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 equivant hours per day [METh/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% ($P<10^{-14}$), diabetes mellitus by 12.1% ($P<10^{-5}$), and CHD by 4.5% per METh/d ($P=0.05$). The corresponding reductions for walking were 7.2% ($P<10^{-6}$), 7.0% ($P<10^{-8}$), 12.3% ($P<10^{-4}$), and 9.3% ($P=0.01$). Relative to <1.8 METh/d, the risk reductions for 1.8 to 3.6, 3.6 to 5.4, 5.4 to 7.2, and ≥7.2 METh/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 METh/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 $O_2 \cdot kg^{-1} \cdot min^{-1}$) are defined as moderate, those that expend more as vigorous, and less as light.[1] Walking is generally performed at moderate intensity[8] 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,[6,7] 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

Received on: November 21, 2012; final version accepted on: February 14, 2013.

From the Life Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA (P.T.W.); and Division of Cardiology, Hartford Hospital, Hartford, CT (P.D.T.).

The online-only Data Supplement is available with this article at http://atvb.ahajournals.org/lookup/suppl/doi:10.1161/ATVBAHA.112.300878/-/DC1.

Correspondence to Paul T. Williams, PhD, Life Sciences Division, Lawrence Berkeley National Laboratory, Donner 464, 1 Cycloton Rd, Berkeley, CA 94720. E-mail ptwilliams@lbl.gov

Table 1. Sample Characteristics

	Men		Women	
	Runners	Walkers	Runners	Walkers
Sample, n	16983	3349	16077	12596
Age, y	48.28±10.98	61.77±11.10	40.89±10.66	53.08±12.05
Follow-up, y	6.30±0.91	5.60±1.17	6.55±0.94	5.69±1.26
Education, y	16.79±2.46	16.31±2.72	16.35±2.31	15.27±2.54
Current smokers, %	1.22	3.40	1.69	3.68
Meat, servings/d	0.44±0.40	0.46±0.41	0.27±0.30	0.37±0.34
Fruit, pieces/d	1.53±1.18	1.62±1.22	1.53±1.06	1.70±1.14
Alcohol, g/d	9.85±13.47	9.16±13.40	5.88±8.21	4.93±9.09
BMI, kg/m^2	24.09±2.59	26.63±4.05	21.62±2.51	25.48±5.18
Energy expenditure, METh/d				
Running	5.29±3.12		4.74±3.03	
Walking		2.20±1.66		2.14±1.63
Other vigorous exercise	1.70±3.21	1.69±3.34	2.06±3.34	1.46±2.95
Other exercise, moderate	0.76±1.63	0.43±1.49	0.83±1.73	0.36±1.26
Other exercise, light	0.02±0.30	0.04±0.59	0.03±0.36	0.03±0.25
Other exercise, strength	0.53±1.26	0.20±0.86	0.54±1.26	0.20±0.75

BMI indicates body mass index; and METh/d, metabolic equivant hours per day.

hypertension, 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] Table 2 shows that greater metabolic equivant hours per day (METh/d) run or walk was associated with significantly lower risks, respectively, for incident hypertension ($P<10^{-7}$ and $P<10^{-6}$), hypercholesterolemia ($P<10^{-14}$ and $P<10^{-8}$), and diabetes mellitus ($P<10^{-5}$ and $P<10^{-4}$). The risk reductions per METh/d were not significantly greater for running than walking for hypertension (running versus walking, $P=0.06$), hypercholesterolemia ($P=0.04$, significantly greater for walking, and not running), or diabetes mellitus ($P=0.94$). The equivalent benefits per METh/d run and METh/d walked persisted even after adjustment for BMI for hypertension (running versus walking, $P=0.54$) and hypercholesterolemia ($P=0.56$), but not for diabetes mellitus (running > walking, $P=0.01$; Table 3).

Other Exercise

Higher levels of nonrunning vigorous exercises were also associated with lower risks of hypertension ($P=0.003$) and hypercholesterolemia ($P=0.0008$), but not diabetes mellitus ($P=0.16$). The METh/d reductions in risk were significantly less for nonrunning vigorous exercise than for running for hypertension: (running–other vigorous exercise, $P=0.006$), hypercholesterolemia ($P<10^{-4}$), and diabetes mellitus ($P=0.0006$). 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: $P<10^{-5}$; and diabetes mellitus: $P=0.03$).

