Effects of Running and Walking on Osteoarthritis and Hip Replacement Risk

PAUL T. WILLIAMS

Life Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA

ABSTRACT

WILLIAMS, P. T. Effects of Running and Walking on Osteoarthritis and Hip Replacement Risk. Med. Sci. Sports Exerc., Vol. 45, No. 7, pp. 1292–1297, 2013. Purpose: Running and other strenuous sports activities are purported to increase osteoarthritis (OA) risk, more so than walking and less-strenuous activities. Analyses were therefore performed to test whether running, walking, and other exercise affect OA and hip replacement risk and to assess the role of body mass index (BMI) in mediating these relationships. Methods: In this article, we studied the proportional hazards analyses of patients’ report of having physician-diagnosed OA and hip replacement versus exercise energy expenditure (METs). Results: Of the 74,752 runners, 2004 reported OA and 259 reported hip replacements during the 7.1-yr follow-up; whereas of the 14,625 walkers, 696 reported OA and 114 reported hip replacements during the 5.7-yr follow-up. Compared with running <1.8 MET•h⁻¹, the risks for OA and hip replacement decreased as follows: 1) 18.1% (P = 0.01) and 35.1% (P = 0.03) for the 1.8- and 3.6-MET•h⁻¹ run, respectively; 2) 16.1% (P = 0.03) and 50.4% (P = 0.002) for the 3.6- and 5.4-MET•h⁻¹ run, respectively; and 3) 15.6% (P = 0.02) and 38.5% (P = 0.01) for the ≥5.4-MET•h⁻¹ run, suggesting that the risk reduction mostly occurred by 1.8 MET•h⁻¹. Baseline BMI was strongly associated with both OA (5.0% increase per kilogram per square meter, P = 2 × 10⁻⁴) and hip replacement risks (9.8% increase per kilogram per square meter, P = 4.8 × 10⁻⁴), and adjustment for BMI substantially diminished the risk reduction from running ≥1.8 MET•h⁻¹ for OA (from 16.5%, P = 0.01, to 8.6%, P = 0.21) and hip replacement (from 40.4%, P = 0.005, to 28.5%, P = 0.07). The reductions in OA and hip replacement risk by exceeding 1.8 MET•h⁻¹ did not differ significantly between runners and walkers. Other (nonrunning) exercise increased the risk of OA by 2.4% (P = 0.009) and hip replacement by 5.0% per MET•h⁻¹ (P = 0.02), independent of BMI. Conclusions: Running significantly reduced OA and hip replacement risk due to, in part, running’s association with lower BMI, whereas other exercise increased OA and hip replacement risk.

Key Words: PREVENTION, EXERCISE, EPIDEMIOLOGY, COHORT STUDY

Osteoarthritis (OA) is the leading cause of disability in the aged, affecting between 7% and 25% of Caucasians >55 yr old, and is projected to become the fourth most common medical condition in women (11). There is a common perception that, over the long run, running is injurious to joints (11). Running and vigorous sports activity do, in fact, increase the risk of knee trauma and injuries, which in turn are known risk factors for knee OA (11). Alternatively, running reduces body weight (38,39), a known risk factor for OA (3), which may offset in part its pro-OA effects, resulting in diminished OA risk or even OA protection. Exercise may also promote cartilage thickening (12,13) and prevent the loss cartilage proteoglycans (30,34), which provide cartilage’s viscoelastic properties (22). These effects are important because cartilage thinning (11) and focal loss of proteoglycans (5) are prominent features of OA.

Case–control studies suggest a positive relationship between OA and physical sporting activities in general, and running in particular, with an odds ratio of approximately 2 for both (20). There are prospective studies in humans that claim that exercise increases (2,3,6,16,23,31,32,37), has no significant effect (1,5,9,10,17,27), or decreases the risks for both (20). There are prospective studies in humans that claim that exercise increases (2,3,6,16,23,31,32,37), has no significant effect (1,5,9,10,17,27), or decreases the risks for hip replacement or OA (18,24). There are also animal studies suggesting that exercise increases (14) or decreases OA risk (7,29).

