Walking Versus Running for Hypertension, Cholesterol, and Diabetes Mellitus Risk Reduction

Paul T. Williams, Paul D. Thompson

Objective—To test whether equivalent energy expenditure by moderate-intensity (eg, walking) and vigorous-intensity exercise (eg, running) provides equivalent health benefits.

Approach and Results—We used the National Runners’ (n=33,060) and Walkers’ (n=15,945) Health Study cohorts to examine the effect of differences in exercise mode and thereby exercise intensity on coronary heart disease (CHD) risk factors. Baseline expenditure (metabolic equivalent hours per day [MET/d]) was compared with self-reported, physician-diagnosed incident hypertension, hypercholesterolemia, diabetes mellitus, and CHD during 6.2 years follow-up. Running significantly decreased the risks for incident hypertension by 4.2% (P<10^-7), hypercholesterolemia by 4.3% (P<10^-15), diabetes mellitus by 12.1% (P<10^-1), and CHD by 4.5% per MET/d (P=0.05). The corresponding reductions for walking were 7.2% (P<10^-4), 7.0% (P<10^-4), 12.3% (P<10^-4), and 9.3% (P=0.01). Relative to <1.8 MET/d, the risk reductions for 1.8 to 3.6, 3.6 to 5.4, 5.4 to 7.2, and ≥7.2 MET/d were as follows: (1) 10.1%, 17.7%, 25.1%, and 34.9% from running and 14.0%, 23.8%, 21.8%, and 38.3% from walking for hypercholesterolemia; (2) 19.7%, 19.4%, 26.8%, and 39.8% from running and 14.7%, 19.1%, 23.6%, and 13.3% from walking for hypertension; and (3) 43.5%, 44.1%, 47.7%, and 68.2% from running, and 34.1%, 44.2% and 23.6% from walking for diabetes mellitus (walking >5.4 MET/d excluded for too few cases). The risk reductions were not significantly different for running than walking for diabetes mellitus (P=0.94), hypertension (P=0.06), or CHD (P=0.26), and only marginally greater for walking than running for hypercholesterolemia (P=0.04).

Conclusions—Equivalent energy expenditures by moderate (walking) and vigorous (running) exercise produced similar risk reductions for hypertension, hypercholesterolemia, diabetes mellitus, and possibly CHD. (Arterioscler Thromb Vasc Biol. 2013;33:1085-1091.)

Key Words: coronary heart disease • diabetes mellitus • exercise • high cholesterol • hypertension • physical activity • prevention • public health • running • walking

Current physical activity guidelines postulate that different activities can be combined to achieve a minimum recommended dose, including activities of different intensities.1-7 Activities that expend 3- to 6-fold the energy expenditure of sitting at rest (3–6 metabolic equivalents [METs], 1 MET=3.5 mL O2·kg^-1·min^-1) are defined as moderate, those that expend more as vigorous, and less as light.1 Walking is generally performed at moderate intensity4 and is specifically recommended by the Centers for Disease Control,1 the American Heart Association,2 the American College of Sports Medicine,1,2 and others,5,7 but whether equivalent doses of moderate and vigorous physical activity yield the same long-term health benefits remains unresolved.9

The current analyses examined whether equivalent energy expenditure by moderate and vigorous exercise produces similar reductions in coronary heart disease (CHD) risk factors. To this end, we examined the associations of incident hypertension, hypercholesterolemia (high cholesterol), and type 2 diabetes mellitus to reported exercise in the National Runners’ Health Study II and the National Walkers’ Health Study.10-12 Walking and running provide an ideal test of the health benefits of moderate-intensity versus vigorous-intensity exercise because they involve the same muscle groups. In addition, the National Runners’ and Walkers’ Health Studies assess running and walking energy expenditure from weekly distance run or walk, which seems to be a better metric than the traditional time-based measurements used by other studies.13-15

Materials and Methods

Materials and Methods are available in the online Supplement.

Results

There were 15,945 walkers (21.0% men), and 33,060 runners (51.4% men) eligible for analysis (Table 1). Baseline
hypothesis, hypercholesterolemia, and diabetes mellitus excluded 3271 walkers and 1841 runners, 2638 walkers and 2148 runners, 716 walkers and 249 runners from the analyses of incident hypertension, hypercholesterolemia, and diabetes mellitus, respectively. Table 1 presents the baseline characteristics of the cohorts. The combined cohorts were 89.1% white, 5.2% Hispanic, 1.8% Native American, 0.5% black, 2.3% Asian, and 1.2% other racial category. Energy expended by running in the runners was more than twice that reported for walking by walkers. The majority of the other exercise reported by runners and walkers was vigorous.

