



## Physical Activity Reduces the Risk of Subsequent Depression for Older Adults

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Previous studies assessing protective effects of physical activity on depression have had conflicting results; one recent study argued that excluding disabled subjects attenuated any observed effects. The authors' objective was to compare the effects of higher levels of physical activity on prevalent and incident depression with and without exclusion of disabled subjects. Participants were 1,947 community-dwelling adults from the Alameda County Study aged 50–94 years at baseline in 1994 with 5 years of follow-up. Depression was measured using criteria from the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (Washington, DC: American Psychiatric Association, 1994). Physical activity was measured with an eight-point scale; odds ratios are based upon a one-point increase on the scale. Even with adjustments for age, sex, ethnicity, financial strain, chronic conditions, disability, body mass index, alcohol consumption, smoking, and social relations, greater physical activity was protective for both prevalent depression (adjusted odds ratio (OR) = 0.90, 95% confidence interval (CI): 0.79, 1.01) and incident depression (adjusted OR = 0.83, 95% CI: 0.73, 0.96) over 5 years. Exclusion of disabled subjects did not attenuate the incidence results (adjusted OR = 0.79, 95% CI: 0.67, 0.92). Findings support the protective effects of physical activity on depression for older adults and argue against excluding disabled subjects from similar studies. *Am J Epidemiol* 2002;156:328–34.

aged; disabled persons; exercise; mental health; prospective studies

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

Associated with both morbidity and mortality, depression is a major public health problem throughout the world and is characterized by lowered mood, loss of capacity to experience pleasure, increased sense of worthlessness, fatigue, and preoccupation with death and suicide (1–7).

Increased levels of physical activity are known to reduce morbidity and mortality (8–10), but the impact on depression is not clear. Three community-based longitudinal studies concluded that physical activity was not protective for subsequent depression (11–13). However, two of these (11, 12) studied only middle-aged males. Although the third study (13) did include both men and women as well as older subjects, physical activity was defined as exercise during sports, which would fail to capture other activities such as walking or jogging that are normally included in assessments of physical activity. One of these studies (12) also involved only 47 subjects. Three large, community-based studies did

report a protective effect. One (14) was limited to male college students, but the other two included a very broad age range as well as both men and women (15, 16). One of these reported a longitudinal protective effect of physical activity on depression for both men and women (15), while the other (16) reported an effect only for women.

Citing such inconsistent results, a recent longitudinal analysis of older subjects based on data from the Rancho Bernardo Study argued that these longitudinal studies erred by failing to exclude physically disabled subjects at baseline (17). Physical disability represents a potentially powerful confounding variable because it is associated with both a higher risk of depression and lower levels of physical activity. In the Rancho Bernardo analyses, with physically disabled subjects (6.7 percent of the initial sample) removed, there were no statistically significant longitudinal effects of

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## APPENDIX

### Estimating the Amount of Biologic Synergism between Two Causes

Let us assume that there are two risk factors for schizophrenia,  $E$  and  $G$ . *Risk* is a measure of the proportion of persons who develop schizophrenia. If there are two risk factors,  $G$  and  $E$ , there are four possible exposure states according to whether each factor is present (+) or absent (-), and each of these four exposure states carries a specific risk. Thus, the risk of schizophrenia in the population exposed to  $E$  only is  $R(E)$ , and the risk in the population exposed to  $G$  only is  $R(G)$ . The risk of schizophrenia in the population exposed to neither  $E$  nor  $G$  is  $R$ , whereas the risk in the population exposed to both  $G$  and  $E$  is  $R(GE)$ . On the additive scale, the effect of a risk factor is expressed as a *risk difference*. For example, if  $R(G)$  is 0.25 and  $R$  is 0.10, the effect of  $G$  is  $0.25 - 0.10 = 0.15$ . We can thus express the effect of  $G$  as  $R(G) - R$ , the effect associated with  $E$  as  $R(E) - R$ , and the effect associated with the  $GE$  exposure as  $R(GE) - R$ . The

following table shows the effects associated with the four different exposure states:

|      | $G-$       | $G+$        |
|------|------------|-------------|
| $E-$ | $R$        | $R(G) - R$  |
| $E+$ | $R(E) - R$ | $R(GE) - R$ |

Because the combined effect of  $G$  and  $E$  is  $R(GE) - R$ , the excess of this effect over the sum of the solitary effects of  $G$  and  $E$  is as follows:  $[R(GE) - R] - [R(G) - R] - [R(E) - R] = [R(GE) - R(G) - R(E) + R]$ .