With nearly 90,000 participants, the National Runners’ and Walkers’ Health Studies are the largest prospective cohorts specifically recruited for the study of health benefits and risk of physical activity. Their data provide a unique opportunity to test whether OA and hip replacement risk are 1) increased by running, walking, and other exercise in relation to amount and intensity; 2) increased more for running than walking; and 3) reduced because of the leanness of higher mileage runners and walkers.
METHODS

The current analyses involve data from the follow-up of three cohorts: the first and the second National Runners’ Health Study (NRHS-I and NRHS-II) cohorts and the National Walkers’ Health Study (NWHS) (38–40). NRHS-I was recruited between 1991 and 1994 (primarily 1993), and follow-up questionnaires were obtained between 1999 and 2002 (38,39). Eighty percent of NRHS-I provided follow-up information or were known deceased. The NRHS-II and NWHS were recruited primarily between 1998 and 2001 (40). The 2006 partial resurvey of the NRHS-II and the NWHS (40) were obtained to identify and qualify approximately 50,000 runners and walkers for a proposed clinical trial rather than a prospective follow-up study per se. These represented approximately one-third of the original walker (33.2%) and one-half of the original runner surveyed (51.7%). Questions for ascertaining distance run and walked, body weight and height, and waist circumference and their reproducibility have been previously described (38,39). The study protocols were approved by the University of California Berkeley committee for the protection of human subjects, and all subjects provided a signed statement of informed consent.

Participants reported whether a physician had told them they had OA and if they had a hip replacement since their baseline questionnaire and reported the year of diagnosis or replacement. Diagnoses and replacements dated the same year as the baseline survey or earlier were excluded in order that the end points represented only newly diagnosed incidence of disease. Usual pace (min·mile⁻¹) was reported for walking in walkers and for running in NRHS-II runners. Nonrunning energy expenditures in the runners and non-walking energy expenditures in the walkers were calculated using published tables of METs (40), where 1 MET is the energy expended sitting at rest (3.5 mL O₂·kg⁻¹·min⁻¹). Physical activities that expended 3–6 METs were classified as moderate-intensity exercise, >6 METs as vigorous, and <3 METs as light (40). In walkers, MET-hours per day was calculated as kilometers run between the reported pace. In runners, MET-hour per day was calculated as kilometers run × 1.02 MET·km⁻¹ (40). Statistical analyses (Cox proportional hazard analyses) were performed using JMP (version 5.1; SAS institute, Cary, NC). Hazard ratios (HR) and 95% confidence intervals (95% CI) were reported for the risk of incident OA and hip replacement per MET-hours per day of energy spent running, walking, and other exercise, running performance, race participation, and kilometers per square meter of body mass index (BMI) using covariates identified as being associated with OA or hip replacement risk.

RESULTS

Of the 91,928 subjects (15,945 walkers, 42,923 NRHS-I runners, and 33,060 NRHS-II runners) who were eligible for analyses, we eliminated 1789 for preexisting OA or hip replacement and 762 for unknown dates for their diagnosis, leaving 89,377 subjects (14,625 walkers, 42,443 NRHS-I runners, and 32,309 NRHS-II runners) for analyses. There were 2004 runners (1175 NRHS-I and 829 NRHS-II) who reported being diagnosed by a physician for OA and 259 runners (159 NRHS-I and 100 NRHS-II) who reported receiving a hip replacement during their follow-up (mean ± SD) 7.1 ± 1.8 year follow-up. Walkers reported 696 and 114 diagnoses for OA and hip replacement, respectively, during their 5.7 ± 1.2 yr follow-up. The runners’ and walkers’ baseline characteristics are displayed in Table 1.