### Runners Versus Walkers
The runners had 38% lower risk for incident hypertension, 36% lower risk for hypercholesterolemia, and 71% lower risk for diabetes mellitus than walkers (Table 2). These differences were independent of the reported exercise but were substantially reduced by adjustment for body mass index (BMI), that is, to 14%, 18%, and 41% lower risk for hypertension, hypercholesterolemia, and diabetes mellitus, respectively (Table 3).

### Energy Expended by Running Versus Walking
Equivalent energy spent running and walking was associated with comparable risk reductions for hypertension, hypercholesterolemia, and diabetes mellitus (Figure 1). Moreover, there were incremental reductions in risk at 2-, 3-, and 4-times the dose of exercise recommended by the American Heart Association and the American College of Sports Medicine.2 Other moderate exercise was not significantly related to hypertension (P=0.72), hypercholesterolemia (P=0.79), or diabetes mellitus (P=0.72), and its risk reduction was significantly less than that of walking (walking > other moderate exercise; hypertension: P=0.0002; hypercholesterolemia: P<0.0001; diabetes mellitus: P=0.03). Although MET/h/d for walking and running were calculated from distance and intensity, MET/h/d for other exercises were calculated from time (duration) and intensity. In part, the weak effects of other exercise may be attributable to its method of estimation rather than the activities themselves. To show that time-based energy estimation underestimates the association of exercise with incident hypertension, hypercholesterolemia, and diabetes mellitus, the analyses of Table 2 were repeated for MET/h/d run as calculated from reported time and intensity (not displayed), rather than distance (Table 2). This shows that the reductions in risk per MET/h/d run were much less

### Table 1. Sample Characteristics

<table>
<thead>
<tr>
<th>Sample Characteristics</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample, n</td>
<td>16,983</td>
<td>16,077</td>
</tr>
<tr>
<td>Age, y</td>
<td>48.28±10.98</td>
<td>40.89±10.66</td>
</tr>
<tr>
<td>Follow-up, y</td>
<td>6.30±0.91</td>
<td>6.55±0.94</td>
</tr>
<tr>
<td>Education, y</td>
<td>16.79±2.46</td>
<td>18.35±2.31</td>
</tr>
<tr>
<td>Current smokers, %</td>
<td>1.22</td>
<td>1.69</td>
</tr>
<tr>
<td>Meat, servings/d</td>
<td>0.44±0.40</td>
<td>0.27±0.30</td>
</tr>
<tr>
<td>Fruit, pieces/d</td>
<td>1.53±1.18</td>
<td>1.53±1.06</td>
</tr>
<tr>
<td>Alcohol, g/d</td>
<td>9.85±13.47</td>
<td>5.88±8.21</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.09±2.59</td>
<td>21.62±2.51</td>
</tr>
<tr>
<td>Energy expenditure, MET/h/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>5.29±3.12</td>
<td>2.20±0.66</td>
</tr>
<tr>
<td>Walking</td>
<td>1.70±3.21</td>
<td>2.06±3.34</td>
</tr>
<tr>
<td>Other vigorous exercise</td>
<td>0.76±1.63</td>
<td>0.83±1.73</td>
</tr>
<tr>
<td>Other exercise, moderate</td>
<td>0.02±0.30</td>
<td>0.03±0.36</td>
</tr>
<tr>
<td>Other exercise, strength</td>
<td>0.53±1.26</td>
<td>0.40±0.26</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; and MET/h/d, metabolic equivalent hours per day.
for the time-based than the distance-based calculations (52% less for hypertension, 29% less for hypercholesterolemia, and 63% less for diabetes mellitus). When the time-based METh/d run and distance-based METh/d run were included together in the same survival analyses so that their coefficients could be compared directly, the distance-based estimates remained significant (hypertension: hazard ratio [HR] 0.961, \( P = 0.0001 \); hypercholesterolemia: HR 0.963, \( P = 10^{-10} \); and diabetes mellitus: HR 0.876, \( P = 0.0002 \)), whereas the time-based estimates were not (hypertension: HR 0.997, \( P = 0.68 \); hypercholesterolemia: HR 0.994, \( P = 0.25 \); and diabetes mellitus: HR 1.003, \( P = 0.88 \)), and in every case the risk reduction for the distance-based estimate was significantly greater than that of the time-based estimate (hypertension: \( P = 0.01 \); hypercholesterolemia: \( P = 0.007 \); and diabetes mellitus: \( P = 0.008 \)). Thus, time-based estimates of exercise energy expenditure seem to substantially underestimate the reductions in hypertension, hypercholesterolemia, and diabetes mellitus risk.