If  $[R(GE) - R(G) - R(E) + R] > 0$ ,  $G$  and  $E$  are said to interact on the additive scale. We will hereafter refer to  $[R(GE) - R(G) - R(E) + R]$  as the statistical additive interaction.

How can we quantify the extent to which  $G$  and  $E$  act synergistically, that is, in some way depend on each other, or coparticipate, in disease causation? Let us consider the proportion of persons in the population who developed schizophrenia after exposure to both  $G$  and  $E$ , or  $R(GE)$ . It is possible that some of these persons would also have contracted the disorder after exposure to either  $G$  or  $E$  alone. The degree to which some persons would also have contracted the disorder after exposure to either  $G$  or  $E$  alone is referred to as the degree of *parallelism*. If there is parallelism,  $G$  and  $E$  "compete" to cause schizophrenia, and, the more they compete, the smaller the proportion of persons who contracted the disease because of the *coparticipation* of  $G$  and  $E$ . Thus, parallelism can be thought of as the opposite of synergism. For example, in the extreme case of 100 percent parallelism, where all persons exposed to  $G$  and  $E$  had developed the disease because of the causal action of either  $G$  or  $E$  alone, no person could have contracted schizophrenia because of the coparticipation of  $G$  and  $E$ . In this case, the amount of synergism would be zero. In practice, it is impossible to assess the amount of parallelism and the amount of synergy in persons exposed to both  $G$  and  $E$ . However, it can be shown that the amount by which synergism exceeds parallelism equals the excess of  $R(GE)$  over the sum of the solitary effects of  $G$  and  $E$  (i.e., the statistical additive interaction as shown above) (33). In other words,  $|\text{synergism}| - |\text{parallelism}| = [R(GE) - R(G) - R(E) + R]$ .

The amount of synergy can then be approximated by using the following table (33):

|                      |                        |                |
|----------------------|------------------------|----------------|
| $ \text{synergism} $ | $ x2 $                 | $R(GE) - R(G)$ |
| $ x1 $               | $ \text{parallelism} $ | $R(G) - R$     |
| $R(GE) - R(E)$       | $R(E) - R$             |                |

The variables  $x1$  and  $x2$  are two unknowns that sum with synergism and parallelism to  $[R(GE) - R(E)]$  and  $[R(E) - R]$ , respectively. In our study, the risks were  $R = 0.08$  percent;  $R(G) = 12$  percent,  $R(E) = 2.2$  percent; and  $R(GE) = 67$  percent. Filling in these risks in the table above reveals that synergism is 79-82 percent.

physical activity on depression (measured as depressed mood).

Results from intervention trials involving physical activity and depression have been equally inconsistent; a recent meta-analysis concluded that the reviewed results were contradictory and had serious methodological difficulties such as lack of concealment for treatment allocation, blinding of results, and intention-to-treat analyses (18).

The analyses reported here attempt to clarify the relation between physical activity and depression by utilizing a broad-based community sample that included both men and women over a wide age range. Follow-up was for 5 years, and likely confounders were included in statistical models. Both cross-sectional and longitudinal associations were examined, and longitudinal analyses were made with and without exclusion of physically disabled subjects at baseline.

## MATERIALS AND METHODS

### Study population

Subjects were members of the Alameda County Study, a longitudinal study of health and mortality that has followed a cohort of 6,928 adults since 1965 (19). The most recent follow-up was held in 1999. Alameda County is located on the east side of San Francisco Bay and includes the cities of Oakland and Berkeley, California. Initial selection in 1965 was by means of a random household sample stratified on census tract median income; at the time, the county was representative of the population of the United States in terms of age and ethnicity. Between 1965 and 1999, 3,077 subjects died and 1,728 were lost to follow-up because they could not be located, were too sick to participate, or refused to continue. The 2,123 subjects still enrolled as of 1999, all of whom had also completed the 1994 questionnaire, remain representative of the older community-dwelling population of the United States in terms of age, sex, chronic conditions, and ethnicity.

