Relative Intensity of Physical Activity and Risk of Coronary Heart Disease

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Background—Current recommendations prescribe at least moderate-intensity physical activity, requiring ≥3 METs (metabolic equivalents) for ≥30 minutes almost daily, generating ≈1000 kcal/wk. Defining intensity using an absolute scale in METs may be limited because it neglects variations in physical fitness: an activity requiring a particular MET value commands greater physical effort among less fit than more fit persons. It is unknown whether moderate-intensity exercise, relative to an individual’s capacity, is associated with reduced coronary heart disease (CHD) rates.

Methods and Results—We followed 7337 men (mean age, 66 years) from 1988 to 1995. At baseline, men reported their actual activities and, using the Borg Scale, the perceived level of exertion when exercising (relative intensity). During follow-up, 551 men developed CHD. After multivariate adjustment, the relative risks of CHD among men who perceived their exercise exertion as “moderate,” “somewhat strong,” and “strong” or more intense were 0.86 (95% confidence interval, 0.66 to 1.13), 0.69 (0.51 to 0.94), and 0.72 (0.52 to 1.00), respectively (P trend = 0.02), compared with “weak” or less intense. This inverse association extended to men not fulfilling current recommendations, ie, expending <1000 kcal/wk in physical activity or not engaging in activities of ≥3 METs (P trend = 0.03 and 0.007, respectively).

Conclusions—There is an inverse association between relative intensity of physical activity (an individual’s perceived level of exertion) and risk of CHD, even among men not satisfying current activity recommendations. Recommendations for “moderate”-intensity physical activity may need to consider individual fitness levels instead of globally prescribing activities of ≥3 METs. (Circulation. 2003;107:1110-1116.)

Key Words: coronary disease ■ epidemiology ■ exercise

Although it is clear that physical activity is associated with decreased risk of chronic diseases,1 debate continues regarding the intensity of activity required.2 What is the minimum intensity needed? At higher intensities, does risk decrease commensurately? Such questions have surfaced partly as a result of recent changes in activity recommendations. Whereas prescriptions before the mid-1990s exhorted expenditures,8,9 may command quite different physical efforts although requiring a fixed MET value (ie, rate of energy expenditure).5,8,9 may command quite different physical efforts among individuals with varying fitness levels. For example, brisk walking at 3 to 4 mph, requiring 4 METs,8 is classified as requiring moderate intensity on the absolute scale regardless of whether it is performed by a young man or an elderly woman. However, it requires greater physical effort from the latter person, who is usually less fit.

We postulate that when prescribing physical activity, using a relative scale to gauge intensity of activity is more appropriate than the absolute scale. The absolute scale for classifying intensity of activity is calibrated on the basis of the physical effort required by healthy, young to middle-aged adults.10 As one moves across the physical fitness spectrum, the relative intensity of effort required for the same activity changes dramatically.10 This has important clinical implications, especially for older, less physically fit persons. If it is the relative intensity of effort that matters, then light activities requiring <3 METs on the absolute scale—which are not currently recommended—may still have health benefits if they require at least moderate effort on a relative scale. There are no published data examining the association between relative intensity of physical activity and risk of developing chronic diseases. We therefore investigated this question for coronary heart disease (CHD).
When you are exercising in your usual fashion how would you rate your level of exertion (degree of effort)?

(Please circle one number)

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<th>1</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing at all</td>
<td>Very weak</td>
<td>Weak</td>
<td>Moderate</td>
<td>Somewhat strong</td>
<td>Strong (heavy)</td>
<td>Very strong</td>
<td>Very, very strong (almost maximal)</td>
<td></td>
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</tbody>
</table>

Assessment of relative intensity of physical activity using the Borg scale.

**Methods**

**Participants**

The Harvard Alumni Health Study is an ongoing study of men who matriculated as undergraduates at Harvard University between 1916 and 1950. Since 1962, alumni have periodically returned mailed questionnaires on their health habits and health status. For this study, the 12,805 men who returned such a survey in 1988 were eligible. We excluded men reporting a history of cardiovascular disease or cancer (n = 3543) and men with missing physical activity information (n = 723). Of those remaining, we successfully followed 7337 (86%) through 1995; they represent subjects for the present investigation.

