Associations of Changes in Exercise Level With Subsequent Disability Among Seniors: A 16-Year Longitudinal Study

David R. Berk, Helen B. Hubert, and James F. Fries

Department of Medicine, Stanford University School of Medicine, California.

**Background.** The effect of changes in physical exercise on progression of musculoskeletal disability in seniors has rarely been studied.

**Methods.** We studied a prospective cohort annually from 1984 to 2000 using the Health Assessment Questionnaire Disability Index (HAQ-DI). The cohort included 549 participants, 73% men, with average end-of-study age of 74 years. At baseline and at the end of the study, participants were classified as “High” or “Low” vigorous exercisers using a cutoff point of 60 min/wk. Four groups were formed: “Sedentary” (Low→Low; N = 71), “Exercise Increasers” (Low→High; N = 37), “Exercise Decreasers” (High→Low; N = 73), and “Exercisers” (High→High; N = 378). The primary dependent variable was change in HAQ-DI score (scored 0–3) from 1984 to 2000. Multivariate statistical adjustments using analysis of covariance included age, gender, and changes in three risk factors, body mass index, smoking status, and number of comorbid conditions. Participants also prospectively provided reasons for exercise changes.

**Results.** At baseline, Sedentary and Increasers averaged little exercise (16 and 22 exercise min/wk), whereas Exercisers and Decreasers averaged over 10 times more (285 and 212 exercise min/wk; p < .001). All groups had low initial HAQ-DI scores, ranging from 0.03 to 0.08. Increasers and Exercisers achieved the smallest increments in HAQ-DI score (0.17 and 0.11) over 16 years, whereas Decreasers and Sedentary fared more poorly (increments 0.27 and 0.37). Changes in HAQ-DI score for Increasers compared to Sedentary were significantly more favorable (p < .05) even after multivariate statistical adjustment.

**Conclusions.** Inactive participants who increased exercise achieved excellent end-of-study values with increments in disability similar to those participants who were more active throughout. These results suggest a beneficial effect of exercise, even when begun later in life, on postponement of disability.

**PARTICIPANTS AND METHODS**

**Study Sample**

In 1984, participants were recruited from the Fifty-Plus Runner’s Association including predominantly Californians.
We studied 549 participants followed from 1984 to 2000 (completers), including 355 runners and 214 controls. Individuals were classified as “High” or “Low” exercisers at baseline and at end of study according to whether they averaged more than 60 min/wk of vigorous exercise in 1984–1986 and 1998–2000; 3-year periods were used to reduce year-to-year variability. Four groups were formed based on exercise during these two periods: “Sedentary” (Low→Low; N = 71); ≤60 exercise min/wk during both periods; “Exercise Increasers” (Low→High; N = 27); ≤60 exercise min/wk at baseline, but ≥60 min/wk at end of study; “Exercise Decreasers” (High→Low; N = 73); >60 exercise min/wk at baseline, but ≤60 min/wk at end of study; and “Exercisers” (High→High; N = 378); >60 exercise min/wk during both periods.

Of the remaining 412 participants who discontinued participation, 106 died and 306 represented attrition. Overall attrition rates were only 2% per year. Dropout rates were similar among baseline Low and High exercisers. However, baseline Low exercisers were more likely than were High exercisers to die during follow-up (1.3% vs 0.5% annually, p < .001). For both groups, those participants who died or dropped out were significantly older than those who were completers, and had higher baseline disability. Among baseline Low exercisers, those who died or dropped out had more comorbid conditions (0.25 vs 0.05 for completers, p < .01). However, there were no significant differences between withdrawals and completers in baseline exercise minutes for either group.