Of the 2,123 subjects in the initial sample frame, 2,061 were age 50 years or older in 1994; of these, 114 were missing responses on one or more of the variables in the analyses reported here and so were excluded. The mean age of the remaining 1,947 in 1994 was 63 years; 56 percent were female. Ethnicity was 84 percent White, 7 percent African American, 4 percent Asian, 3 percent Hispanic, and 2 percent other groups.

### Measures

Except for the inclusion of 1999 depression, all measures reflect 1994 values.

**Physical activity.** We constructed a physical activity scale based on four questions: usual frequency of physical exercise, taking part in active sports, taking long walks, and swimming. The response set for each item was never, sometimes, or often; scoring was zero, one, or two, respectively. The resulting scale had a range of 0–8 with a mean of 3.4; reliability (standardized Cronbach's alpha) was 0.64. This scale has been used in previous analyses to demonstrate a protective effect for physical activity on all-cause and

cardiovascular mortality for both men and women (20, 21) and as a 5-year predictor of successful aging (22).

**Depression.** The measure of depression was a set of 12 items that operationalized the diagnostic criteria for a major depressive episode outlined in *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (23)*. Designated the DSM-12D, the items or symptom queries were adapted from the PRIME-MD mood disorders section of the *Manual*. Cases of major depressive episode were subjects who had experienced five or more symptoms of depression almost every day for the previous 2 weeks, including disturbed mood or anhedonia. There were 145 cases of depression in 1994, for a prevalence of 7.4 percent. This number is within the range of results reported in other community studies of older persons for major depression but is probably lower than that which would have been obtained with symptom scales specifically designed to capture those older persons with significant depressive symptoms who do not otherwise meet diagnostic criteria for major depression (24–27). Incident cases in 1999 totaled 98 (5.4 percent) among the 1,802 subjects who were not scored as depressed in 1994.

**Disability.** Four variables common to many data sets were used to assess disability: walking a quarter mile (0.4 km); walking up 10 stairs without resting; getting up from a stooping, kneeling, or crouching position; and standing up after sitting in a chair (28–30). Those who reported having a lot of difficulty or needing help to do any of the four items were scored as disabled.

**Covariates.** Covariates included demographic variables, financial problems, neighborhood problems, chronic conditions, health behaviors, and social relations. Each factor can be categorized as a status attribute, a psychosocial resource, or a stressor and has been shown to predict depression in Alameda County Study analyses and elsewhere (31–34). Demographic variables included age (50–69, 70–79, and  $\geq 80$  years), sex, ethnicity (White vs. other), and education ( $< 12$  years vs.  $\geq 12$  years of education). Financial problems included any one of the following: not having enough money in the previous 12 months to buy clothing, fill a prescription, see a doctor, pay rent or mortgage, or (in the previous 30 days) buy food. Neighborhood problems included responding that any of the following conditions constituted a very serious problem: crime, traffic, noise, trash and litter, night lighting, and availability of public transportation. Chronic conditions included the prevalence in the previous 12 months of arthritis, asthma, bronchitis, diabetes, emphysema, heart disease, and high blood pressure. These were collapsed into three variables of zero, one, or two or more conditions. Health behaviors included cigarette smoking (current, former, never), alcohol consumption (0, 1–60, and  $> 60$  drinks per month), and body mass index (BMI) (weight (kg)/height (m)<sup>2</sup>), which was used to divide subjects into three categories: underweight (BMI,  $< 18.5$ ), normal/overweight (BMI, 18.5– $< 30$ ), and obese (BMI,  $\geq 30$ ) using recent guidelines from the National Heart, Lung, and Blood Institute (35). Social relations included fewer than three close friends versus three or more, fewer than three close relatives versus three or more, and being somewhat or not satisfied with