Older age was the strongest risk factor, increasing OA risk by 3.9% per year in men (95% CI = 3.3%–4.4%, P < 10⁻¹⁵) and 6.1% in women (95% CI = 5.5%–6.8%, P < 10⁻¹⁵) and hip replacement risk by 7.4% per year in men (95% CI = 6.1%–8.7%, P < 10⁻¹⁵) and 10.6% in women (95% CI = 8.1%–13.0%, P < 10⁻¹⁵). The age-adjusted OA risk was significantly greater for women than men (HR = 1.86; 95% CI = 1.70–2.06, P < 10⁻¹⁵), whereas the risk for hip replacement was not (P = 0.06). The best age-adjustment model for OA included separate intercepts and separate linear and quadratic regression terms for men and women. When adjusted

| TABLE 1. Characteristics (mean ± SD) of runners and walkers by self-reported physician-diagnosed OA.
<table>
<thead>
<tr>
<th>N</th>
<th>Runners</th>
<th>Females</th>
<th>Runners</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident OA (cases)</td>
<td>1141</td>
<td>893</td>
<td>3122</td>
<td>11,503</td>
</tr>
<tr>
<td>Incident hip replacement (cases)</td>
<td>208</td>
<td>51</td>
<td>74</td>
<td>78</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>46.09 ± 10.73</td>
<td>39.89 ± 10.38</td>
<td>61.48 ± 11.15</td>
<td>52.45 ± 11.95</td>
</tr>
<tr>
<td>Education (yr)</td>
<td>16.59 ± 2.46</td>
<td>16.15 ± 2.34</td>
<td>16.33 ± 2.69</td>
<td>15.28 ± 2.53</td>
</tr>
<tr>
<td>Smokers (%)</td>
<td>1.33</td>
<td>1.65</td>
<td>3.40</td>
<td>3.39</td>
</tr>
<tr>
<td>Meat (servings per day)</td>
<td>0.42 ± 0.38</td>
<td>0.26 ± 0.30</td>
<td>0.46 ± 0.41</td>
<td>0.33 ± 0.34</td>
</tr>
<tr>
<td>Fruit (pieces per day)</td>
<td>1.56 ± 1.19</td>
<td>1.58 ± 1.07</td>
<td>1.62 ± 1.23</td>
<td>1.69 ± 1.13</td>
</tr>
<tr>
<td>Alcohol (g·d⁻¹)</td>
<td>10.03 ± 13.93</td>
<td>5.80 ± 8.37</td>
<td>9.15 ± 13.39</td>
<td>4.89 ± 8.98</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>23.91 ± 2.54</td>
<td>21.43 ± 2.42</td>
<td>26.58 ± 4.01</td>
<td>25.30 ± 5.01</td>
</tr>
<tr>
<td>Exercise energy expenditure (MET·h·d⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>5.44 ± 3.24</td>
<td>4.98 ± 3.09</td>
<td>2.20 ± 1.65</td>
<td>2.17 ± 1.64</td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other exercise</td>
<td>2.45 ± 3.64</td>
<td>2.90 ± 3.82</td>
<td>2.14 ± 3.69</td>
<td>1.84 ± 3.25</td>
</tr>
<tr>
<td>Years run or walked</td>
<td>13.20 ± 8.13</td>
<td>9.81 ± 6.76</td>
<td>11.30 ± 10.42</td>
<td>8.30 ± 7.61</td>
</tr>
<tr>
<td>Marathons (no. in 5 yr)</td>
<td>1.95 ± 4.26</td>
<td>1.15 ± 2.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-km performance (m·s⁻¹)</td>
<td>3.89 ± 0.55</td>
<td>3.42 ± 0.53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
for age, neither menstrual status (OA risk: \(P = 0.57\); hip replacement: \(P = 0.95\)) nor estrogen use (OA risk: \(P = 0.76\); hip replacement: \(P = 0.44\)) affected risk, whereas estrogen/progestrone hormone use did for OA (HR = 1.34, 95% CI = 1.08–1.65, \(P = 0.008\)) but not hip replacement (\(P = 0.72\)).

The risk for OA also increased with years of education (HR = 1.03, 95% CI = 1.01–1.04 per year, \(P = 0.007\)) and intake of red meat (HR = 1.17, 95% CI = 1.04–1.33 per serving per day, \(P = 0.01\)), but not fruit (\(P = 0.41\)), alcohol intake (\(P = 0.09\)), or smoking (\(P = 0.62\)). On the basis of these results, the analyses that follow were all adjusted for running cohort (NRHS-I vs NRHS-II), sex, sex-specific age effects (age and age\(^2\)), education, estrogen/progestrone hormone use, and intake of red meat.