### Strengthening Exercise

When METh/d of strengthening and nonstrengthening exercises replaced other exercise in the analyses of Table 2, the effects of strengthening exercises and nonstrengthening exercise did not differ significantly from each other for incident hypertension (\( P = 0.08 \)), hypercholesterolemia (\( P = 0.21 \)), or diabetes mellitus (\( P = 0.13 \)). Specifically, the per METh/d effect of strengthening exercise was modestly significant for hypercholesterolemia (HR, 0.973; 95% confidence interval [CI], 0.949–0.998; \( P = 0.03 \)) and diabetes mellitus (HR, 0.902; 95% CI, 0.802–0.999; \( P = 0.05 \)), but not hypertension (HR, 1.011; 95% CI, 0.982–1.040; \( P = 0.49 \)). Nonstrengthening other exercise was significantly associated with hypertension (HR, 0.983; 95% CI, 0.973–0.993; \( P = 0.0007 \)) and hypercholesterolemia risk (HR, 0.990; 95% CI, 0.983–0.998; \( P = 0.01 \)), but not diabetes mellitus risk (HR, 0.984; 95% CI, 0.957–1.009; \( P = 0.21 \)).

### Running and Walking Intensity

Within both walkers and runners, faster pace (per m/s) was associated with lower risks of hypertension (runners: HR, 0.609; 95% CI, 0.553–0.671; \( P = 10^{-15} \); walkers: HR, 0.758; 95% CI, 0.639–0.899; \( P = 0.002 \)), hypercholesterolemia (runners: HR, 0.667; 95% CI, 0.619–0.720; \( P = 10^{-15} \); walkers: HR, 0.823; 95% CI, 0.720–0.942; \( P = 0.005 \)), and diabetes mellitus (runners: HR, 0.433; 95% CI, 0.334–0.574; \( P = 10^{-7} \); walkers: HR, 0.427; 95% CI, 0.331–0.573; \( P = 10^{-3} \)), which were, for the most part, independent of exercise dose but largely accounted for by BMI. There were no significant interactions between energy expended (METh/d) and intensity (m/s) to suggest that the same energy expended at a greater intensity produced a greater reduction in the risk of hypertension (significance of interaction, runners: \( P = 0.13 \); walkers: \( P = 0.33 \)), hypercholesterolemia (runners: \( P = 0.24 \); walkers: \( P = 0.51 \)), or diabetes mellitus (runners: \( P = 0.98 \); walkers: \( P = 0.71 \)).

### Coronary Heart Disease

The limited number of incident cases (530) provides limited statistical power for testing whether running and walking were associated with equivalent reductions in CHD risk. Nevertheless, the results were at least consistent with their equivalent effects per METh/d. There were 706 walkers (442 men, 264 women) and 370 runners (337 men, 33 women) excluded for preexisting CHD, leaving 189 de novo myocardial infarctions (102 walkers, 87 runners), 122 coronary artery bypass grafts (68 walkers, 54 runners), 185 angioplasties (93 walkers, 92 runners), and 34 angiina cases (19 walkers, 15 runners). The runners, as a group, had 52% lower CHD risk than the walkers (\( P < 10^{-7} \); Table 2), which was diminished somewhat by adjustment for BMI (\( P = 0.002 \); Table 3). Table 2 shows that both METh/d run and METh/d walk were associated with significantly lower CHD risk (\( P = 0.05 \) and \( P = 0.01 \), respectively), which did not differ from each other (\( P = 0.26 \)). The hazard ratios of Figure 2 are consistent with equivalent CHD risk reductions for walking and running.

### Adjustment for Recruitment

Different recruitment rates between the runners (51.7%) and walkers (33.2%) did not affect the analyses. Repeating the analyses using only the first 33.2% of the runners recruited (to match the 33.2% recruitment rate in the walkers) produced

<table>
<thead>
<tr>
<th>Sample size, n</th>
<th>Hypertension</th>
<th>Hypercholesterolemia</th>
<th>Diabetes Mellitus</th>
<th>CHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runners (0.1)</td>
<td>63 (0.552–0.704)§</td>
<td>640 (0.583–0.702)¶</td>
<td>294 (0.214–0.405)§</td>
<td>0.478 (0.342–0.666)§</td>
</tr>
<tr>
<td>Walking</td>
<td>0.95 (0.944–0.973)§</td>
<td>0.95 (0.946–0.968)¶</td>
<td>0.87 (0.832–0.929)§</td>
<td>0.95 (0.912–1.000)*</td>
</tr>
<tr>
<td>Other vigorous</td>
<td>0.98 (0.972–0.994)†</td>
<td>0.98 (0.978–0.994)‡</td>
<td>0.98 (0.950–1.007)</td>
<td>0.94 (0.966–1.024)</td>
</tr>
<tr>
<td>Other moderate</td>
<td>0.99 (0.787–1.018)</td>
<td>0.98 (0.982–1.014)</td>
<td>0.96 (0.908–1.024)</td>
<td>0.98 (0.927–1.044)</td>
</tr>
<tr>
<td>Other light</td>
<td>0.88 (0.739–1.006)</td>
<td>1.01 (0.955–1.061)</td>
<td>0.99 (0.736–1.121)</td>
<td>0.98 (0.807–1.197)</td>
</tr>
</tbody>
</table>

Analyses of runners and walkers combined adjusted for baseline age (age, age²), sex, and race (self-identified black, Hispanic, Asian, Native American), education, smoking, and intakes of red meat, fruit, and alcohol. Analyses of hypertension, hypercholesterolemia, and diabetes mellitus also included adjustment for preexisting CHD at baseline. CHD indicates coronary heart disease; and METh/d, metabolic equivalent hours per day.