Although METh/d for walking and running were calculated from distance and intensity, METh/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 METh/d run as calculated from reported time and intensity (not displayed), rather than distance (Table 2). This shows that the reductions in risk per METh/d run were much less

Table 2. Hazard Ratios (95% Confidence Intervals) From Cox Proportional Hazard Analyses of Self-Reported Incident Hypertension, Hypercholesterolemia, Diabetes Mellitus, and CHD

	Hypertension	Hypercholesterolemia	Diabetes Mellitus	CHD
Sample size, n	43 341	44 216	48 116	47 921
Incident events	3874	6637	647	530
Runners (0,1)	0.623 (0.552–0.704)§	0.640 (0.583–0.702)¶	0.294 (0.214–0.405)§	0.478 (0.342–0.666)§
Energy expenditure at baseline (per METh/d)				
Running	0.958 (0.944–0.973)§	0.957 (0.946–0.968)¶	0.879 (0.832–0.929)§	0.955 (0.912–1.000)*
Walking	0.928 (0.899–0.957)§	0.930 (0.908–0.953)§	0.877 (0.824–0.934)§	0.907 (0.839–0.981)†
Other vigorous	0.983 (0.972–0.994)†	0.986 (0.978–0.994)‡	0.980 (0.950–1.007)	0.994 (0.966–1.024)
Other moderate	0.997 (0.976–1.018)	0.998 (0.982–1.014)	0.969 (0.908–1.024)	0.984 (0.927–1.044)
Other light	0.886 (0.739–1.006)	1.011 (0.955–1.061)	0.992 (0.736–1.121)	0.983 (0.807–1.197)

Analyses of runners and walkers combined adjusted for baseline age (age, age^2), 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 equivant 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}.

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^{-6}; 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^{-9}), 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 angina cases (19 walkers, 15 runners). The runners, as a group, had 52% lower CHD risk than the walkers (P<10^{-5}; 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

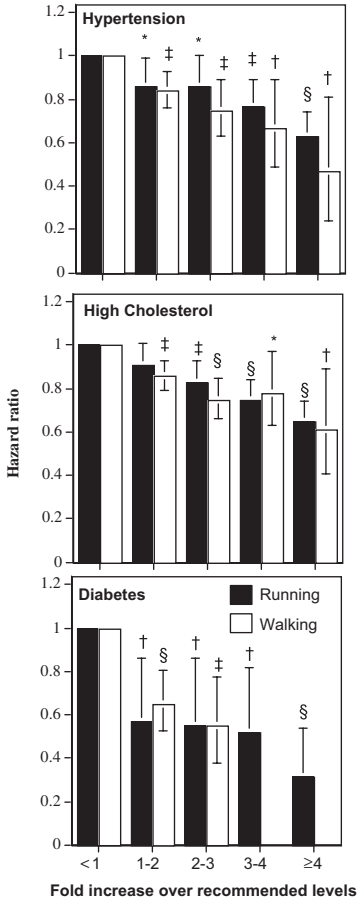

Figure 1. Reduction in the risks for hypertension, hypercholesterolemia, and diabetes mellitus vs baseline metabolic equivant hours per day (METh/d) energy expended by walking or running. Energy expenditure (*x* axis) is categorized in terms of the upper limit of the minimum recommended physical activity levels (750 METmin/wk=1.8 METh/d),[2] for example, 1- to 2-fold higher activity covers from 1.8 to 3.6 METh/d, etc. The average energy expended by runners and walkers within each interval were 314 and 371 METmin/wk for <1-fold of the recommended levels (<1.8 METh/d), respectively; 1208 and 1108 METmin/wk for 1- to 2-fold (1.8–3.6 METh/d), respectively; 1927 and 1845 METmin/wk for 2- to 3-fold (3.6–5.4 METh/d), respectively; 2684 and 2587 METmin/wk for 3- to 4-fold (5.4–7.2 METh/d), respectively; and 4197 and 3436 METmin/wk for ≥4-fold (≥7.2 METh/d). Analyses performed separately in runners and walkers, adjusted for age, sex, race, smoking, prior coronary heart disease, and intakes of red meat, fruit, and alcohol. Incident diabetes mellitus in walkers excluded for 3- to 4-fold and ≥4-fold attributable to the small number of cases. Error bars represent 95% confidence intervals. Significant levels relative to the least active runners and walkers coded: **P*<0.05; †*P*<0.01; ‡*P*<0.001; and §*P*<0.0001.

