Comparison of Cardioprotective Benefits of Vigorous Versus Moderate Intensity Aerobic Exercise

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Aerobic fitness, not merely physical activity, is associated with a reduced risk of cardiovascular disease. Vigorous intensity exercise has been shown to increase aerobic fitness more effectively than moderate intensity exercise, suggesting that the former may confer greater cardioprotective benefits. An electronic search of published studies using PubMed was conducted for 2 types of investigations, epidemiologic studies that evaluated the benefits of physical activity of varying intensity levels and clinical trials that trained individuals at different intensities of exercise while controlling for the total energy expenditure. A secondary search was conducted using the references from these studies. The epidemiologic studies consistently found a greater reduction in risk of cardiovascular disease with vigorous (typically ≥6 METs) than with moderate intensity physical activity and reported more favorable risk profiles for individuals engaged in vigorous, as opposed to moderate, intensity physical activity. Clinical trials generally reported greater improvements after vigorous (typically ≥60% aerobic capacity) compared with moderate intensity exercise for diastolic blood pressure, glucose control, and aerobic capacity, but reported no intensity effect on improvements in systolic blood pressure, lipid profile, or body fat loss. In conclusion, if the total energy expenditure of exercise is held constant, exercise performed at a vigorous intensity appears to convey greater cardioprotective benefits than exercise of a moderate intensity. **(Am J Cardiol 2006;97:141–147)**

Recent public health recommendations have focused on the value of moderate intensity aerobic exercise for improving cardiovascular health and reducing the risk of coronary heart disease (CHD).[1–3] However, reviews of training studies have found that the higher the exercise intensity, the greater the increase in aerobic fitness.[4,5] If exercise of a more vigorous intensity elicits a greater increase in aerobic fitness than does moderate intensity exercise, perhaps more vigorous exercise has greater cardioprotective benefits. Exercise of a vigorous intensity incurs a greater energy expenditure (EE) than does exercise of a moderate intensity performed for the same duration. To determine whether vigorous intensity exercise has greater benefits, one must control for total EE. This review evaluated previous scientific publications to determine whether vigorous intensity or moderate intensity exercise of equal EE has disparate effects on cardiovascular health, that is, on the risk factors for, and incidence of, CHD.

Methods

Epidemiologic studies and clinical trials were examined. For the former, only those that controlled for EE, or that found a relation between 1 intensity level and the study end points (incidence of CHD or development of CHD risk factors) but not for other intensity levels, were included. For clinical trials, only those that controlled for EE were included. A meta-analysis of the data was not feasible, because the number of studies that examined any 1 end point (such as blood pressure or insulin sensitivity) while controlling for EE was small, and such studies used varying durations and frequencies of exercise.

To perform the review, an electronic search (PubMed) was conducted of published medical studies using the search term "exercise intensity" in conjunction with "heart disease," "cardiovascular," "clinical trial," or "risk." More than 500 scientific reports were identified in this manner. References of studies that met the search criteria were used for a secondary search.

Results

Epidemiologic studies: Tables 1 and 2 list the epidemiologic studies of exercise intensity and incidence of CHD, or risk factors for CHD, respectively. In such studies, the determination of exercise intensity was imprecise. Subjects reported their physical activity, and investigators designated activities as "moderate" or "vigorous," or assigned an intensity on the basis of estimated multiples of metabolism at rest (METs; 1 MET = $3.5\ ml \cdot min^{-1} \cdot kg^{-1}$). However, the actual intensity of a given activity can vary considerably according to the patient's fitness, motivation, interaction with competitors, and environmental conditions. In some

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Table 1
Epidemiologic studies of exercise intensity and coronary heart disease (CHD) incidence in previously healthy subjects

Study	No. of Subjects	Age (yrs)/Sex	Follow-up (yrs)	Intensity of Physical Activity	Association With Incidence
Lakka et al[6]*	1,166	42–60 M	5	Mean 6.0 METs	Yes
				Mean 3.6 METs	No
Lee et al[7]*	7,337	66 M	7	>6 METs	Yes
				3–6 METs	No
Manson et al[8]	72,488	40–65 F	8	Various walking speeds	Inverse correlation
Sesso et al[9]*	12,516	39–88 M	16	≥6 METs	Yes
				4–5.9 METs	No
				<4 METs	No
Tanasescu et al[10]	44,452	40–75 M	12	≥6 METs	Yes
				4–6 METs	No
				Various walking speeds	Inverse correlation
Yu et al[11]*	1,975	49–64 M	11	≥6 METs	Yes
				4.5–5.5 METs	No
				2–4 METs	No

* These studies did not control for EE across intensities per se, but found a relation at 1 intensity level but not for other intensity levels.

