9. The ES went from small negative to medium positive. BF% is an interesting anthropometric variable because it provided more insight to what is happening to the person's body. Weight and BMI are largely influenced by the diet aspect, but they can also be negatively affected by exercise. When a person initiates an exercise program that is more demanding than what the person is used to, muscle hypertrophy can occur. This is one of the main outcomes of resistance training,

but it also happens with aerobic training (Haskell et al., 2007). For this reason, analyzing BF% can provide practitioners and researchers with a more complete view of what is happening to exercisers. Although no significant difference was found among the categories, the dose-response relationship is somewhat clear for BF%. Going from a low duration to a medium duration at vigorous intensity resulted in a larger effect, and going from moderate intensity to vigorous intensity at medium duration also provided a larger effect. One of the limitations for this analysis was the lack of studies in the categories below the current physical activity recommendations.

An insufficient number of studies were found to conduct the dose-response relationship between exercise and waist circumference and waist-to-hip ratio. It was found that exercise provides a small positive effect for both of those variables.

Atherogenic Dyslipidemia

Cholesterol measures include four variables: Total cholesterol, cholesterol ratio, HDL-C, and LDL-C. Cholesterol levels are well established as strong independent predictors of CVD (Stampfer et al., 2004). Large cohort studies have identified HDL-C as a strong, independent, inverse predictor of risk of CVD. The overall ESs were very similar across the variables, and for the variables that a dose-response analysis was conducted, no dose-response relationship was found. In addition, similar to the findings of Leon and Sanchez (2001), a marked inconsistency was observed in responsiveness of blood lipids. For triglycerides, the dose-response investigation demonstrated that only a medium duration at vigorous intensity provided a medium effect. The recommended levels of low duration at vigorous intensity and medium duration at moderate intensity

exercise showed no effects in triglycerides, suggesting that more exercise than currently recommended might be necessary for positive results.

Enough studies were also found for a dose-response analysis for HDL-C and LDL-C. The results for those two variables were interesting. For HDL-C a medium duration at moderate intensity showed no effect, while the other dose categories showed a low to medium effect. For LDL-C the medium duration and moderate intensity was the only category that showed a medium effect, while no or small effects were observed in the other dose categories. No dose-response relationship was observed for total cholesterol.

Impaired Fasting Glucose

A high fasting blood glucose level is the diagnosis of type 2 diabetes, which accounts for ~ 90–95% of those with diabetes. The CVD mortality rate is 3 times greater in people with diabetes than in those without diabetes. Although the overall ES for fasting glucose was only small, the dose-response analysis provided interesting results. No significant difference in ESs was found among the categories, and a dose-response was not present. The ESs for light and moderate intensity at medium duration were identical, which demonstrates that even a level of intensity below the recommended level can provide some benefits. In addition, a low duration at vigorous intensity exercise was not better than moderate exercise, which also shows some benefits of a combination of intensity and duration lower than the physical activity recommendations. One of the limitations of this analysis was the low number of ESs; only three studies in the dose categories were included in the analysis. The findings of this analysis suggest that

duration might be more important than intensity for improvements in the control of fasting glucose levels.

Hypertension

Hypertension measures include systolic and diastolic blood pressures. It is common knowledge that high blood pressure is a risk factor for CVD. It has been estimated that a small 2 mm Hg reduction in average resting SBP can reduce mortality from CVD by 4%, while a reduction of 5 mm Hg can reduce mortality risk by 9% (Stamler et al., 1989). The results for the systolic and diastolic blood pressures were fairly similar. An overall small to medium effect was found for both, and no dose-response relationship was found. A small to medium effect was observed in the two dose categories that represent the current physical activity guidelines (i.e., low duration at vigorous intensity and medium duration at moderate intensity). However, it was not expected that the dose category with medium duration at vigorous intensity has the lower effect.

Limitations

An extensive review of the literature was conducted, however this study is not free of limitations. Due the homogeneity of the duration and intensity of the intervention studies, at the most 5 categories were represented for an individual variable. In some cases the under representation of categories made it impossible to conduct a dose-response analysis and in all cases it limited the range of the analysis. There is a lack of studies investigating exercise at duration and intensities well below and above the current recommendations and those studies are necessary to understand if the dose-response

exists. In addition, there is the possibility that studies have been conducted but have not been published, which is common for studies that do not find significant differences. The current dose-response information available is based on cross sectional studies and relies on questionnaires to measure physical activity.