results entirely consistent with the complete sample, as follows: (1) there were significant declines per METh/d 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, *P*=0.02, and *P*=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, *P*=0.97, and *P*=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 METh/d 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 METh/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

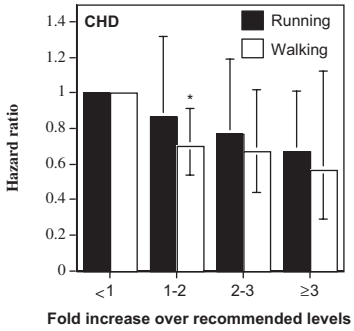

Figure 2. Reduction in coronary heart disease (CHD) risks per metabolic equivant hours per day (METh/d) energy expended by walking or running at baseline. Error bars represent 95% confidence intervals. Significant levels relative to the least active runners and walkers coded: **P*<0.05; †*P*<0.01; ‡*P*<0.001; and §*P*<0.0001.

Table 3. Hazard Ratios (95% Confidence Intervals) From Cox Proportional Hazard Analyses of Self-Reported Incident Hypertension, Hypercholesterolemia, Diabetes Mellitus, and CHD, Adjusted for BMI

	Hypertension	Hypercholesterolemia	Diabetes Mellitus	CHD
Sample size, n	42 853	43 683	47 584	47 339
Incident events	3811	6520	629	509
BMI, kg/m^2	1.087 (1.079–1.095)¶	1.061 (1.055–1.067)¶	1.138 (1.125–1.150)¶	1.070 (1.048–1.093)§
Runners (0,1)	0.862 (0.759–0.979)*	0.819 (0.743–0.903)§	0.587 (0.420–0.821)†	0.569 (0.401–0.808)†
Energy expenditure at baseline (per METh/d)				
Running	0.977 (0.962–0.992)†	0.968 (0.957–0.979)§	0.912 (0.861–0.963)‡	0.978 (0.934–1.025)
Walking	0.987 (0.957–1.018)	0.976 (0.952–1.000)*	1.013 (0.950–1.078)	0.946 (0.873–1.025)
Other vigorous	0.988 (0.977–0.999)*	0.990 (0.982–0.998)*	0.995 (0.965–1.022)	0.997 (0.968–1.027)
Other moderate	0.995 (0.974–1.016)	0.996 (0.980–1.013)	0.965 (0.904–1.020)	0.983 (0.925–1.044)
Other light	0.920 (0.776–1.034)	1.026 (0.973–1.075)	1.040 (0.801–1.158)	0.998 (0.828–1.204)

Analyses of runners and walkers combined adjusted for baseline age (age, age^2), 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. BMI indicates body mass index; CHD, coronary heart disease; and METh/d, metabolic equivant hours per day.

Significance levels for individual coefficients are coded: *P<0.05; †P<0.01; ‡P<0.001; §P<0.0001; ¶P<10^{-15}. Samples sizes differ slightly from Table 2 because of missing BMI.