Table 2
Epidemiologic studies of exercise intensity and coronary heart disease risk factors in healthy subjects

Study	No. of Subjects	Age (yrs)/Sex	Follow-up (yrs)	Intensity of Physical Activity	Effect on Risk Factors
Hu et al[12]	70,102	40–65 F	8	Various walking speeds	Inverse correlation to type 2 DM incidence
Hu et al[13]	37,918	40–75 M	10	Various walking speeds	Inverse correlation to type 2 DM incidence
Lynch et al[14]*	897	32–60 M	4	≥5.5 METs	Reduced incidence of type 2 DM
				<5.5 METs	No effect
Marrugat et al[15]	537	20–60 M	Cross-sectional	>9 kcal/min	Lesser cholesterol and TG
				>7 kcal/min	Greater HDL
				>5 kcal/min	Greater VO_2max
				<5 kcal/min	Baseline group
Mensink et al[16]	5,943	25–69 M	Cross-sectional	7.5–9.0 METs	Lesser cholesterol, HDL, TG, diastolic BP, BMI
				5.9–7.0 METs	No effect
				3.5–4.5 METs	Baseline group
Mensink et al[16]	6,039	25–69 F	Cross-sectional	7.5–9.0 METs	Lesser sys. BP, BMI
				5.9–7.0 METs	Lesser BMI
				3.5–4.5 METs	Baseline group
Paffenbarger and Lee[17]*	14,786	45–84 M	12	≥4.5 METs	Reduced incidence of HTN
				<4.5 METs	No effect
Siscovick et al[18]	2,274	≥65 M&F	Cross-sectional	Various intensities	Inverse correlation to fasting insulin, serum fibrinogen, ABI, CI/I
Williams[19]	8,896	45 M&F	Cross-sectional	Various running speeds	Inverse correlation to systolic and diastolic BP, total/HDL, BMI, waist circumference

* These studies did not control EE across intensities per se, but found a relation at 1 intensity level but not for other intensity levels.
ABI = ankle-brachial index; BMI = body mass index; BP = blood pressure; CI/I = cardiac injury/infarction score; DM = diabetes mellitus; HDL = high-density lipoprotein; HTN = hypertension; PA = physical activity; TG = serum triglycerides; VO_2max = aerobic capacity.

studies, activities classified as vigorous (typically ≥6 METs) could have been performed at a moderate intensity, such as swimming and bicycling. Accordingly, it should be recognized that the epidemiologic studies only provided a general impression regarding the effects of different exercise intensities.

Six studies listed in Table 1 prospectively considered CHD incidence.[6–11] Five found that vigorous physical activities were associated with a reduced risk of CHD, and physical activities of lower intensities were not, regardless of their total EE.[6,7,9–11] Although Lee et al[7] reported a cardioprotective effect for vigorous, but not moderate, intensity exercise when the intensity was expressed in absolute terms (i.e., METs), these investigators also found benefits within a subgroup of low-intensity exercisers when their activity was stratified by relative intensity.[7] Among patients whose only physical activity was <3 METs, those who subjectively rated their intensity as being high had a lower CHD risk than those whose activity was perceived as less intense. Thus, greater cardioprotective benefits were obtained with increases in either the relative or absolute intensity of exercise. Two prospective studies listed in Table 1 found that a faster walking speed was associated with a reduced CHD risk, independent of the total EE.[8,10]

Table 3
Clinical trials of exercise intensity and blood pressure with total work equated between groups

Study	Age (yrs)/Sex	Study Length	Training Intensity	No. per Group	Change in VO_2max	Change in Blood Pressure
Asikainen et al[20]	Postmenopausal F	24 wks	65% VO_2max	87	↑	↓ diastolic BP
			55% VO_2max	20	↑	No effect
			45% VO_2max	21	↑	No effect
Braith et al[21]	60–79 M&F	3 mo	85% HRR	14	↑ ↑	↓ systolic and diastolic BP
			70% HRR	19	↑	↓ systolic and diastolic BP
Kang et al[22]	13–16 M&F	8 mo	77% VO_2max	20	↑	↓ diastolic BP
			57% VO_2max	21	No effect	No effect
Tashiro et al[23]	33–57 M&F*	10 wks	75% VO_2max	8	Not reported	↓ systolic and diastolic BP
			50% VO_2max	8		↓ systolic BP only

* Subjects in Tashiro et al[23] were initially hypertensive.
HRR = heart rate reserve; other abbreviations as in Table 2.