**TABLE 1. Depression by study risk factors among 1,947 men and women, Alameda County Study, California, 1994–1999**

| Risk factor                    | No.   | %    | Prevalent 1994 depression |      |            | Incident 1999 depression |      |            |
|--------------------------------|-------|------|---------------------------|------|------------|--------------------------|------|------------|
|                                |       |      | %                         | OR*  | 95% CI*    | %                        | OR   | 95% CI     |
| <b>Physical activity scale</b> |       |      |                           |      |            |                          |      |            |
| Low (0–2)                      | 662   | 34.0 | 11.5                      | 4.21 | 2.08, 8.52 | 7.7                      | 4.94 | 1.95, 12.5 |
| Medium (3–5)                   | 984   | 50.5 | 6.1                       | 2.11 | 1.03, 4.30 | 4.3                      | 2.64 | 1.04, 6.73 |
| High (6–8)                     | 301   | 15.5 | 3.0                       | 1.00 |            | 1.7                      | 1.00 |            |
| <b>Physically disabled</b>     |       |      |                           |      |            |                          |      |            |
| Yes                            | 190   | 9.8  | 20.5                      | 4.02 | 2.69, 6.02 | 12.6                     | 3.29 | 2.02, 5.35 |
| No                             | 1,757 | 90.2 | 6.0                       | 1.00 |            | 4.2                      | 1.00 |            |
| <b>Age (years)</b>             |       |      |                           |      |            |                          |      |            |
| ≥80                            | 113   | 5.8  | 8.9                       | 1.28 | 0.65, 2.52 | 4.4                      | 1.03 | 0.40, 2.61 |
| 70–79                          | 420   | 21.6 | 8.3                       | 1.20 | 0.80, 1.78 | 7.6                      | 1.83 | 1.18, 2.85 |
| 50–69                          | 1,414 | 72.6 | 7.1                       | 1.00 |            | 4.3                      | 1.00 |            |
| <b>Gender</b>                  |       |      |                           |      |            |                          |      |            |
| Female                         | 1,089 | 55.9 | 8.6                       | 1.50 | 1.05, 2.13 | 6.1                      | 1.67 | 1.08, 2.57 |
| Male                           | 858   | 44.1 | 5.9                       | 1.00 |            | 3.7                      | 1.00 |            |
| <b>Ethnicity</b>               |       |      |                           |      |            |                          |      |            |
| White                          | 1,645 | 84.5 | 7.2                       | 0.79 | 0.51, 1.22 | 4.8                      | 0.75 | 0.45, 1.26 |
| Others                         | 302   | 15.5 | 8.9                       | 1.00 |            | 6.3                      | 1.00 |            |
| <b>Education (years)</b>       |       |      |                           |      |            |                          |      |            |
| <12                            | 242   | 12.4 | 13.6                      | 2.25 | 1.48, 3.40 | 8.7                      | 2.01 | 1.22, 3.32 |
| ≥12                            | 1,705 | 87.6 | 6.6                       | 1.00 |            | 4.5                      | 1.00 |            |
| <b>Financial strain</b>        |       |      |                           |      |            |                          |      |            |
| Yes                            | 317   | 16.3 | 18.0                      | 3.84 | 2.69, 5.50 | 9.5                      | 2.40 | 1.54, 3.76 |
| No                             | 1,630 | 83.7 | 5.4                       | 1.00 |            | 4.2                      | 1.00 |            |
| <b>Neighborhood problems</b>   |       |      |                           |      |            |                          |      |            |
| Yes                            | 210   | 10.8 | 16.7                      | 2.96 | 1.96, 4.46 | 6.7                      | 1.41 | 0.78, 2.52 |
| No                             | 1,737 | 89.2 | 6.3                       | 1.00 |            | 4.8                      | 1.00 |            |

Table continues

friendships and relations with others versus being very satisfied.

#### Data analyses

The relation between each independent variable used in the analyses and both prevalent and incident depression was first examined for all 1,947 subjects using percentages and unadjusted odds ratios. To test the physical activity scale for linearity, we plotted the log odds of depression against the physical activity scale (data not shown); results

did not depart substantially from linearity, so physical activity was used as a linear scale in subsequent analyses.

Four sequential logistic models were then used to analyze associations between physical activity and depression. The first model included only physical activity along with age, sex, and ethnicity. The second model added education, financial problems, and neighborhood problems as covariates. The third model added disability, chronic conditions, and health behaviors, while the fourth added the social relation variables.