Significance levels for individual coefficients are coded: *\( P < 0.05 \); †\( P < 0.01 \); §\( P < 0.001 \); ¶\( P < 0.0001 \); ‡\( P < 10^{-14} \).
results entirely consistent with the complete sample, as follows: (1) there were significant declines per MET/h run in risks for hypertension (4.2%; 95% CI, 2.4%–6.0%; \(P<10^{-5}\)), hypercholesterolemia (3.8%; 95% CI, 2.5%–5.2%; \(P<10^{-7}\)), and diabetes mellitus (11.4%; 95% CI, 4.4%–16.1% lower; \(P=0.001\)), whose differences from those of the walkers differed little from the complete sample (\(P=0.08\), 0.02, and 0.60, respectively); (2) adjustment for BMI did not eliminate the significant declines in risk for hypertension (2.4%; 95% CI, 0.6%–4.3%; \(P=0.01\)), hypercholesterolemia (2.8%; 95% CI, 1.4%–4.1% lower; \(P=0.0001\)), and diabetes mellitus (6.9%; 95% CI, 0.6%–12.8%; \(P=0.03\)) and produced runner-walker differences comparable to the complete sample (\(P=0.66\), 0.97, and 0.09, respectively), and (3) declines in CHD risk that were consistent with the complete sample (HR, 0.957; 95% CI, 0.906–1.008 per MET/h run; \(P=0.10\)).

**Discussion**

These results from these very large, prospective, cohorts suggest that equivalent doses of running (a vigorous exercise) and walking (a moderate exercise) are associated with largely equivalent reductions in the risks for new onset hypertension, hypercholesterolemia, and diabetes mellitus. These results also show continued reduction in risk for new onset hypertension, hypercholesterolemia, and diabetes mellitus when the exercise dose exceeds 450 to 750 MET minutes per week (1.1–1.8 MET/h/d), the amount of exertion currently recommended by the American Heart Association and the American College of Sports Medicine for health (Figure 1). Furthermore, it does not seem to matter whether these exercise doses are achieved by running or by walking. The equivalence of walking, the most commonly performed exercise,\(^{16}\) and running has not, to our knowledge, been previously demonstrated prospectively in a large sample, nor has the dose–response relationship between walking and these end points been assessed prospectively over such a broad activity range. The additional health benefits of exceeding the currently recommended exercise levels are consistent with cross-sectional data in runners and walkers.\(^{17,18}\) The runners’ results showing increased benefit with increased running energy expenditure also provide confirmation in a new independent sample of a progressively beneficial dose–response relationship for this activity.\(^{19}\)

Activity in the present study was self-selected both with respect to the intensity, running versus walking, and the total exercise dose. The average exercise dose measured as estimated caloric expenditure was more than twice as great for those who chose running over those who chose walking. Specifically, there were substantially more walkers whose walking was at or below the guideline levels than runners whose running was at or below the guidelines (48.1% versus 12.2%), and substantially fewer walkers than runners whose walking or running exceeded the guideline levels by 2-fold.
(15.4% versus 61.1%), 3-fold (4.5% versus 40.1%), and 4-fold (1.1% versus 17.9%). This is likely a result of the fact that runners can expend more calories in a given period of time. Our results suggest that this caloric expenditure is the key issue to reducing CHD risk factors and possibly CHD events.

Clinical trials are required to settle the role of exercise intensity on CHD risk, but clinical trials are necessarily restricted by sample size and duration. Available clinical trials on the influence of exercise intensity on new onset blood pressure, cholesterol, and blood glucose control or insulin sensitivity have yielded mixed results. Both moderate and vigorous-intensity training improve blood pressure with approximately equal effects,26 although greater benefits have been ascribed to both moderate25 and vigorous intensity.27 The ability of exercise to lower total and low-density lipoprotein cholesterol is lower than expected,28 although greater benefits have been ascribed to both moderate21 and vigorous intensity. 9 The ability of exercise (Table 2).

The superiority of the distance-based versus time-based estimation of exercise energy expenditure has other important implications. If runners and walkers substantially overestimate exercise duration for a sustained activity, it is reasonable to assume even greater bias for unsustained activities by more sedentary populations. Most epidemiological studies estimate exercise dose by time and intensity,1–7,20 and if people would substantially underestimate the true health benefits of physical activity. Moreover, all public health recommendations prescribe physical activity by duration,1–7,20 and if people overestimate exercise by time, then implementing time-based recommendations may be problematic.