**Usual running distance.** Figure 1 displays the reductions in the risks for OA and hip replacement by MET-hour per day run. Compared with running <1.8 MET-h\(^{-1}\), OA risk decreased 18.1% for those between 1.8 and 3.6 MET-h\(^{-1}\) (\(P = 0.01\), 16.1% between 3.6 and 5.4 MET-h\(^{-1}\) (\(P = 0.03\), and 15.6% \(\geq 5.4\) MET-h\(^{-1}\) (\(P = 0.02\)). The corresponding values for hip risk replacement were 35.1% (\(P = 0.03\)), 50.4% (\(P = 0.002\), and 38.5% (\(P = 0.01\), respectively. Most of risk reduction appeared to have occurred by 1.8 MET-h\(^{-1}\) for both OA and hip replacement.

**Marathon and 10-km footrace.** There were 43,672 subjects who never ran a marathon during the previous 5 yr, 24,897 that ran at least one during the previous 5 yr but less than one marathon annually, 4,196 who ran between one and two marathons annually, 1,593 who ran between two and five marathons annually, and 284 who ran more than five marathons annually. Marathon frequency at baseline was unrelated to both OA risk (HR = 1.00, 95% CI = 0.99–1.01 per marathon, \(P = 0.43\)) and hip replacement risk (HR = 0.99, 95% CI = 0.96–1.02 per marathon, \(P = 0.69\)).

Marathon performance during the previous 5 yr was also unrelated to both OA risk (HR = 1.09, 95% CI = 0.95–1.25 per meter per second, \(P = 0.22\)) and hip replacement risk (HR = 1.15, 95% CI = 0.77–1.70 per meter per second, \(P = 0.57\)). Similarly, 10-km race performance times did not affect the risks for OA (HR = 0.91, 95% CI = 0.82–1.01 per meter per second, \(P = 0.08\)) or hip replacement (HR = 0.98, 95% CI = 0.73–1.31 per meter per second, \(P = 0.88\)).

**Running intensity, longest run, and running history.** Baseline usual running speed, longest usual run, and other vigorous and moderate-intensity exercise were only collected for the second runners cohort (\(N = 32,309\)), whose 6.4-yr follow-up included 829 incident OA and 100 hip replacements. In this subset, OA risk was not increased by usual running speed (HR = 0.86, 95% CI = 0.72–1.01 per meter per second, \(P = 0.07\)) or longest usual run (HR = 1.00, 95% CI = 0.98–1.02 per kilometer, \(P = 0.98\)). Similarly, the risk for hip replacement was unrelated to usual running speed (HR = 0.67, 95% CI = 0.43–1.07 per meter per second, \(P = 0.09\)) or longest usual run (HR = 0.99, 95% CI = 0.93–1.04 per kilometer, \(P = 0.63\)). Running history (years run) appears to increase the risk for hip replacement (HR = 1.02, 95% CI = 1.00–1.03 per kilometer, \(P = 0.04\)) but not OA (HR = 1.00, 95% CI = 0.99–1.00 per year, \(P = 0.50\)).

**Other exercise.** For both OA and hip replacement, baseline other (nonrunning) exercise in the runners was associated with their increased risk (OA: HR = 1.02, 95% CI = 1.01–1.04 per MET-hour per day, \(P = 0.009\); hip replacement: HR = 1.05, 95% CI = 1.01–1.08 per MET-hour per day, \(P = 0.02\)). Exercising \(\geq 5.4\) MET-h\(^{-1}\) other than running was associated with a 21% increased risk for incident OA (\(P = 0.05\)) and 99% increased risk for hip replacement (\(P = 0.009\)) as compared with <1.8 MET-h\(^{-1}\) of other exercise (Fig. 2). This association was specific to other vigorous exercise for hip replacement (other vigorous HR = 1.05, 95% CI = 1.01–1.11 per MET-hour per day, \(P = 0.03\);
Running versus walking. Figure 3 shows that most of the walkers’ reduction in OA risk also occurred by 1.8 METs, that is, those that exceeded 1.8 MET·h⁻¹ were at 18.3% lower risk than less active walkers (P = 0.008). They were also at 23.2% lower risk for hip replacement, but for 114 replacements, this did not achieve statistical significance (P = 0.16). Figure 3 compares the risks for incident OA of the runners to those of walkers. Runners who ran less than 1.8 MET·h⁻¹ were at lower risk than walkers who walked less than 1.8 MET·h⁻¹, and this difference in risk appeared to be sustained at all activity levels. The decrease in risk from exceeding 1.8 MET·h⁻¹ was not significantly different for running versus walking for either OA (P = 0.68 for difference) or hip replacement (P = 0.31). Thus, the risk for OA was reduced significantly by exceeding 1.8 MET·h⁻¹ by walking or running, and their effects appeared comparable.