Three sets of analyses were conducted by using the sequential models. In the cross-sectional analyses, 1994

TABLE 1. Continued

| Risk factor                        | No.   | %    | Prevalent 1994 depression |      |            | Incident 1999 depression |      |            |
|------------------------------------|-------|------|---------------------------|------|------------|--------------------------|------|------------|
|                                    |       |      | %                         | OR*  | 95% CI*    | %                        | OR   | 95% CI     |
| Chronic conditions                 |       |      |                           |      |            |                          |      |            |
| ≥2                                 | 388   | 19.9 | 14.7                      | 3.78 | 2.47, 5.77 | 6.4                      | 2.19 | 1.26, 3.80 |
| 1                                  | 642   | 33.0 | 7.5                       | 1.77 | 1.15, 2.73 | 7.0                      | 2.39 | 1.48, 3.88 |
| 0                                  | 917   | 47.1 | 4.4                       | 1.00 |            | 3.1                      | 1.00 |            |
| Body mass index                    |       |      |                           |      |            |                          |      |            |
| Obese (BMI,* ≥30)                  | 333   | 17.1 | 12.6                      | 2.12 | 1.45, 3.10 | 7.8                      | 1.86 | 1.17, 2.97 |
| Underweight (BMI, <18)             | 30    | 1.5  | 6.7                       | 1.05 | 0.25, 4.47 | 10.0                     | 2.44 | 0.72, 8.24 |
| Normal/overweight                  | 1,584 | 81.4 | 6.4                       | 1.00 |            | 4.4                      | 1.00 |            |
| Alcohol consumption (drinks/month) |       |      |                           |      |            |                          |      |            |
| >60                                | 116   | 6.0  | 7.8                       | 0.74 | 0.35, 1.55 | 6.0                      | 1.03 | 0.44, 2.40 |
| 1-60                               | 1,321 | 67.8 | 6.4                       | 0.60 | 0.42, 0.86 | 4.6                      | 0.78 | 0.49, 1.21 |
| 0                                  | 510   | 26.2 | 10.2                      | 1.00 |            | 5.9                      | 1.00 |            |
| Cigarette smoking                  |       |      |                           |      |            |                          |      |            |
| Current                            | 255   | 13.1 | 11.4                      | 1.64 | 1.03, 2.60 | 9.8                      | 2.23 | 1.33, 3.74 |
| Former                             | 811   | 41.6 | 6.4                       | 0.88 | 0.60, 1.28 | 4.0                      | 0.84 | 0.53, 1.35 |
| Never                              | 881   | 45.3 | 7.3                       | 1.00 |            | 4.7                      | 1.00 |            |
| No. of close friends               |       |      |                           |      |            |                          |      |            |
| <3                                 | 408   | 21.0 | 13.0                      | 2.35 | 1.64, 3.36 | 5.4                      | 1.10 | 0.67, 1.79 |
| ≥3                                 | 1,539 | 79.0 | 6.0                       | 1.00 |            | 4.9                      | 1.00 |            |
| No. of close relatives             |       |      |                           |      |            |                          |      |            |
| <3                                 | 393   | 20.2 | 13.2                      | 2.40 | 1.67, 3.43 | 4.8                      | 0.95 | 0.57, 1.59 |
| ≥3                                 | 1,554 | 79.8 | 6.0                       | 1.00 |            | 5.1                      | 1.00 |            |
| Friendship satisfaction            |       |      |                           |      |            |                          |      |            |
| Somewhat/not satisfied             | 558   | 28.7 | 16.0                      | 4.52 | 3.18, 6.41 | 6.8                      | 1.62 | 1.07, 2.46 |
| Very satisfied                     | 1,389 | 71.3 | 4.0                       | 1.00 |            | 4.3                      | 1.00 |            |

\* OR, odds ratio; CI, confidence interval; BMI, body mass index.

physical activity was used to predict prevalent depression in 1994 for all 1,947 subjects. In the longitudinal analyses, 1994 physical activity was first used to predict incident depression in 1999 after the exclusion of the 145 subjects with prevalent depression in 1994. Finally, as a test of the Rancho Bernardo Study recommendation, the longitudinal models were rerun after excluding 151 additional subjects who reported physical disability in 1994. Because the incidence rate of depression was low (5.4 percent after exclusion of subjects with prevalent depression), the resulting odds ratios from the logistic analyses for the longitudinal models closely approximate relative risks.