**Statistical Analysis**

Differences between those participants who remained in their exercise group and those who changed were tested using analysis of variance to contrast variable means and Kruskal–Wallis chi-square tests to compare proportions. Adjusted change in HAQ-DI score was estimated using analysis of covariance controlling for age, gender, changes in BMI and smoking status (yes/no) from 1984 to 2000, and change in number of comorbid conditions from 1989 to 2000. Comorbid conditions that were considered include cardiovascular conditions, pulmonary conditions, cancer, gastrointestinal conditions, diabetes, neurologic conditions, musculoskeletal conditions, and other. Not all factors thought to influence disability, such as cognitive function, could be included in our analysis due to lack of data in early study years. Other possible covariables such as dietary factors were also not included for the same reasons. Interaction terms were not tested due to small numbers in several groups. Statistical significance was considered (p < .05) using a two-tailed test.

**Results**

Table 1 describes participants at baseline and end of study. Compared to Sedentary, Increasers were more likely to be men and to be slightly more educated. Compared to Exercisers, Decreasers were more likely to be women, smokers, slightly older, and have a higher BMI. Comorbidity data were similar at baseline across groups. However, by 2000, Decreasers averaged more comorbid conditions than Exercisers (1.4 vs 1.1, p < .05). Decreasers compared to Exercisers, and Sedentary compared to Increasers more often had arthritic, neurological, and cardiovascular comorbidities. The Sedentary cohort had the most pulmonary comorbidities.

At baseline, Sedentary and Increasers (the original sedentary groups) averaged well below the 60 exercise min/wk cutoff (16 and 22 min/wk), whereas Exercisers and Decreasers (the original exercising groups) averaged well above this cutoff (285 and 212 min/wk). The baseline difference between Exercisers and Decreasers, however, was significant (p < .001). At end of study, exercise minutes were 22 for Sedentary compared to 134 for Increasers (p < .01), and 261 for Exercisers compared to 24 for Decreasers (p < .001).

By end of study, Decreasers increased BMI more than did Exercisers (1.6 vs 1.1, p < .05; Table 2). The percentage of smokers remained low. The increase in number of comorbidities ranged from 1.0 to 1.4 and showed no statistically significant difference between Decreasers and Exercisers.
Table 1. Participant Characteristics at Baseline and End of Study

<table>
<thead>
<tr>
<th>Participant Characteristics</th>
<th>Exercise Groups</th>
<th>Sedentary</th>
<th>Increasers</th>
<th>Decreasers</th>
<th>Exercisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, 1984, y</td>
<td>Low→Low (N = 71)</td>
<td>59.8 (0.7)</td>
<td>59.6 (1.1)</td>
<td>59.2 (0.8)</td>
<td>57.5 (0.3)*</td>
</tr>
<tr>
<td>Mean age, 2000, y</td>
<td>Low→High (N = 27)</td>
<td>76.5 (0.6)</td>
<td>75.5 (1.1)</td>
<td>75.2 (0.8)</td>
<td>73.4 (0.3)*</td>
</tr>
<tr>
<td>BMI, 1984, mean kg/m²</td>
<td>High→Low (N = 73)</td>
<td>49.3</td>
<td>85.2 2</td>
<td>63.0</td>
<td>78.0 2</td>
</tr>
<tr>
<td>BMI, 2000, mean kg/m²</td>
<td>High→High (N = 378)</td>
<td>15.9 (0.3)</td>
<td>17.0 (0.4)*</td>
<td>16.5 (0.3)</td>
<td>16.8 (0.1)</td>
</tr>
<tr>
<td>Exercise min/wk, 1984</td>
<td>1984, mean</td>
<td>15.9 (4.3)</td>
<td>21.5 (7.0)</td>
<td>212.2 (19.5)</td>
<td>285.2 (9.4)</td>
</tr>
<tr>
<td>Exercise min/wk, 1984</td>
<td>median</td>
<td>0.0</td>
<td>0.0</td>
<td>160.0</td>
<td>240.0</td>
</tr>
<tr>
<td>Exercise min/wk, 2000, mean</td>
<td>2000, median</td>
<td>21.5 (4.3)</td>
<td>133.5 (17.5)</td>
<td>24.2 (4.5)</td>
<td>261.1 (10.7)</td>
</tr>
<tr>
<td>BMI, 1984, mean kg/m²</td>
<td>2000, median</td>
<td>24.4 (0.4)</td>
<td>24.9 (0.4)</td>
<td>23.8 (0.4)</td>
<td>22.9 (0.1)*</td>
</tr>
<tr>
<td>BMI, 2000, mean kg/m²</td>
<td>2000, median</td>
<td>25.2 (0.5)</td>
<td>25.4 (0.5)</td>
<td>25.5 (0.6)</td>
<td>24.0 (0.1)</td>
</tr>
<tr>
<td>% Smokers, 1984</td>
<td>1984, mean</td>
<td>12.7</td>
<td>7.4</td>
<td>12.3</td>
<td>11.0</td>
</tr>
<tr>
<td>% Smokers, 2000</td>
<td>2000, mean</td>
<td>7.0</td>
<td>0.0</td>
<td>4.1</td>
<td>1.6</td>
</tr>
<tr>
<td>No. of comorbid conditions</td>
<td>1989, mean</td>
<td>0.06 (0.03)</td>
<td>0.00 (0.00)</td>
<td>0.08 (0.03)</td>
<td>0.06 (0.01)</td>
</tr>
<tr>
<td>No. of comorbid conditions</td>
<td>2000, mean</td>
<td>1.5 (0.1)</td>
<td>1.2 (0.2)</td>
<td>1.4 (0.1)</td>
<td>1.1 (0.1)*</td>
</tr>
</tbody>
</table>