**Assessment of Physical Activity**

On the 1988 survey, we asked men to report the actual activities they undertook (to estimate intensity on an absolute scale) and to subjectively rate their usual level of exertion when exercising (to estimate intensity on a relative scale). For the actual activities, we asked men about their daily walking and stair climbing, as well as sports and recreational activities undertaken in the past week. For each activity, we inquired about the frequency and duration of participation. This assessment of physical activity is reliable and valid for large population studies. For example, the test-retest correlation coefficient over 1 month was 0.72, and estimates of energy expenditure from questionnaires compared with physical activity records yielded a correlation coefficient of 0.65.

For the subjective rating of exertion, we used the Borg Scale (Figure 1), for which subjects were asked, “When you are exercising in your usual fashion, how would you rate your level of exertion (degree of effort)?” Men responded using a scale ranging from “nothing at all” to “maximal.” The Borg Scale is commonly used during exercise stress testing, and good correlation exists between ratings on this scale and heart rate (r = 0.80 to 0.90), a measure of exertion required by an individual.

**Assessment of Other Predictors of CHD**

In 1988, we also asked about factors that could affect the relation between physical activity and CHD risk. These included weight; height; cigarette smoking; diet; history of hypertension, high total cholesterol, and diabetes mellitus; and parental history of early (< 65 years) mortality.

**Ascertainment of CHD**

We mailed another health survey in 1993 that queried whether a physician had diagnosed myocardial infarction or angina pectoris, and whether men had undergone coronary artery bypass grafting or percutaneous transluminal coronary angioplasty. If so, we inquired about the year of diagnosis or procedure. We randomly selected 49 men living in Massachusetts who declared these conditions, and we contacted their physicians. Self-reports, including dates, were confirmed in 44 men, whereas the physicians of another three men confirmed the diagnoses but provided different dates of onset, for a total confirmation of 96%. Additionally, we obtained copies of death certificates for men who had died by the end of 1993 and examined the underlying and contributing causes of death (mortality follow-up is >99% complete). Using these sources, we determined whether men developed CHD.

**Statistical Analyses**

We examined the following three dimensions of physical activity: (1) the energy expended on all physical activities, (2) the absolute intensity of sports or recreational activities undertaken, and (3) the relative intensity of exercise. To estimate total energy expenditure, we summed kilocalories per week from walking, stair climbing, and all sports and recreation. We estimated that walking one block daily rated 56 kcal/wk; climbing up and down one flight of stairs daily, 14 kcal/wk. The energy expended on each sport or recreational activity was estimated by considering its energy cost and the frequency and duration of participation. On the basis of this estimation of energy expenditure, we categorized men into approximate thirds: < 1000, 1000 to 2499, and ≥ 2500 kcal/wk. For the absolute intensity of sports or recreational activities undertaken, we created three groups on the basis of the most intense activity reported and using current guidelines for defining light, moderate, and vigorous activities, as follows: none or light, < 3 METs; moderate, 3 to 6 METs; and vigorous, > 6 METs. For the relative intensity of exercise, we a priori created four categories to obtain as even a distribution as possible: 0 to 2 (“nothing” to “weak”), 3 (“moderate”), 4 (“somewhat strong”), and ≥ 5 (“strong” to “maximal”) on the Borg Scale.

We used proportional hazards regression to estimate the hazard ratios (relative risks [RRs]) of CHD associated with the three dimensions of physical activity, with time 0 set at 1988. Initially, models were adjusted only for age. We then additionally controlled for smoking; alcohol, red meat, and vegetable consumption; and early parental mortality (classified as in Table 1). In the main analyses, we did not adjust for the following variables that mediate some of the effects of physical activity on CHD risk: body mass index (BMI) and history of hypertension, hypercholesterolemia, and diabetes mellitus. In other analyses, we further controlled for these intermediates (classified as in Table 1).

Finally, we investigated whether the association of relative intensity of exercise and CHD risk differed among the various subgroups of men in Table 3. To test whether the associations differed, an interaction term between relative intensity and each characteristic was added in separate multivariate models.