Effects of body weight. On average, the risk for OA increased 5.0% (P = 2 × 10⁻⁸), and hip replacement increased 9.8% (P = 4.8 × 10⁻⁵) per kilogram per square meter increase in BMI. Figure 4 displays the relationship of baseline BMI to incident OA and hip replacement during follow-up. Compared with subjects <22.5 kg·m⁻², OA risk increased 12.1% for those between 22.5 and 25.0 kg·m⁻² (P = 0.04), 37.5% between 25 and 27.5 kg·m⁻² (P = 5 × 10⁻⁶), and 50.4% ≥27.5 kg·m⁻² (P = 4.5 × 10⁻⁵). The corresponding values for hip replacement risk were 44.8% (P = 0.02), 111.8% (P = 3.3 × 10⁻⁵), and 71% (P = 0.05), respectively. Adjustment for BMI diminished the decrease in risk from running ≥1.8 MET·h⁻¹ from 16.5% (P = 0.01) to 8.6% (P = 0.21) for OA, and from 40.4% (P = 0.005) to 28.5% (P = 0.07) for hip replacement, and diminished the decrease in risk from walking ≥1.8 MET·h⁻¹ from 18.3% (P = 0.008) to 10.3% (P = 0.17) for OA. However, adjustment for BMI did not eliminate the effects of other (nonrunning) exercise on OA (adjusted HR = 1.02, 95% CI = 1.00–1.04 per MET-hour per day, P = 0.01) or hip replacement (adjusted HR = 1.05, 95% CI = 1.01–1.08 per MET-hour per day, P = 0.02).

DISCUSSION

The number of runners studied here is larger than any previous study of physical activity and OA and hip replacement and exceeds by more than 10 times the number of runners previously studied in all previous cross-sectional studies combined. Included among these were 863 runners who reported running ≥60 miles·wk⁻¹. Contrary to many previous reports (2,3,6,16,23,31,32,37), we find no evidence that increasing cumulative hours of recreational physical activity are much fewer than those showing a risk increase or no effect. In one, joint space loss was observed in nonrunners but not runners, suggesting that running preserved cartilage thickness (18). In another, knee replacements decreased with increasing cumulative hours of recreational physical activity.

FIGURE 3—Reduction in the risks for incident OA and hip replacement by BMI adjusted for age, sex, education, hormone use in women, and meat intake. Error bars represent 95% CI. Significant levels relative to the least active walkers (the referent group) are coded as follows: *P < 0.05, †P < 0.01, ‡P < 0.001, and §P < 0.001.

FIGURE 4—Increase in the risks for incident OA and hip replacement by BMI adjusted for age, sex, education, hormone use in women, and meat intake. Error bars represent 95% CI. Significant levels relative to the least active walkers (the referent group) are coded as follows: *P < 0.05, †P < 0.01, ‡P < 0.001, and §P < 0.001.
Our data even showed that marathon frequency, marathon intensity, and 10-km intensity did not predict any risk increase for OA or hip replacement, in contrast to the report of Michaelsson et al. (26) that skiers who repeatedly participated in a 90-km ski race increased OA risk in proportion to the number of races run and performance (speed).