All calculations were performed using SAS, version 6.12 (SAS Institute, Inc., Cary, North Carolina).

## RESULTS

### Baseline associations with depression for individual study risk factors

Table 1 presents the associations between individual study risk factors and both prevalent and incident depression. All 1,947 subjects are included throughout this table. Physical activity was divided into three categories as low, medium, and high (scores of 0-2, 3-5, and 6-8, respectively).

For prevalent depression, low and medium physically active subjects were more likely to be depressed than were those with high activity. Physical disability showed a strong association with depression, since subjects who reported such impairment were four times more likely to be depressed

than were subjects with no mobility impairment (odds ratio (OR) = 4.02, 95 percent confidence interval (CI): 2.69, 6.02).

Associations between depression and age as well as ethnicity were not statistically significant. Females and subjects with fewer than 12 years of education were more likely to be depressed, as were those who reported financial strain or neighborhood problems. Compared with those with no alcohol consumption, those who consumed 1–60 drinks per month were less likely to be depressed, while current smokers were more likely to be depressed than were nonsmokers.

Reporting one or two or more chronic conditions compared with no condition was associated with depression, as was obesity. Subjects who reported fewer than three close friends or relatives were more likely to be depressed, as were those who reported being somewhat satisfied or not satisfied with friendships.

The two right columns of table 1 present the associations between baseline risk factors and incident depression in 1999. With only several exceptions, associations with depression are similar to those for the prevalent associations. Major differences involve age, where the increased rate for those in their 70s was statistically significant, and the social relation variables, where only satisfaction with friendships was statistically significant.

#### Cross-sectional association between physical activity and depression in 1994

When adjusted for age, gender, and ethnicity, 1994 physical activity was associated cross-sectionally with 1994 depression (table 2, columns 2 and 3). The relative likelihood of being depressed associated with a one-point increase in the physical activity scale was 0.75 (95 percent CI: 0.68, 0.84) in model 1. Subsequent adjustments reduced the relation, but even with all of the adjustments in model 4, the relation between physical activity and depression was still marginally significant (OR = 0.90, 95 percent CI: 0.79, 1.01).

#### Longitudinal association between physical activity and incident depression

The middle columns of table 2 present the relative risks and confidence intervals for incident depression in 1999 associated with 1994 physical activity scale after exclusion of 145 subjects with prevalent 1994 depression. In all four models, physical activity was protective for subsequent depression. In the fully adjusted model (model 4), the relative risk was 0.83 (95 percent CI: 0.73, 0.96), meaning that each one-point increase in the 1994 physical activity scale was associated with nearly a 20 percent reduction in the likelihood of becoming depressed in 1999.

The right columns of table 2 present the relative risks and confidence intervals for incident depression in 1999 associated with 1994 physical activity scale after exclusion of an additional 151 subjects with prevalent 1994 disability. In all four models, physical activity remained protective for subsequent depression, and the exclusion of disabled subjects did

not attenuate the observed protective effects (OR = 0.79, 95 percent CI: 0.67, 0.92).

## DISCUSSION

Our analyses were based on a community sample with a large number of subjects and a scale of physical activity that included frequency of long walks, exercise, sports, and swimming. We used a widely accepted measure for depression incorporating *Diagnostic and Statistical Manual, Fourth Edition*, criteria (23) and had a sufficiently high prevalence of cases for cross-sectional and longitudinal analyses. The cross-sectional analyses showed an association between physical activity and depression even when adjustments were made for a relatively large number of potentially confounding variables including baseline disability. The longitudinal analyses demonstrated a protective effect of physical activity on subsequent depression both when disabled subjects were included and when they were excluded.

These results lend support to those other longitudinal studies that have previously reported a protective effect for physical activity against incident depression. Unlike the Rancho Bernardo findings (17), our study found a relatively strong longitudinal protective effect for physical activity that was not attenuated when physically disabled subjects were excluded. Physicians generally counsel physically disabled patients to avoid inactivity for fear that their condition will worsen. Because the prevalence of disability increases rapidly with age and because disability is strongly associated with depression, excluding older persons with disabilities would both render studies that excluded subjects less representative and possibly involve removing those who might benefit the most. Although we concur that physical disability represents a potentially powerful confounder, our recommendation is to continue including such subjects in research studies involving older persons but to ascertain their influence on the results by adjustment as we did in our first set of longitudinal analyses.