**Results**

The mean age of subjects was 66 years. Eight percent rated their usual level of exertion during exercise as “weak” or less intense; 39%, “moderate”; 27%, “somewhat strong”; and 27%, “strong” or more intense. Men who exercised at higher relative intensity had a better cardiovascular risk profile than
those who exercised at lower relative intensity with respect to age, BMI, cigarette smoking, prevalence of hypertension and diabetes mellitus, early parental mortality, alcohol intake, and diet (Table 1). The former also expended more energy on all activities and were more likely to engage in vigorous activities of >6 METs.

During follow-up (mean, 5.3 years), 551 men developed CHD. Table 2 shows the RRs of CHD according to the following three dimensions of physical activity: energy expended on all activities, the absolute intensity of activities undertaken, and the relative intensity of exercise. In age-adjusted analyses, higher levels of each predicted lower CHD risk ($P_{\text{trend}}=0.08$, 0.01, and 0.0002, respectively). Further adjustment for smoking, alcohol, diet, and early parental mortality changed the RRs only slightly. After controlling for these characteristics, men who expended 1000 to 2499 kcal/wk on all activities had a lower CHD risk compared to those who expended <1000 kcal/wk ($P_{\text{trend}}=0.001$).
We then examined subgroups of men with different characteristics (Table 3). After adjusting for age, smoking, alcohol, diet, and early parental mortality, there were no statistically significant interactions (all $P>0.05$) by energy expended on all activities, the absolute intensity of activities carried out, or coronary risk factors. This indicates that the associations were not different among the different subgroups. Of note, the inverse association between relative intensity of exercise and CHD risk persisted among men who did not satisfy current recommendations for physical activity. Additional adjustment for BMI, hypertension, hypercholesterolemia, and diabetes mellitus did not materially alter these findings. Among men expending <1000 kcal/wk in physical activity, those who exercised at relative intensities rated as “moderate,” “somewhat strong,” and “strong” or more intense had CHD rates that were 19%, 38%, and 40% lower, respectively. Additional adjustment for the energy expended on all physical activities did not change these results (data not shown).

When we additionally controlled for BMI, hypertension, hypercholesterolemia, and diabetes mellitus, the findings for energy expended on all activities and absolute intensity of activities became attenuated and not statistically significant (Table 2). This indicates that the decreased risk of CHD associated with these two dimensions of physical activity is largely mediated through these intermediate variables. However, the results for relative intensity of exercise, although attenuated, remained significant ($P_{\text{intd}}=0.02$), suggesting that other biological mechanisms apart from weight reduction, blood pressure control, improved lipid profile, and glycemic control were operating.

**Discussion**

The main finding from this study is that the relative intensity of physical activity (the perceived level of exertion when exercising) was a strong predictor of lower CHD rates among older men. There was a dose-response relation, with greater...
decimals in CHD rates at higher relative intensities. This extended to men not fulfilling current recommendations for physical activity.\(^1,6,7\) The absolute intensity of physical activity, on the other hand, did not perform as well in distinguishing CHD risk groups. This suggests that physical activity recommendations need to be tailored to the individual and that global requirements for activities of \(\geq 3\) METs may not be appropriate, especially for older persons.

Before 1995, physical activity guidelines recommended vigorous intensity exercise for at least 20 minutes continuously, 3 days a week,\(^3,5\) with the goal of improving physical fitness and body composition.\(^22\) In 1995, a new recommendation from the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) emphasized health-related physical activity instead. This prescribed the accumulation of at least 30 minutes of moderate-intensity physical activity, almost daily.\(^6\) Subsequently, an NIH Consensus Development Panel\(^7\) and the Surgeon General\(^1\) issued their own recommendations, which essentially mirrored the CDC/ACSM recommendation. These recent recommendations were not meant to supplant the older recommendations for vigorous exercise; rather, they were intended to provide other options.

The intensity of physical activity can be measured as absolute, referring to the actual rate of energy expenditure often expressed in METs, or relative, referring to the energy required in a particular individual compared with his or her physical fitness.\(^10\) The CDC/ACSM guideline specifically recommends activities of 3 to 6 METs,\(^5\) which corresponds to moderate relative intensity for most young to middle-aged adults.\(^10\) The NIH Consensus Development Panel did not specify a MET range for recommended activities, but provided examples (brisk walking, cycling, swimming, house repair, and yard work) falling into the 3- to 6-MET range.\(^7\) The Surgeon General’s report also did not prescribe specific MET values for exercise, giving examples (brisk walking, raking leaves, running, and volleyball) that required \(\geq 3\) METs.\(^1\) For older or less fit individuals, these recommendations may, in fact, require relative intensities that are more intense than a moderate level.\(^10\) The latest position stand by the ACSM,\(^23\) in contrast to the three recommendations above, does prescribe physical activity of at least moderate intensity.