Summary

The objective of this study was to classify studies in twelve possible categories of duration and intensity interactions to be able to examine a possible dose-response relationship between exercise and CVD risk factors. The dose-response analysis was conducted for 12 variables related to CVD and the results varied from a clear dose-response to no pattern at all. This study makes clear that CVD risk factors do not have the same response to exercise and the current recommendations for duration and intensity of exercise do not guarantee positive and effective results to all CVD risk factors. Some risk factors respond to a lower combination of duration and intensity and others might require much higher duration and intensity then the current recommended amount of exercise to achieve better health.

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APPENDIXES

APPENDIX A

Tables with All Dose Response Categories

ESs for all dose categories of VO_2max studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.52 (-0.22,1.26) n = 3	1.40 (0.10,2.70 n = 1
Moderate	0.57 (-0.18,1.31) n = 2	0.69 (0.08,1.29) n = 4	0.89 (0.63,1.14) n = 21	1.02 (-0.11,2.14) n = 1
Vigorous	-	1.01 (0.75,1.28) n = 21	0.86 (0.48,1.24) n = 10	0.89 (0.05,1.73) n = 2

ESs for all dose categories of HR studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.35 (-0.77,1.47) n = 1	-
Moderate	-0.18 (-1.14,0.78) n = 1	0.09 (-0.72,0.91) n = 2	0.20 (-0.18,0.58) n = 7	-
Vigorous	-	0.48 (0.17,0.79) n = 11	0.38 (-0.13,0.11) n = 4	-

ESs for all dose categories of BMI studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.27 (-0.39,0.94) n = 1	0.56 (0.13,0.99) n = 3	-0.27 (-0.81,0.28) n = 1
Moderate	0.21 (-0.28,0.70) n = 1	0.15 (-0.23,0.53) n = 3	0.23 (0.08,0.38) n = 24	0.24 (-0.11,0.59) n = 3
Vigorous	-	0.32 (0.14,0.50) n = 15	0.22 (-0.04,0.48) n = 7	-

ESs for all dose categories of weight studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.13 (-0.39,0.66) n = 2	-0.24 (-0.62,0.13) n = 4	0.51 (-0.35,1.37) n = 1
Moderate	0.24 (-0.21,0.69) n = 1	0.16 (-0.15,0.47) n = 5	0.19 (0.05,0.32) n = 26	0.32 (0.01,0.62) n = 4
Vigorous	-	0.15 (-0.02,0.32) n = 18	0.41 (0.17,0.65) n = 9	0.25 (-0.28,0.77) n = 2

ESs for all dose categories of body fat percentage studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-0.03 (-0.79,0.73) n = 1	-0.13 (-0.73,0.47) n = 1	-
Moderate	-0.12 (-0.71,0.44) n = 1	0.10 (-0.39,0.59) n = 2	0.36 (0.21,0.52) n = 17	0.27 (-0.03,0.57) n = 3
Vigorous	-	0.21 (0.00,0.41) n = 10	0.59 (0.25,0.93) n = 4	-

ESs for all dose categories of waist studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-0.04(-0.82,0.75) n = 1	-0.51 (-1.50,0.48) n = 1	-
Moderate	0.16 (-0.16,0.49) n = 2	0.26 (-0.08,0.62) n = 2	0.30 (0.09,0.51) n = 10	0.25 (-0.13,0.63) n = 2
Vigorous	-	0.35 (0.06,0.65) n = 5	-0.05 (-1.06,0.96) n = 1	-

ESs for all dose categories of waist-to-hip studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.49 (-0.20,1.17) n = 1	0.40 (-0.21,1.37) n = 1
Moderate	-	0.52 (-0.05,1.09) n = 2	0.38 (0.06,0.70) n = 4	-
Vigorous	-	0.20 (-0.14,0.54) n = 3	0.32 (-0.32,0.96) n = 1	0.34 (-0.06,1.26) n = 1