Caveats
The subsample included in this report is a sample of convenience because it was recruited to obtain ≈50,000 subjects to determine their interest in a possible internet-based intervention, and therefore represent only a portion of the original National Runners’ Health Study II and the National Walkers’
Health Study participants. It is unlikely, however, that the biological interaction of between exercise and hypertension, hypercholesterolemia, and diabetes mellitus is different between the current and less-selected populations. We cannot exclude the possibility that subjects who exercise have lower innate risks for hypertension, hypercholesterolemia, diabetes mellitus, or CHD. We have shown that men with higher high-density lipoprotein cholesterol at baseline (a CHD protective factor) run longer distances when randomized to exercise training.28,29 and others have shown that selective breeding for fitness in rats produces substantial inherited differences in CHD risk factors even in the absence of training.30 Diet and other variables that could have affected our results were not collected. We doubt the possibility that lower rates of new onset hypertension, hypercholesterolemia, and diabetes mellitus with greater exercise levels was attributable to less medical care contact in more active men because more vigorously active participants in the Health Professional Study had more frequent medical check-ups than less active men,31 and there was no difference in the frequency of routine medical check-ups by activity level in the Nurses Health Study.32 The slightly greater risk reductions for hypertension and hypercholesterolemia for walking than running may relate to residual effects of the walkers’ older age and greater body weight that was not completely removed by statistical adjustment.

Our results probably provide among the best available answers to the important public health question as to what intensity of exercise is required to reduce CHD risk. Our results suggest similar benefit for similar energy expenditures. These results should be used to encourage physical activity in general, regardless of its intensity. However, those who choose running achieved more than twice the exercise doses as those who choose walking, and given the strong dose-response relationship, higher exercise doses and lower risk factors, promoting more vigorous exercise, are likely to produce greater health benefits.

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Disclosures
None.

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Significance

We used the National Runners’ and Walkers’ Health Study cohorts to show that equivalent energy expenditures by moderate-intensity exercise (e.g., walking) and vigorous-intensity exercise (e.g., running) produced similar risk reductions for hypertension, hypercholesterolemia, diabetes mellitus, and possibly coronary heart disease. This result is important because current physical activity guidelines for health by government and nongovernment organizations postulate that different activities can be combined to achieve a minimum recommended dose, including activities of different intensities. Running significantly decreased the risks for incident hypertension by 4.2%, hypercholesterolemia by 4.3%, diabetes mellitus by 12.1%, and coronary heart disease by 4.5% per metabolic equivalent hours per day, where 1 metabolic equivalent is the energy equivalent of running 1 km. The corresponding reductions for walking were 7.2%, 7.0%, 12.3%, and 9.3%. We also show that significantly greater reductions in the risks for hypertension, hypercholesterolemia, diabetes mellitus, and coronary heart disease are achieved by exceeding the current public health recommendations.
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Methods and Materials

The National Runners’ Health Study II and the National Walkers’ Health Study were initially recruited in 1998 and 1999 respectively to examine the relationships between various amounts and intensity of physical activity in a large national cohort of 63,308 runners and 42,140 walkers. The original cohorts were partially resurveyed in 2006 to establish a population of approximately 50,000 runners and walkers for a proposed clinical trial, rather than a prospective follow-up study per se [1-3]. These represented approximately a third of the original walker (33.2%), and one-half of the original runner surveyed (51.7%). The difference in recruitment rates was due to the greater effort made to recruit runners (two mailings) than walkers (one mailing). Compared to non-responders, those that responded were slightly more likely to be female, younger, slightly less educated, weighed slightly more, were less likely to report taking medications for blood pressure, hypertension, or diabetes at baseline, but reported approximately the same number of km/day run if a runner or walked if a walker as reported on their baseline questionnaire. The two cohorts may be more accurately characterized as a single cohort that targeted the runners and walkers, since both were recruited over the same approximate time interval, using the same questionnaire (modified slightly for the different activities), using the same sampling domain (subscription lists to running and walking publications, running and walking events), using the same survey staff, and were funded by the same grant.
Participants completed baseline and follow-up questionnaires on height, current weight, diet, current and past cigarette use, and history of diseases. Intakes of meat and fruit were based on the questions “During an average week, how many servings of beef, lamb, or pork do you eat”, and “…pieces of fruit do you eat”. Alcohol intake was estimated from the corresponding questions for 4-oz (112 mL) glasses of wine, 12-oz (336 mL) bottles of beer, and mixed drinks and liqueurs. Alcohol was computed as 10.8 g/4-oz glass of wine, 13.2 g/12-oz bottle of beer, and 15.1 g/mixed drink. Education was solicited by requesting the participant provide “years of education (examples: HS=12; BS or BA = 16; MS or MA = 18; PhD or MD = 20).” Height and weight were determined by asking the participant, “What is your current height (in inches, without shoes)?” and, “What is your current weight (pre-pregnancy weight if pregnant)?” BMI was calculated as weight in kilograms divided by the square of height in meters. Elsewhere, we have reported the strong correlations between self-reported and clinically measured heights (r=0.96) and weights (r=0.96) [4]. The study protocol was reviewed by the University of California Berkeley committee for the protection of human subjects, and all subjects provided a signed statement of informed consent.