**TABLE 3. Relative Risks* (With 95% Confidence Intervals) of Coronary Heart Disease Among Subgroups of Men, 1988–1995, According to Relative Intensity of Physical Activity in 1988**

<table>
<thead>
<tr>
<th>Subgroup Defined By:</th>
<th>No. of Cases</th>
<th>Nothing to Weak</th>
<th>Moderate</th>
<th>Somewhat Strong</th>
<th>Strong to Maximal</th>
<th>(P) for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy expended,(\dagger) kcal/wk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1000</td>
<td>211</td>
<td>1.00</td>
<td>0.76 (0.54–1.06)</td>
<td>0.51 (0.32–0.82)</td>
<td>0.62 (0.34–1.09)</td>
<td>0.009</td>
</tr>
<tr>
<td>(\geq 1000)</td>
<td>340</td>
<td>1.00</td>
<td>1.12 (0.63–1.99)</td>
<td>0.93 (0.52–1.68)</td>
<td>0.85 (0.47–1.54)</td>
<td>0.06</td>
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<tr>
<td>Absolute intensity of sports or recreational activities,(\ddagger)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>No moderate activity</td>
<td>184</td>
<td>1.00</td>
<td>0.74 (0.52–1.04)</td>
<td>0.53 (0.31–0.89)</td>
<td>0.41 (0.19–0.88)</td>
<td>0.002</td>
</tr>
<tr>
<td>At least moderate activity</td>
<td>367</td>
<td>1.00</td>
<td>1.09 (0.63–1.89)</td>
<td>0.87 (0.49–1.53)</td>
<td>0.87 (0.49–1.54)</td>
<td>0.09</td>
</tr>
<tr>
<td>Age, y</td>
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<tr>
<td>&lt;70</td>
<td>267</td>
<td>1.00</td>
<td>0.71 (0.46–1.11)</td>
<td>0.68 (0.43–1.07)</td>
<td>0.60 (0.37–0.96)</td>
<td>0.06</td>
</tr>
<tr>
<td>(\geq 70)</td>
<td>284</td>
<td>1.00</td>
<td>0.85 (0.61–1.19)</td>
<td>0.51 (0.34–0.78)</td>
<td>0.56 (0.35–0.91)</td>
<td>0.0007</td>
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<td>Smoking status</td>
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<tr>
<td>Never smoked</td>
<td>189</td>
<td>1.00</td>
<td>0.67 (0.42–1.09)</td>
<td>0.60 (0.36–1.01)</td>
<td>0.53 (0.31–0.92)</td>
<td>0.04</td>
</tr>
<tr>
<td>Past smoker</td>
<td>307</td>
<td>1.00</td>
<td>0.84 (0.59–1.21)</td>
<td>0.59 (0.39–0.89)</td>
<td>0.65 (0.43–0.99)</td>
<td>0.04</td>
</tr>
<tr>
<td>Current smoker</td>
<td>52</td>
<td>1.00</td>
<td>1.11 (0.51–2.42)</td>
<td>0.95 (0.38–2.35)</td>
<td>0.25 (0.05–1.17)</td>
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<td>Alcohol intake</td>
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<tr>
<td>Less than daily</td>
<td>342</td>
<td>1.00</td>
<td>0.77 (0.55–1.07)</td>
<td>0.62 (0.43–0.90)</td>
<td>0.60 (0.40–0.89)</td>
<td>0.007</td>
</tr>
<tr>
<td>Daily</td>
<td>206</td>
<td>1.00</td>
<td>0.85 (0.53–1.34)</td>
<td>0.62 (0.37–1.03)</td>
<td>0.59 (0.34–1.02)</td>
<td>0.02</td>
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<tr>
<td>Body mass index, kg/m(^2)</td>
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<tr>
<td>&lt;25</td>
<td>290</td>
<td>1.00</td>
<td>0.72 (0.49–1.05)</td>
<td>0.62 (0.41–0.95)</td>
<td>0.64 (0.41–0.99)</td>
<td>0.07</td>
</tr>
<tr>
<td>(\geq 25)</td>
<td>260</td>
<td>1.00</td>
<td>0.92 (0.63–1.35)</td>
<td>0.64 (0.41–0.99)</td>
<td>0.60 (0.38–0.97)</td>
<td>0.004</td>
</tr>
<tr>
<td>History of hypertension</td>
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<td></td>
</tr>
<tr>
<td>No</td>
<td>316</td>
<td>1.00</td>
<td>0.92 (0.63–1.34)</td>
<td>0.73 (0.48–1.12)</td>
<td>0.75 (0.49–1.16)</td>
<td>0.08</td>
</tr>
<tr>
<td>Yes</td>
<td>223</td>
<td>1.00</td>
<td>0.67 (0.45–0.99)</td>
<td>0.51 (0.32–0.79)</td>
<td>0.50 (0.30–0.84)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