The OA-protective effects of running or walking appeared to have already occurred by 1.8 MET·h⁻¹, suggesting the association may be due primarily to increased OA in the least active individuals. Articular cartilage thickness is reduced in animals subject to prolonged immobilization (36). Cartilage is also thinned in the absence of normal joint loading in spinal cord injury patients (35). In children, articular cartilage volume is increased in association with vigorous physical activity and muscle strength cross-sectionally (13), and those who engaged in more intense sport gained more cartilage over time (12). Triathletes have thicker patellae cartilage than inactive subjects, albeit thinner medial femoral condyle cartilage (28). Some (4), but not all (8), studies suggest that physical activity may enlarge the knee joint surface area in adults. Glycosaminoglycans are used in the synthesis of proteoglycans, which provide cartilage’s viscoelastic properties (22). Early OA consists of a focal loss of proteoglycans (5). Running increases the glycosaminoglycan content of human knee cartilage (34). Roos and Dahlberg’s (30) randomized trial showed that exercise produced a healthier distribution of proteoglycans in cartilage vis-à-vis nonexercising control. Animal studies also suggest that the patellar cartilage of sedentary hamsters have a lower proteoglycan content than those that are active (29). Moderate exercise has also been shown to inhibit the development of surgically induced OA in the rat (7). In dogs, however, shifting from moderate to strenuous running eliminated increases in cartilage thickness and proteoglycan content produced with moderate running (14).

Our analyses showed that in contrast to running, other (nonrunning) exercise increased the risks for both OA and hip replacement. This result is consistent with more than twofold greater prevalence of tibiofemoral or patellofemoral OA in soccer players (29%) and weight lifters (31%) than runners (14%) reported by Kujala et al. (15). Research on occupational activity shows that OA is more common in jobs requiring knee bends, kneeling, or squats (25), which may be more characteristic of exercise performed in gyms, circuit training, and aerobic classes than running or walking. Work-related knee bending exposure increases the odds for knee OA by up to sixfold (21).

Our analyses confirmed the well-established association between BMI and incident risk of OA and hip replacement even within the purported healthy weight range, and attributed 45% and 28% of the running associated decrease in OA and hip replacement to BMI, respectively. In addition to promoting weight loss directly (39), running attenuates middle-age weight gain (38), such that higher mileage runners gain only half as much as low mileage runners. The prevention of weight gain is an additional mechanism for limiting risk OA and hip replacement risk. Body weight has a much weaker association with other exercise than with running (40), which may explain in part their different associations with OA and hip replacement, particularly given that adjustment for BMI did not affect the concordance between baseline other exercise and both OA and hip replacement.

There are important limitations to these analyses that warrant acknowledgment. The results are based on self-reported physician-diagnosed OA and hip replacement rather than medical chart review or imaging. However, reviews suggest stronger associations have been reported for clinically assessed hip OA than its radiographic assessment (20). Patient self-report of physician-diagnosed arthritis has been found by others to be the best predictor of radiologically ascertained OA, showing 64% specificity, a 57% positive predictive value, and 71% negative predictive value (33). We do not believe that the declining incidence of OA and hip replacement with greater MET-hour per day walked or run was due to fewer opportunities for diagnosis in the more athletic men. The Health Professional Study reported that their more vigorously active participants had more routine medical checkups than less active men (19). It is possible that there is a higher pain threshold in longer distance runners, but it is unclear why this would not also be true for other exercise as well. It is unclear whether the exclusion of preexisting injury would be warranted in assessing the OA risk in runners, if such injuries were the consequence of the exercise per se. Finally, we acknowledge that the analyses would have benefited from the complete follow-up of NRHS-II and NWHS. Heretofore, we have been unable to secure funding for their follow-up, and there is no evidence that the NRHS-I (80% follow-up) and NRHS-II (51.7% follow-up) show different relationships between MET-hour per day run and the risks for OA ($P = 0.45$ for difference) or hip replacement ($P = 0.89$ for difference). The lower follow-up of the walkers (33.2%) than NRHS-II (51.7) reflected our recruitment priorities rather than differences in the responsiveness of the walkers and runners; however, we do not believe that this affected the comparison of walkers and runners given that comparable results were obtained when the analyses were restricted to the initial 33.2% of the NRHS-II runners recruited.

In conclusion, these results may not apply to truly elite athletes, but for recreational runners who even substantially exceed current guideline activity levels and participate in multiple marathons annually, running does not appear to increase OA and hip replacement risk and may, in fact, be preferable to other exercise.
REFERENCES