(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,[20] although greater benefits have been ascribed to both moderate[21] and vigorous intensity.[9] The ability of exercise to lower total and low-density lipoprotein cholesterol is not widely accepted,[20,22,23] irrespective of intensity, and some maintain that any reduction in low-density lipoprotein is attributable to plasma volume expansion.[24] Our results suggest that exercise does affect low-density lipoprotein levels, and that this effect increases with increasing exercise doses, consistent with the suggestion that low-density lipoprotein concentrations are more responsive to the exercise quantity than intensity.[25] Both moderate and vigorous exercise have been associated with lower risk of type 2 diabetes mellitus[20]; however, studies of blood glucose control tend to achieve significant improvement for vigorous and more than moderate physical activity.[9] The benefits of walking, in particular, in lowering type 2 diabetes mellitus risk are well-documented.[26] Prospective epidemiological studies tend to show a greater CHD risk reduction for vigorous than moderate-intensity exercise[20]; however, vigorous physical activity is more accurately reported than moderate-intensity exercise,[27] which could contribute to its stronger relationship to CHD, hypertension, hypercholesterolemia, and diabetes mellitus when studied prospectively in epidemiological cohorts.[20] This may be less of an issue for the analyses presented here, which compares 2 specific activities, running and walking, quantified by distance rather than duration. The superiority of vigorous over moderate exercise, in some studies, may simply reflect the fact that more calories can be expended per minute of activity with vigorous exercise. Consequently, when exercise is compared by time spent in activity, vigorous exercise seems more beneficial.

This last point we believe to be of particular significance. In this article, we have shown that the effects of exercise on incident hypertension, hypercholesterolemia, and diabetes mellitus are at least 2-fold greater, when exercise energy expenditure calculated from distance than when exercise is measured by time. Similar results have been shown for using distance to assess energy expenditure cross-sectionally for body weight, hypertension, hypercholesterolemia, and diabetes mellitus.[13–15] Presumably, deficiencies in time-based estimates of exercise energy expenditure apply to nonrunning and nonwalking activities as well, which may contribute to the significant differences between running and other vigorous exercise, and walking versus other moderate 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,[20] which our analyses 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)[22] 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.

Sources of Funding

This research was supported by grant HL094717 from the National Heart, Lung, and Blood Institute and was conducted at the Ernest Orlando Lawrence Berkeley National Laboratory (Department of Energy DE-AC03-76SF00098 to the University of California).

Disclosures

None.