Note: Standard errors are shown in parentheses. Values of p used for testing differences between Sedentary versus Increasers and Exercisers versus Decreasers:

* p < .05
2 p < .01
3 p < .001

BMI = body mass index.

The Sedentary group maintained exercise between 16 and 23 min/wk during the baseline (1984–1986) and final (1998–2000) periods (Figure 1). Exercisers maintained exercise between 233 and 327 minutes throughout, whereas the exercise minutes of the Decreasers declined more than 8-fold.

Activity change data indicated that among Decreasers, 75% of swimmers and 64% of runners diminished levels of their specific exercise. Lack of time and/or interest and joint pain were the most common reasons for declining activity among Decreasers. Orthopedic problems and injuries were more frequently reasons for decreasing running or walking than for decreasing swimming or cycling. Runners also were most likely to change forms of exercise (20% did so).

Increasers most frequently increased walking and cycling. One third of those who initially cycled and 29% of those who initially walked increased their exercise, whereas only 15% of runners in this group increased their overall exercise min/wk. Doctors’ recommendations and personal desires for better fitness most often motivated Increasers’ positive change in exercise. Activities that Increasers most often started were aerobics (19%), cycling (19%), and weight lifting (11%). No Increasers started running.

Table 3 indicates that all groups averaged low HAQ-DI scores in 1984, ranging from 0.03 to 0.08 disability units on the 0–3 scale, well below a score of 0.125 that reflects some difficulty in 1 of 8 domains of function evaluated by the HAQ-DI. However, the baseline HAQ-DI score in Decreasers already was significantly higher than in Exercisers (0.08 vs 0.03). Sedentary recorded the greatest change and poorest end-of-study HAQ-DI scores, increasing 0.37 disability units to 0.42, equivalent to more than some difficulty in 3 domains of daily function or inability to perform 1 domain evaluated by the HAQ-DI. Decreasers showed poor end-of-study scores, increasing 0.28 to 0.36 units. Increasers achieved very good end-of-study scores, increasing only 0.17 to 0.20 units. Exercisers demonstrated the least change and the best end-of-study scores, increasing 0.11 to 0.14 units. Disability for Decreasers approaches that for Sedentary over time, whereas disability levels of Exercisers and Increasers remained relatively low through-
Table 3. HAQ-DI Score (Standard Error) at Baseline, End of Study, and Change Over Time