Walking and running were reported in miles per week. In runners, we have reported that the test-retest correlation for self-reported usual distance run per week to be r=0.89 [4], which compares well with other assessments [5]. In addition, the questionnaires asked how many hours per week on average did respondents spend running, walking, swimming, cycling, and in other exercises which they described in detail. They were also asked for their usual pace (minutes per mile) during walking and running. Time based calculations of MET/h/d of vigorous, moderate, and light exercise were summed as the product of average daily hours spent on each activity and the activity’s estimated energy
expenditure [6]. The distance-based calculation of MET\(h/d\) walked converted distance into duration (i.e., distance/mph) and calculated the average hours walked per day and the MET value for the reported pace [7,8]. Running MET values were calculated as 1.02 MET\(•h\) per km [8,9]. Time-based calculation of MET\(h/d\) run was computed by converting the hours run into distance (i.e., hours*kmph).

New onset or ”incident” hypertension, hypercholesterolemia, diabetes, and CHD (myocardial infarction, coronary artery bypass graphs (CABG), percutaneous coronary intervention, and angina pectoris) were defined as physician diagnosis or starting medications for these conditions since the baseline questionnaire. Self-reported hypertension and hypercholesterolemia have been demonstrated as consistent by repeated surveys and reliable as confirmed by medical records [10] and have been used by the Nurses’ Health Study [11] and other major cohort studies [12].

Statistical analyses were performed using JMP (SAS institute, Cary NC, version 5.1) and Stata (StataCorp LP, College Station TX, version 11). Cox proportional hazard analyses were used to estimate the hazard rate per MET\(h/d\) of running, walking, and other vigorous, moderate, and light intensity exercise adjusted for sex, age (age and age\(^2\)), race (self-identified Black, Hispanic, Asian, Native American, White), education, smoking (yes, no), and runner vs. walker cohort. The analyses of hypertension, hypercholesterolemia, and diabetes also included adjustment for prior CHD. All analyses were for runners and walkers combined, except where noted (Figures 1 and 2). With 80% power and 5% statistical significance, we should be able to detect a runner vs. walker difference in the hazard rates of 5.0% for hypertension, 3.9% for hypercholesterolemia, 12.1% for diabetes, and 12.1% for CHD.
References for methods


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9. Williams PT. Non-exchangeability of running vs. other exercise in their association
with adiposity, and its implications for public health recommendations. PLOSOne 2012;7:e36360


Methods and Materials

The National Runners’ Health Study II and the National Walkers’ Health Study were initially recruited in 1998 and 1999 respectively to examine the relationships between various amounts and intensity of physical activity in a large national cohort of 63,308 runners and 42,140 walkers. The original cohorts were partially resurveyed in 2006 to establish a population of approximately 50,000 runners and walkers for a proposed clinical trial, rather than a prospective follow-up study per se [1-3]. These represented approximately a third of the original walker (33.2%), and one-half of the original runner surveyed (51.7%). The difference in recruitment rates was due to the greater effort made to recruit runners (two mailings) than walkers (one mailing). Compared to non-responders, those that responded were slightly more likely to be female, younger, slightly less educated, weighed slightly more, were less likely to report taking medications for blood pressure, hypertension, or diabetes at baseline, but reported approximately the same number of km/day run if a runner or walked if a walker as reported on their baseline questionnaire. The two cohorts may be more accurately characterized as a single cohort that targeted the runners and walkers, since both were recruited over the same approximate time interval, using the same questionnaire (modified slightly for the different activities), using the same sampling domain (subscription lists to running and walking publications, running and walking events), using the same survey staff, and were funded by the same grant.
Participants completed baseline and follow-up questionnaires on height, current weight, diet, current and past cigarette use, and history of diseases. Intakes of meat and fruit were based on the questions “During an average week, how many servings of beef, lamb, or pork do you eat”, and “…pieces of fruit do you eat”. Alcohol intake was estimated from the corresponding questions for 4-oz (112 mL) glasses of wine, 12-oz (336 mL) bottles of beer, and mixed drinks and liqueurs. Alcohol was computed as 10.8 g/4-oz glass of wine, 13.2 g/12-oz bottle of beer, and 15.1 g/mixed drink. Education was solicited by requesting the participant provide “years of education (examples: HS=12; BS or BA = 16; MS or MA = 18; PhD or MD = 20).” Height and weight were determined by asking the participant, “What is your current height (in inches, without shoes)?” and, “What is your current weight (pre-pregnancy weight if pregnant)?” BMI was calculated as weight in kilograms divided by the square of height in meters. Elsewhere, we have reported the strong correlations between self-reported and clinically measured heights (r=0.96) and weights (r=0.96) [4]. The study protocol was reviewed by the University of California Berkeley committee for the protection of human subjects, and all subjects provided a signed statement of informed consent.