Table 4
Clinical trials of exercise intensity and blood lipids with total work equated between groups

Study	Age (yrs)/Sex	Study Length	Training Intensity	No. per Group	Change in VO_2max	Change in Blood Lipids
Kang et al[22]	13–16 M&F	8 mo	77% VO_2max	20	↑	↓ TG, ↑ LDL particle size
			57% VO_2max	21	No effect	No effect
Crouse et al[24]	47 M*	24 wks	80% VO_2max	12	↑ ↑	↑ HDL_2, ↓ HDL_3
			50% VO_2max	14	↑	↑ HDL_2, ↓ HDL_3
Duncan et al[25]	20–40 F	24 wks	walk 8.0 km/h	16	↑ ↑ ↑	↑ HDL
			walk 6.4 km/h	12	↑ ↑	↑ HDL
			walk 4.8 km/h	18	↑	↑ HDL
King et al[26]	50–65 M&F	2 yr	80% peak HR	69	↑	No effect
			80% peak HR	74	↑	↑ HDL
			66% peak HR	64	↑	↑ HDL
Kraus et al[27]	40–65 M&F*	6 mo	65–80% VO_2max	17	↑ ↑	↓ Several risk factors
			40–60% VO_2max	19	↑	↓ Several risk factors
Savage et al[28]	8–37 M	10 wks	75% VO_2max	24	↑	↓ HDL
			40% VO_2max	16	No effect	↓ HDL
Spate-Douglas and Keyser[29]	40 F	12 wks	80% HRR	12	↑	↑ HDL, ↑ HDL_2
			60% HRR	13	↑	↑ HDL, ↑ HDL_2
Gaesser and Rich[30]	20–30 M	18 wks	82% VO_2max	7	↑	No effect
			45% VO_2max	10	↑	No effect

* Subjects in Crouse et al[24] and Kraus et al[27] were initially dyslipidemic.
Abbreviations as in Tables 2 and 3.

Three studies listed in Table 2 prospectively examined the role of exercise intensity in the development of type 2 diabetes mellitus,[12–14] a major CHD risk factor. Two studies found that vigorous activities were no more protective than walking,[12,13] but 1 study found that only physical activities at intensities of ≥5.5 METs were protective.[14] Two studies found that faster walking was associated with less risk than slower walking.[12,13] However, the duration of walking, but not EE, was controlled for, and thus one could not exclude the possibility that the faster walkers experienced lower risk because of greater EE.

Five studies listed in Table 2 evaluated other CHD risk factors relative to the intensity of physical activity.[15–19] One study found that only physical activities at intensities ≥4.5 METs were associated with a decreased incidence of hypertension and reduced all-cause mortality.[17] The other 4 studies controlled for total EE and found more favorable risk profiles for vigorous, than for moderate, intensity physical activities. Of particular interest is Williams' investigation of runners.[19] The runners reported their weekly running distance as an indicator of total EE and their 10-km race time as an indicator of exercise intensity (the exercise intensity of faster racers during training would be greater than that of slower racers). After controlling for running distance, several CHD risk factors were inversely related to running intensity. This study was noteworthy, because the runners' recollection of training distance and running speed was likely to be more accurate than researchers' assignments of MET levels to various physical activities.

Clinical trials: Tables 3 to 6 list the clinical trials that had subjects perform exercise at different intensities while varying the duration to control for EE.

Four studies listed in Table 3 found reductions in blood pressure at rest as a result of exercise training.[20–23] In 3 studies, the group that exercised at the highest intensity

Table 5
Clinical trials of exercise intensity and blood glucose control with total work equated between groups

Study	Age (yrs)/Sex	Study Length	Training Intensity	No. per Group	Change in VO_2max	Change in Blood Glucose Control
Asikainen et al[20]	Postmenopausal F	24 wks	65% VO_2max	87	↑	↓ fasting glucose
			55% VO_2max	20	↑	No effect
			45% VO_2max	21	↑	No effect
Ben-Ezra et al[31]	23 F	1 d	70% VO_2max	24	Not applicable	↓ OGTT insulin response
			40% VO_2max	24		No effect
Braun et al[32]	35–50 F*	2 d	75% VO_2max	8	Not applicable	↑ insulin sensitivity
			50% VO_2max	8		↑ insulin sensitivity
Houmard et al[33]	40–65 M&F	6 mo	65–80% VO_2max	30	Not reported	↑ insulin sensitivity
			40–60% VO_2max	41		↑ ↑ insulin sensitivity
Kang et al[34]	43 M	1 wk	70% VO_2max	6	Not reported	↑ insulin sensitivity
			50% VO_2max	6		No effect
			70% VO_2max	6		No effect
		44 M*	50% VO_2max	6		No effect

* Subjects in Braun et al[32] and 1/2 of subjects in Kang et al[34] had type 2 diabetes mellitus.
OGTT = oral glucose tolerance test; other abbreviations as in Table 2.