References

1. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995;273:402–407.
2. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39:1423–1434.
3. Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*. Washington, DC: The National Academies Press; 2005:880–935.
4. US Department of Agriculture and US Department of Health and Human Services. *Dietary Guidelines for Americans, 2010*. 7th ed, Washington, DC: US Government Printing Office; 2010.
5. O'Donovan G, Blazevich AJ, Boreham C, et al. The ABC of physical activity for health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci*. 2010;28:573–591.
6. US Department of Health and Human Services. 2008 Physical activity guidelines for Americans. Washington (DC):ODPHP Publication No. U0036. 2008;61 [cited 2010 Oct 10]. 61 p. http://www.health.gov/paguidelines/pdf/paguide.pdf. Accessed October 10, 2010.
7. World Health Organization. Global Strategy on Diet, Physical Activity, and Health. 2006. http://www.who.int/dietphysicalactivity/en/index.html. Accessed Jan 19, 2012.
8. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, O'Brien WL, Bassett DR Jr, Schmitz KH, Emplaincourt PO, Jacobs DR Jr, Leon AS. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(suppl 9):S498–S504.
9. Swain DP, Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *Am J Cardiol*. 2006;97:141–147.
10. Williams PT. Walking and running are associated with similar reductions in cataract risk. *Med Sci Sports Exerc*. December 27, 2012. DOI: 10.1249/MSS.0b013e31828121d0. http://journals.lww.com/acsm-msse/Abstract/publishahead/Walking_and_Running_Are_Associated_with_Similar.98471.aspx. Accessed April 1, 2013.
11. Williams PT. Greater weight loss from running than walking during 6.2-yr prospective follow-up. *Med Sci Sports Exerc*. 2013;45:706–713.
12. Williams PT. Effects of running and walking on osteoarthritis and hip replacement risk. *Med Sci Sports Exerc*. January 30, 2013. DOI: 10.1249/MSS.0b013e3182885f26. http://journals.lww.com/acsm-msse/Abstract/publishahead/Effects_of_Running_and_Walking_on_Osteoarthritis.98453.aspx. Accessed April 1, 2013.
13. Williams PT. Advantage of distance- versus time-based estimates of walking in predicting adiposity. *Med Sci Sports Exerc*. 2012;44:1728–1737.
14. Williams PT. Non-exchangeability of running vs. other exercise in their association with adiposity, and its implications for public health recommendations. *PLoS ONE*. 2012;7:e36360
15. Williams PT. Distance walked and run as improved metrics over time-based energy estimation in epidemiological studies and prevention; evidence from medication use. *PLoS ONE*. 2012;7:e41906.
16. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Frequently reported activities by intensity for US adults: the American Time Use Survey. *Am J Prev Med*. 2010;39:e13–e20
17. Williams PT. Reduced diabetic, hypertensive, and cholesterol medication use with walking. *Med Sci Sports Exerc*. 2008;40:433–443.
18. Williams PT, Franklin B. Vigorous exercise and diabetic, hypertensive, and hypercholesterolemia medication use. *Med Sci Sports Exerc*. 2007;39:1933–1941.
19. Williams PT. Vigorous exercise, fitness and incident hypertension, high cholesterol, and diabetes. *Med Sci Sports Exerc*. 2008;40:998–1006.
20. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008*. Washington, DC: US Department of Health and Human Services; 2008.
21. Kelley GA, Sharpe Kelley K. Aerobic exercise and resting blood pressure in older adults: a meta-analytic review of randomized controlled trials. *J Gerontol A Biol Sci Med Sci*. 2001;56:M298–M303.
22. Third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. *Circulation*. 2002;106:3143–421.
23. Durstine JL, Grandjean PW, Davis PG, Ferguson MA, Alderson NL, DuBose KD. Blood lipid and lipoprotein adaptations to exercise: a quantitative analysis. *Sports Med*. 2001;31:1033–1062.
24. Cullinane EM, Sady SP, Vadeboncoeur L, Burke M, Thompson PD. Cardiac size and VO2max do not decrease after short-term exercise cessation. *Med Sci Sports Exerc*. 1986;18:420–424.
25. Kraus WE, Houmard JA, Duscha BD, Knetzger KJ, Wharton MB, McCartney JS, Bales CW, Henes S, Samsa GP, Otvos JD, Kulkarni KR, Slentz CA. Effects of the amount and intensity of exercise on plasma lipoproteins. *N Engl J Med*. 2002;347:1483–1492.
26. Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical activity of moderate intensity and risk of type 2 diabetes: a systematic review. *Diabetes Care*. 2007;30:744–752.
27. Jacobs DR Jr, Ainsworth BE, Hartman TJ, Leon AS. A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Med Sci Sports Exerc*. 1993;25:81–91.

28. Williams PT, Wood PD, Haskell WL, Vranizan K. The effects of running mileage and duration on plasma lipoprotein levels. *JAMA*. 1982;247:2674–2679.
29. Williams PT, Stefanick ML, Vranizan KM, Wood PD. The effects of weight loss by exercise or by dieting on high-density lipoprotein (HDL) levels in men with low, intermediate, and normal-to-high HDL at baseline. *Metabolism*. 1994;43:917–924.
30. Wisløff U, Najjar SM, Ellingsen O, Haram PM, Swoap S, Al-Share Q, Fernström M, Rezaei K, Lee SJ, Koch LG, Britton SL. Cardiovascular risk factors emerge after artificial selection for low aerobic capacity. *Science*. 2005;307:418–420.
31. Leitzmann MF, Giovannucci EL, Rimm EB, Stampfer MJ, Spiegelman D, Wing AL, Willett WC. The relation of physical activity to risk for symptomatic gallstone disease in men. *Ann Intern Med*. 1998;128:417–425.
32. Leitzmann MF, Rimm EB, Willett WC, Spiegelman D, Grodstein F, Stampfer MJ, Colditz GA, Giovannucci E. Recreational physical activity and the risk of cholecystectomy in women. *N Engl J Med*. 1999;341:777–784.

Significance

We used the National Runners' and Walkers' Health Study cohorts to show that equivalent energy expenditures by moderate-intensity exercise (eg, walking) and vigorous-intensity exercise (eg, 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 equivant hours per day, where 1 metabolic equivant 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.