ESs for all dose categories of triglycerides studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-0.10 (-0.79,0.59) n = 1	0.16 (-0.64,0.97) n = 1	0.28 (-0.50,1.06) n = 1
Moderate	0.19 (-0.07,0.45) n = 1	0.18 (-0.02,0.37) n = 5	0.13(-0.04,0.30) n = 10	-
Vigorous	-	0.05 (-0.15,0.25) n = 7	0.43 (0.16,0.70) n = 5	0.13 (-0.51,0.78) n = 1

ESs for all dose categories of fasting glucose studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.40 (0.05,0.74) n = 3	-0.37 (-0.76,0.01) n = 2
Moderate	0.19 (-0.04,0.43) n = 2	0.35 (0.12,0.59) n = 4	0.39 (0.21,0.55) n = 10	-
Vigorous	-	0.07 (-0.18,0.32) n = 4	-	-0.31 (-1.07,0.45) n = 1

ESs for all dose categories of high density lipoprotein cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-0.13 (-0.75,0.48) n = 2	0.17 (-0.52,0.86) n = 2	0.62 (-0.36,1.60) n = 1
Moderate	-0.04 (-0.68,0.61) n = 1	0.24 (-0.12,0.59) n = 5	0.11 (-0.18,0.39) n = 9	-
Vigorous	-	0.38 (0.10,0.66) n = 8	0.27 (-0.17,0.71) n = 4	0.26 (-0.61,1.13) n = 1

ESs for all dose categories of low density lipoprotein cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.51 (-0.03,1.05) n = 2	0.20 (-0.60,1.00) n = 1	0.89 (-0.01,1.79) n = 1
Moderate	0.06 (-0.41,0.53) n = 1	0.00 (-0.29,0.29) n = 4	0.27 (0.03,0.50) n = 9	-
Vigorous	-	0.20 (-0.08,0.48) n = 5	0.14 (-0.20,0.48) n = 4	-0.14 (-0.89,0.6) n = 1

ESs for all dose categories of total cholesterol studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.17 (-0.22,0.57) n = 2	0.31 (-0.21,0.83) n = 1	0.75 (-0.11,1.60) n = 1
Moderate	0.78 (0.14,1.41) n = 1	0.47 (0.11,0.83) n = 2	0.16 (-0.03,0.34) n = 8	-
Vigorous	-	0.26 (0.03,0.49) n = 6	0.26 (-0.10,0.62) n = 4	0.01 (-0.53,0.55) n = 1

ESs for all dose categories of cholesterol ratio studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	-	0.45 (-0.74,1.64) n = 1	0.63 (-0.60,1.87) n = 1
Moderate	-	0.18 (-0.46,0.83) n = 3	1.14 (0.32,1.96) n = 2	-
Vigorous	-	0.29 (-0.46,1.04) n = 2	0.66 (-0.43,1.74) n = 1	-

ESs for all dose categories of systolic blood pressure studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.71(0.17,1.25) n = 2	0.42 (0.00,0.85) n = 4	-
Moderate	-0.12 (-0.50,0.26) n = 2	0.17 (-0.10,0.43) n = 6	0.31 (0.10,0.52) n = 13	0.11 (-0.37,0.60) n = 1
Vigorous	-	0.40 (0.18,0.61) n = 11	0.17 (-0.12,0.47) n = 7	0.25 (-0.50,1.00) n = 1

ESs for all dose categories of diastolic blood pressure studies.

	Duration			
Intensity	Inactive (< 75 min)	Low (75 – 149 min)	Medium (150 – 300 min)	High (> 300 min)
Light	-	0.27 (-0.27,0.82) n = 2	0.37 (-0.14,0.87) n = 3	-
Moderate	-0.10 (-0.50,0.31) n = 2	0.10 (-0.20,0.39) n = 5	0.33 (0.11,0.56) n = 11	0.06 (-0.46,0.58) n = 1
Vigorous	-	0.32 (0.10,0.53) n = 12	0.09 (-0.20,0.38) n = 8	0.10 (-0.67,0.87) n = 1