<table>
<thead>
<tr>
<th>Exercise Groups</th>
<th>Sedentary</th>
<th>Increasers</th>
<th>Decreasers</th>
<th>Exercisers</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAQ-DI Score</td>
<td>Low→Low</td>
<td>Low→High</td>
<td>High→Low</td>
<td>High→High</td>
</tr>
<tr>
<td>Disability, 1984</td>
<td>0.05 (0.01)</td>
<td>0.03 (0.01)</td>
<td>0.08 (0.02)</td>
<td>0.03 (0.00)†</td>
</tr>
<tr>
<td>Disability, 2000</td>
<td>0.42 (0.07)</td>
<td>0.20 (0.07)†</td>
<td>0.36 (0.06)</td>
<td>0.14 (0.02)‡</td>
</tr>
<tr>
<td>Change in disability, 1984–2000</td>
<td>0.37 (0.06)</td>
<td>0.17 (0.07)*</td>
<td>0.27 (0.05)</td>
<td>0.11 (0.01)†</td>
</tr>
<tr>
<td>Change in disability, 1984–2000, adjusteda</td>
<td>0.29 (0.06)</td>
<td>0.12 (0.08)*</td>
<td>0.20 (0.06)</td>
<td>0.12 (0.06)y</td>
</tr>
</tbody>
</table>

Note: aAdjusted for age and gender in 1984, change in body mass index and change in smoking status (yes/no) from 1984 through 2000, and change in number of comorbid conditions from 1989 through 2000. Values of p for testing differences between Sedentary versus Increasers and Exercisers versus Decreasers:

- *p < .05.
- †p < .01.
- ‡p < .001.
- §p = .06.

out (Figure 2). Final disability scores were more associated with the current than with the initial exercise group. The HAQ-DI score change from 1984 to 2000 differed significantly between groups, with Sedentary worse than Increasers and Exercisers better than Decreasers. Differences between groups regarding the HAQ-DI score change from 1984 to 2000, our main outcome measure, persisted after adjustments for age, gender, and changes in three risk factors, BMI, smoking status, and number of comorbidities. In fact, adjusted change in HAQ-DI score was the same for Increasers and Exercisers.

**DISCUSSION**

Because those persons older than 65 years compose the fastest growing segment of the population in many nations (24), methods to maximize disability-free life now have critical medical, social, and economic importance (1,25). Despite medical advances, primary prevention and health risk reduction will remain important approaches to health improvement, especially with increasingly sedentary, overweight populations (26–29).

This longitudinal study supports the thesis that exercising at high levels, even late in life, delays disability development. Additionally, the results examining effects of exercise change suggest that increasing exercise in seniors may still have important health effects. Individuals with high exercise levels throughout our study period (Exercisers, High→High) had the smallest adjusted increase in disability, consistent with a beneficial effect of exercise. Those participants with little exercise throughout our study period (Sedentary, Low→Low) had the greatest adjusted increase in disability, consistent with a negative effect of more sedentary lifestyles.

This analysis focused on those individuals who initially self-selected for inactivity, but later increased exercise. These Increasers had little progression of disability, similar to Exercisers who initially self-selected for exercise and exercised at high levels throughout (Exercisers, High→High). Despite the small number of Increasers, comparisons with Sedentary were statistically significant in both unadjusted and adjusted analyses. These findings are consistent with a beneficial effect of vigorous exercise on disability development, even when exercise starts later in life. Through 74 years of age, continuation or increase in vigorous activity from a sedentary level appears beneficial.

Although this analysis focused on those individuals who increased exercise (Increasers, Low→High), it is interesting to explore why individuals who decreased exercise (Decreasers, High→Low) had poor outcomes. Decreasers had progression of disability almost as rapid as individuals who were Sedentary throughout. Either disability developed because exercise was discontinued, or some individuals developed comorbid conditions that caused the exercise decrease; the latter seems likely considering the higher level of arthritic, neurological, and cardiovascular comorbidities among Decreasers and their reported reasons for exercise reduction. When change in number of comorbid conditions was included in adjustments, the difference in change in disability between Exercisers and Decreasers reached borderline significance (p = .056), suggesting that the development of comorbid conditions explained part but not all of the difference in disability progression between the two groups.