The measure of disability used in the analyses presented here involved difficulty in four lower-body tasks, whereas in the Rancho Bernardo Study, disability was defined as being largely or extremely physically limited during the previous month. The prevalence of disability in their study was 6.7 percent, whereas our measure yielded 9.8 percent. Other researchers might want to explore the issue of including or excluding disabled subjects by using other measures of disability.

A variety of mechanisms have been proposed by which physical activity might reduce the incidence of depression, but research to date is not definitive (36). Two mechanisms often discussed include increased levels of two types of brain neurotransmitters after exercise: monoamines and endorphins (36, 37). The preventive aspects of physical activity for development of serious chronic conditions such as diabetes or heart disease could be important as well because of the strong link between physical health and depression in old age (38). Other plausible mechanisms include improved fitness and increased self-esteem as a result of greater physical activity (39).

**TABLE 2. Sequential logistic regression models showing relations between 1994 physical activity and depression in 1994 and 1999 with adjustments for other risk factors among 1,947 men and women, Alameda County Study, California, 1994–1999**

| Model and 1994 covariates   | Prevalent 1994 depression<br>(cross-sectional analyses) with<br>all subjects included (n = 1,947) |            | Incident 1999 depression (longitudinal analyses)<br>with 1994 depressed subjects excluded |            |                                  |            |
|---|---|------------|---|------------|----------------------------------|------------|
|   | OR*   | 95% CI†    | Disabled included<br>(n = 1,802)  |            | Disabled excluded<br>(n = 1,651) |            |
|   |   |            | OR  | 95% CI     | OR                               | 95% CI     |
| 1. Age, sex, and ethnicity  | 0.75  | 0.68, 0.84 | 0.75  | 0.66, 0.85 | 0.73                             | 0.63, 0.85 |
| 2. Model 1 + education, financial strain, and<br>neighborhood problems                              | 0.78  | 0.70, 0.87 | 0.76  | 0.67, 0.87 | 0.75                             | 0.65, 0.87 |
| 3. Model 2 + physical disability,‡ chronic<br>conditions, BMI,† smoking, and alcohol<br>consumption | 0.86  | 0.76, 0.96 | 0.82  | 0.72, 0.94 | 0.78                             | 0.67, 0.91 |
| 4. Model 3 + no. of relatives, no. of friends, and<br>satisfaction with relations                   | 0.90  | 0.79, 1.01 | 0.83  | 0.73, 0.96 | 0.79                             | 0.67, 0.92 |

\* Odds ratios (OR) represent the approximate relative likelihood of being depressed associated with a one-point increase in the physical activity scale. Because the incidence rate for depression is relatively small (5.4%), the resulting odds ratios for the longitudinal analyses closely approximate relative risks.

† CI, confidence interval; BMI, body mass index.

‡ This variable is omitted from models in which physically disabled subjects were excluded.

Two additional mechanisms question adjusting for social relations and chronic conditions in analyses of physical activity and depression. Physically active older persons may interact more and form relations with those with whom they come into contact as a result of their physical activity. If this is true, social relations constitute an intervening variable between physical activity and depression rather than a confounder and should not be included as adjustment variables. Because of the strong linkage between physical activity and onset of chronic conditions, adjustment for chronic conditions could raise the same issue. We adjusted for both sets of variables in our analyses (models 3 and 4). Readers concerned about possible overadjustment should focus on our results for model 2.

Finally, although studies of the impact of physical activity on depression try to measure independent effects, it is plausible that persons with high levels of physical activity are also more likely to engage in other beneficial health behaviors such as not smoking, avoiding obesity, and not drinking to excess. The potential impact of one beneficial health behavior on adoption of others deserves further research.

Further research with representative community samples and more exact measures of physical activity is needed to definitively answer the question of how strong a protective effect physical activity has on the risk of subsequent depression and to clarify further the role of disability in any observed relation. If results continue to be positive, such findings would be the most helpful for practitioners advising patients about the benefits of physical activity for both somatic and psychologic well-being.

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