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*Adjusted for age; cigarette smoking (except for analyses by smoking status); intake of alcohol (except for analyses by alcohol intake), red meat, and vegetables; and early parental mortality.
\(\dagger\)Estimated from walking, climbing stairs, and participating in sports or recreational activities.
\(\ddagger\)Based on the most intense sport or recreational activity; moderate activities require \(\geq 3\) METs.
relative to the physical fitness of the individual. However, this recommendation is less well known and less cited than the other guidelines above.

Studies investigating the health benefits of physical activity show a clear demarcation regarding whether absolute or relative intensity of physical activity is measured. To date, all studies of physical activity intensity and disease occurrence have examined absolute intensity.24 In the present study, we used self-reports of perceived exertion on the Borg Scale to assess relative intensity also. The Borg Scale is a valid measure of relative intensity given that the self-ratings show good correlation with exercise heart rate, which is a measure of individual exertion.15,17,18

Another group of studies primarily has utilized relative intensity of effort. These are experimental studies of factors such as blood pressure, lipid profile, insulin sensitivity, or coagulation and hemostasis that change over a short time. Investigators have measured individual levels of fitness and assigned subjects to exercise at relative intensity levels.25–28 Such studies show moderate relative intensity of exercise to be associated with improvements in these physiological variables, and provide the biological underpinnings for our findings.

Strengths of the present study include well-characterized subjects and detailed assessment of physical activity, allowing the investigation of different dimensions of physical activity. Limitations include the unknown generalizability of findings, because subjects were older, well-educated men. Although the biological effects of physical activity are likely to extend to women and those with different educational and socioeconomic backgrounds, it is unclear whether younger persons, not fulfilling current physical activity recommendations, might also experience the same strong inverse associations with relative intensity of exercise. Nonetheless, the present focus on older subjects is appropriate, because 85% of all CHD deaths occur in those age ≥65 years.29

We assessed relative intensity only once, and it is unclear how constant this is over time. We did assess walking, climbing stairs, and participation in sports and recreational activities in 1988 and again in 1993. The correlation over time for these measures was moderate (r=0.5), but it is unclear whether this is also true for the relative intensity of exercise. However, the follow-up was relatively short (mean, 5.3 years), reducing the likelihood of large changes in relative intensity. Finally, we did not examine other health outcomes. In particular, preventing unhealthy weight gain is likely to require higher levels of physical activity than that currently recommended.30

In conclusion, the present study of older men shows an inverse relation between relative intensity of physical activity (an individual’s perceived level of exertion) and risk of developing CHD, even among those not satisfying current recommendations for physical activity. When “moderate” intensity exercise is prescribed, this recommendation needs to match the physical fitness of the individual. Our findings in no way negate current activity recommendations—men who expended >1000 kcal/wk or who exercised at vigorous absolute intensity had lower CHD rates than those who did not. However, the findings do offer encouragement for older persons who may be unable or unwilling to follow current recommendations. With the high prevalence of individuals not meeting current activity recommendations,31 there is a need to clarify the thresholds of physical activity for specific health benefits.32

Acknowledgments

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References