There are limitations to all observational studies. Although analyses were adjusted for BMI and smoking status changes, Increasers and Decreasers may have changed in other ways that were not ascertained. Although our approach was designed to diminish self-selection bias, it is impossible to eliminate all such bias in nonrandomized studies given that, in this case, groups were categorized by self-selected changes in exercise. These analyses did not
capture individuals who attempted but could not maintain increases in exercise. Accordingly, we considered covariates differing between groups, including age, gender, and change in BMI, smoking status, and number of comorbidities. Validation studies in runners and nonrunners found no evidence to suggest reporting biases in such data (21).

Although our cohort is a selective group that is socio-economically homogeneous and not representative of most elderly populations, it may provide advantages for examining health outcomes in relation to lifestyle modifications such as exercise. A generally healthy, well-educated, highly selected population may allow us to more easily isolate the impact of other risk factors such as exercise without the confounding effects of other factors such as socioeconomic status.

Moreover, there may be biases that could result in underestimation of the magnitude of intergroup differences. For example, baseline Low exercisers more frequently died during follow-up than did baseline High exercisers. Many deaths were undoubtedly among individuals who had greater changes in disability prior to death. Their exclusion would cause underestimation of accrued disability in Sedentary individuals. Additionally, not all factors known to influence disability, such as cognitive function, could be included in adjustments due to incomplete available data.

The loss of participants who were not known to have died also may introduce bias, although we feel that our attrition rate is small for a study of its duration (overall attrition rate = 2% annually). Within both baseline High and Low exercise groups, later withdrawals had higher baseline disability but equivalent exercise levels compared to ongoing participants.

By identifying reasons for activity changes, these results may help target efforts at exercise enhancement. Cycling and aerobics were most frequently initiated. Cycling and walking were most frequently increased. Runners were most likely to change types of exercise. Thus, efforts to promote starting, increasing, or maintaining vigorous exercise among seniors might be most successful when emphasizing walking, cycling, or aerobics.

Although most studies of older adults have used cross-sectional (not longitudinal) designs (30–34), poor health, fear of injury, and perceived decreased activity needs have been cited as principal barriers to exercise (30,32). Environmental factors (access to facilities, weather, lack of exercise companion) and program-based factors (inconvenience, expense, lack of time and/or interest) have been less frequently reported (30,32). Seniors’ reasons for maintaining or increasing activity include their desire for better health and doctors’ recommendations (30,34). Prospective studies examining what motivates seniors’ activity changes are limited, but suggest similar interpretations (34).

Orthopedic problems and lack of time and/or interest were the most common reasons for exercise declines in this study, suggesting that injury prevention may promote exercise maintenance. Few seniors who decreased vigorous exercise reported changing their type of exercise. The poor outcomes of decreasing exercise suggest the importance of sustainable exercise forms, even after comorbidity and chronic illness. For example, cycling and swimming represent low impact alternatives for runners with joint difficulties. Weight training allows individuals to focus on uninvolved muscles after injuries develop. Isometric exercise isolates muscle groups and allows exercise without movement. Indeed, exercise for elderly individuals with joint disease or injuries is clearly beneficial (35).

Reports of loss of time or interest are greater here than in other studies (30–33), but suggest that exercise should be made more interesting and of greater priority for seniors. For example, a stationary bicycle by the television may make exercise interesting. Exercise clubs or neighborhood walking groups can maintain seniors’ interest with social components.

Doctors’ recommendations to maintain or improve health most often motivated increases in exercise. However, young adults more frequently exercise to improve physical appearance (36). Given more medical visits in seniors, physicians have more opportunity to educate and motivate (33). Improving Medicare reimbursement for visits for exercise promotion would encourage more active roles for physicians (37).

Our data suggest that increasing vigorous exercise decreases disability progression. More sophisticated analyses of time order issues (individual exercise change before or after disability) is beyond the scope of this report, and could help clarify interpretation of associations described. These findings strongly suggest, however, that addressing modifiable health risks even late in life may promote healthier aging.

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Address correspondence to James F. Fries, MD, Professor of Medicine, Immunology and Rheumatology, 1000 Welch Rd. #203, Stanford, CA 94305-5755. E-mail: jff@stanford.edu

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