Walking and running were reported in miles per week. In runners, we have reported that the test-retest correlation for self-reported usual distance run per week to be r=0.89 [4], which compares well with other assessments [5]. In addition, the questionnaires asked how many hours per week on average did respondents spend running, walking, swimming, cycling, and in other exercises which they described in detail. They were also asked for their usual pace (minutes per mile) during walking and running. Time based calculations of METh/d of vigorous, moderate, and light exercise were summed as the product of average daily hours spent on each activity and the activity’s estimated energy.
expenditure [6]. The distance-based calculation of MET/h walked converted distance into duration (i.e., distance/mph) and calculated the average hours walked per day and the MET value for the reported pace [7,8]. Running MET values were calculated as 1.02 MET•h per km [8,9]. Time-based calculation of MET/h run was computed by converting the hours run into distance (i.e., hours•kmph).

New onset or "incident" hypertension, hypercholesterolemia, diabetes, and CHD (myocardial infarction, coronary artery bypass graphs (CABG), percutaneous coronary intervention, and angina pectoris) were defined as physician diagnosis or starting medications for these conditions since the baseline questionnaire. Self-reported hypertension and hypercholesterolemia have been demonstrated as consistent by repeated surveys and reliable as confirmed by medical records [10] and have been used by the Nurses’ Health Study [11] and other major cohort studies [12].

Statistical analyses were performed using JMP (SAS institute, Cary NC, version 5.1) and Stata (StataCorp LP, College Station TX, version 11). Cox proportional hazard analyses were used to estimate the hazard rate per MET/h of running, walking, and other vigorous, moderate, and light intensity exercise adjusted for sex, age (age and age²), race (self-identified Black, Hispanic, Asian, Native American, White), education, smoking (yes, no), and runner vs. walker cohort. The analyses of hypertension, hypercholesterolemia, and diabetes also included adjustment for prior CHD. All analyses were for runners and walkers combined, except where noted (Figures 1 and 2). With 80% power and 5% statistical significance, we should be able to detect a runner vs. walker difference in the hazard rates of 5.0% for hypertension, 3.9% for hypercholesterolemia, 12.1% for diabetes, and 12.1% for CHD.
References for methods


9. Williams PT. Non-exchangeability of running vs. other exercise in their association
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 걸기(Walking)와 뛰기(Running)는 같은 에너지를 소비할 경우 고혈압, 콜레스테롤 및 당뇨병 발병 위험인자를 비슷한 정도로 감소시킨다.

조 현 재 교수
서울대학교 보라매병원 내분비내과

Summary

배경
걸기처럼 적절한 강도(moderate-intensity)의 운동과 뛰기 같은 강렬한 강도(vigorous-intensity)의 운동으로 같은 에너지를 소비했을 때, 이러한 운동이 건강에 얼마나 도움이 되는지 알아보고자 하였다.

방법 및 결과
본 실험은 운동 방법의 차이에 의한 효과와, 운동의 강도가 심혈관질환(coronary heart disease, CHD) 위험인자에 미치는 영향을 알아보고자 National Health Study cohorts에서 뛰기 운동을 하는 33,060명과 걷기 운동을 하는 15,945명을 대상으로 연구를 진행하였다. Self-reported 또는 의사에게 진단을 받은 고혈압, 고콜레스테롤혈증, 당뇨병, 심혈관질환 등에서 기본 에너지 소비시간당 대사당량(METh/d)을 기준으로 6년 2개월 동안 운동으로 인한 질환 위험인자의 변화를 비교하였다. 뛰기와 걷기 운동 모두에서 고혈압(뛰기: 4.2% (P<10^{-3}), 걷기: 7.2% (P<10^{-3})), 고콜레스테롤혈증(뛰기: 4.3%, (P<10^{-3}), 걷기: 7.0% (P<10^{-3})), 당뇨병(뛰기: 12.1% (P<10^{-3}), 걷기: 12.3% (P<10^{-3})), 그리고 CHD(뛰기: 4.5% per METh/d (P=0.05), 걷기: 9.3% per METh/d (P=0.01)) 등의 질환 위험인자가 크게 감소하는 효과를 보였다. 대사당량(METh/d)이 1.8 보다 작을 때, 질환 위험인자가 1.8에서 3.6, 3.6에서 5.4, 5.4에서 7.2로 감소하였다. 대사당량(METh/d)이 7.2 이하로 증가했을 때, (1) 고콜레스테롤혈증에서 뛰기는 10.1%, 17.7%, 25.1%, 그리고 34.9% 걷기는 14.0%, 23.8%, 21.8%, 38.3% (2) 고혈압에서 뛰기는 19.7%, 19.4%, 26.8%, 39.8% 걷기는 14.7%, 19.1%, 23.6%, 13.3% (3) 당뇨병에서 뛰기는 43.5%, 44.1%, 47.7%, 68.2% 걷기는 34.1%, 44.2%, 23.6%로 위험인자가 감소하였다. 뛰기와 걷기 모두 당뇨병(P=0.94), 고혈압(P=0.06), 또한 CHD (P=0.26) 등의 위험인자의 감소에 비슷한 효과를 보였으며, 다만 미세하게 고콜레스테롤혈증은 뛰기보다 걷기가 조금 더 효과를 보이는 것으로 나타났다(P=0.04).