Table 6
Clinical trials of exercise intensity and body fat with total work equated between groups

Study	Age (yrs)/Sex	Study Length	Training	No. of Subjects per Group	Change in VO_2max	Change in Body Fat
Braith et al[21]	60–79 M&F	3 mo	85% HRR	14	↑ ↑	↓
			70% HRR	19	↑	↓
Grediagin et al[35]	25–40 F	12 wks	80% VO_2max	6	No effect	↓
			50% VO_2max	6	No effect	↓
Gutin et al[36]	13–16 M&F	8 mo	77% VO_2max	21	↑	↓
			57% VO_2max	21	No effect	↓
Leutholtz et al[37]	41 M&F	12 wks	60% HRR	20	↑	↓
			40% HRR	20	↑	↓
Slentz et al[38]	40–65 M&F	6 mo	65–80% VO_2max	28	Not reported	↓
			40–60% VO_2max	28		↓

Abbreviations as in Tables 2 and 3.

(65% to 77% of aerobic capacity [VO_2max]) experienced a decrease in diastolic blood pressure, but the groups that exercised at lower intensities (45% to 57% VO_2max) did not.[20,22,23] In 1 study, the 2 intensity groups (70% and 85% heart rate reserve) experienced similar decreases in diastolic blood pressure.[21] In 2 studies, training resulted in a decrease in systolic blood pressure that was similar between the exercise intensity groups.[21,23]

Seven studies listed in Table 4 found improvements in the lipid profile after exercise training.[22,24–29] Six studies found increased levels of high-density lipoprotein cholesterol, but no intensity effect was noted.[24–29] Only 2 studies reported significant reductions in triglycerides or low-density lipoprotein cholesterol; 1 reported benefits in the high-intensity, but not the low-intensity, group;[22] the other found no intensity effect when the total EE was low, and observed the greatest benefits in the group that performed high-volume and high-intensity training.[27] Several studies reported no change in low-density lipoprotein cholesterol with training.[20,24–26,28,30]

Five studies listed in Table 5 found improvements in glucose control or insulin sensitivity.[20,31–34] In 3 studies, improvements were found among healthy subjects who exercised at vigorous intensities (65% to 70% VO_2max) but not at moderate intensities (40% to 55% VO_2max).[20,31,34] One study found more improvement at a moderate intensity (40% to 60% VO_2max) than at a vigorous intensity (65% to 80% VO_2max) when the total EE was low.[33] Two studies of short-term training in subjects with type 2 diabetes mellitus found either similar improvements at the 2 intensities[32] or no improvement at either intensity.[34] These 2 studies used very brief exposures to exercise (2 days[32] and 1 week[34]). Additional studies of longer duration would be useful, given that 3 of the 4 studies with nondiabetic subjects found more improvements with vigorous, than with moderate, intensity exercise.[20,31,34]

Five studies listed in Table 6 reported reductions in body fat after exercise training.[21,35–38] In all cases, no intensity effect was noted.

Of the studies listed in Tables 3 to 6, 11 reported increases in VO_2max after exercise training.[20–22,24–26,28–30,36,37] Six studies found that the higher intensity groups demonstrated greater increases in VO_2max than did the lower intensity groups.[21,22,24,25,28,36] Five studies reported similar increases in aerobic capacity between intensity groups,[20,26,29,30,37] and no study found a greater increase in the lower than in the higher intensity group.

Discussion

Although many studies have evaluated the cardioprotective benefits of exercise, relatively few have compared different intensities while controlling EE. Although additional studies are warranted, a consistent picture has emerged. Several epidemiologic studies found benefits for accumulated EE performed at a vigorous intensity but not at a moderate intensity.[6,7,9–11,14,17] The epidemiologic studies that specifically controlled EE all found greater benefits at higher intensities.[8,10,15,16,18,19] No epidemiologic study reported greater benefits for moderate than for vigorous intensity physical activity. Clinical trials provided complementary results. When the EE between groups was held constant, vigorous intensity was more beneficial than moderate intensity exercise in altering ≥1 CHD risk factor,[20–25,27,28,31,34,36] sometimes produced no greater benefit,[26,29,30,32,35,37,38] and in only 1 study was of lesser benefit.[33] Thus, the preponderance of evidence favors more cardioprotective benefits from vigorous than from moderate intensity exercise.

Additional clinical trials that compare ≥2 exercise intensities while controlling total EE are needed to confirm the findings in this review. A recent meta-analysis concluded that moderate and vigorous intensity exercise were comparable at lowering blood pressure at rest,[39] but 3 of the 4 clinical trials identified in this review as having controlled total EE found that vigorous intensity exercise was more effective than moderate intensity exercise.[20,22,23] In the 1 trial that found no difference between the 2 intensity groups, both groups exercised vigorously (i.e., 70% and 85% of the heart rate reserve).[21] Meta-analyses are powerful tools but, in combining data from different studies, variations between studies in the frequency and duration of exercise and in the subjects' baseline blood pressure and aerobic capacity could serve as confounding variables when interpreting the role of exercise intensity. Individual clinical trials that compared ≥2 exercise intensities provide stronger evidence, because confounding variables are equal between groups.

Long-term aerobic exercise has clear cardioprotective benefits.[2] Although an accumulation of moderate intensity EE on a regular basis is sufficient to provide some benefit, the epidemiologic studies in this review that compared different exercise intensities generally found that exercise of a more vigorous nature resulted in a lower incidence of CHD than did moderate intensity exercise. In epidemiologic studies, exercise intensity is commonly expressed in absolute terms, that is, as a given EE (often described in METs) irrespective of the subject's fitness level. In these terms, vigorous intensities are typically defined as those requiring ≥6 METs. However, the studies of walking speed have found significantly greater reductions in risk when walking speeds of only 4.8 km/hour were compared with lower speeds.[8,10] Walking at 4.8 km/hour requires only 3.2 METs. At the other end of the intensity scale, a study of 10-km runners found a graded reduction in CHD risk factors with greater intensity.[19] Thus, it appears that a continuum of greater cardioprotection exists from low to high absolute exercise intensities, a finding that is also suggested by correlations of aerobic fitness level to the incidence of CHD.[40–44]

Exercise intensity can also be classified in relative terms, as a percentage of one's aerobic capacity or as a subjective level of effort. Most clinical trials are conducted with exercise intensity established as a percentage of VO_2max, and have generally found that greater relative intensities result in greater improvements in aerobic fitness and in selected CHD risk factors. Thus, is it necessary for very-low-fit patients to achieve an exercise intensity of 6 METs, which may approach or exceed their aerobic capacity, to achieve optimum benefits, or is it sufficient that they work at a level that is vigorous relative to their VO_2max? The epidemiologic studies of walking, including the study of subjective intensities <3 METs,[7] and most clinical trials have suggested that higher relative exercise intensities are more beneficial than lower ones, and that it is not essential that 6 METs be achieved to benefit.

Mechanisms by which physical activity or improved aerobic fitness, or both, may provide cardioprotective benefits are multiple. Why vigorous intensity provides greater benefits than moderate intensity physical activity, even with the EE equated, is unclear at present. Certainly, vigorous intensities are more effective than moderate intensities at increasing aerobic capacity, as shown in this and previous reviews.[4,5] This is particularly true for patients with higher baseline fitness.[45] Moreover, recent epidemiologic studies have shown that each 1-MET increase in exercise capacity confers an 8% to 17% reduction in cardiovascular and all-cause mortality.[42–44,46] Yet, the question remains as to how the increased aerobic capacity, or perhaps other adaptations that are simultaneously elicited by vigorous intensity exercise, yield greater physiologic benefits than does the mere accumulation of moderate intensity caloric expenditure.

One possible mechanism might be through adaptations in autonomic control. As a consequence of aerobic training, sympathetic drive at rest is reduced and vagal tone is increased, with potential effects on blood pressure, thrombosis, and other factors associated with coronary risk. During exercise, higher intensities elicit exponentially greater increases in sympathetic drive.[47] Thus, one might hypothesize that vigorous intensity training would result in greater autonomic adaptations than moderate intensity exercise of equal EE. For example, a shift from fat to carbohydrate use is brought about by increased adrenergic activity as exercise intensity increases, which has been proposed as the mechanism for improvements in insulin sensitivity observed after vigorous, but not moderate, intensity training.[34]

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