결론
적당한 강도의 걸거나, 강렬한 강도의 뛰기로 같은 양의 에너지를 소비했을 때, 각각의 운동은 모두 고혈압, 고콜레스테롤혈증, 당뇨병 그리고 부가적으로 CHD 유발 위험인자의 감소에 효과적이다.
대사당량(metabolic equivalent)은 휴식 시 1분당 1 kg에 대해 3.5 ml의 산소를 소비하는 것을 1 MET 로 산정하여 계산된다. 휴식 상태보다 3배에서 6배의 에너지 소비하는 운동[3-6 대사당량(METs)]을 적당한 강도의 운동, 그 이상을 소비하는 운동을 격렬한 운동, 그 이하를 가벼운 운동이라고 정의한다. 걷기는 일반적으로 적당한 강도의 운동이며 뛰기는 격렬한 강도의 운동을 대표한다. 하지만 적당한 혹은 격렬한 운동으로 같은 정도의 운동을 했을 때, 장기적으로 건강에 이들 운동이 어떤 영향이 있는지는 명확하지 않은 상태이다. 이에 본 연구에서는 National Health Study cohorts를 통해 적당한(걷기) 혹은 격렬한(뛰기) 운동으로 같은 에너지를 소비했을 때, CHD 위험인자가 비슷하게 감소하는지, 고혈압, 고콜레스테롤혈증, 당뇨병증을 가진 사람들은 baseline에서 제외하였다. Runners는 walkers 보다 고혈압, 고콜레스테롤혈증, 당뇨병증 위험인자가 더 낮았으며, 이 차이는 체질량지수(body mass index, BMI)로 보정하였다. 뛰기와 걷기로 같은 에너지를 소비하였을 때, 고혈압, 고콜레스테롤혈증, 당뇨병증의 위험인자를 감소시키는 효과가 비슷한 것으로 나타났다. 그리고 미국심장학회(AHA)와 미국대학스포츠의학회(ACSM)에서 권장한 운동량이 늘수록 위험인자도 비례하여 감소하였다(Figure 1).

![Figure 1. 권장 운동량과 질환 위험인자들의 감소효과.](image-url)
걷기나 뛰기 모두 운동으로 인한 에너지소비가 증가할수록, 고혈압, 고콜레스테롤혈증, 당뇨병증 위험 인자를 감소시키는 효과를 보였다. 또한, 운동강도(단위시간당 운동량 per m/s)를 늘렸을 때는 걷기와 뛰기 모두에서 고혈압, 고콜레스테롤혈증, 당뇨병증 위험인자를 감소시키는 효과를 보였다. 하지만 운동강도를 높여 에너지 소비를 촉진한다고 해서 고혈압, 고콜레스테롤혈증, 당뇨병증 위험인자가 더 많이 감소하는 효과를 보이지 않았다. CHD 위험인자 감소 또한 걷기와 뛰기 모두에서 유의하게 감소하였다(Figure 2). 이는 CHD 위험인자 감소가 운동 방법이 아닌 에너지(calories) 소비의 정도에 의해 조절될을 의미한다.

이상의 결과는 고혈압, 고콜레스테롤혈증, 당뇨병, CHD의 발병을 낮추기 위해 어떤 강도의 운동을 어떤 방식으로 할 것인가라는 질문에 답을 줄 수 있다. 방법에 관계없이 비슷한 에너지의 소비는 비슷한 운동 효과를 줄 수 있다는 것이다. 일주일간 AHA와 ACSM에서 권장한 450-750 MET minutes (1.1-1.8 METh/d) 정도의 운동을 하였을 때, 고혈압, 고콜레스테롤혈증, 당뇨병증 발병을 억제할 수 있으며, 또한 그것이 뛰기이든 걷기이든 관계 없음을 보여준다.

**REFERENCES**

Figure 2. 권장 운동량과 CHD 위험인자의 감소효과.