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Physical Activity and Depression: Evidence from the Alameda County Study

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The relation between level of physical activity and risk of subsequent depression was examined using three waves of data from the Alameda County Study. Among subjects who were not depressed at baseline, those who reported a low activity level were at significantly greater risk for depression at the 1974 follow-up than were those who reported high levels of activity at baseline. Adjustments for physical health, socioeconomic status, life events, social supports, and other health habits did not affect the association appreciably. Associations between 1965–1974 changes in activity level and depression in the 1983 follow-up suggest that the risk of depression can be altered by changes in exercise habits, although these associations were not statistically significant after adjustment for covariates. These results provide somewhat stronger evidence for an activity-depression link than do previous studies, and they argue for the inclusion of exercise programs as part of community mental health programs, as well as for further studies that focus on the relation between life-style and mental health. *Am J Epidemiol* 1991;134:220–31.

depression; exercise; prospective studies

In recent decades, it has become generally accepted that regular physical exercise confers mental health benefits on participants. The scientific and popular literatures on this subject now include a wide variety of possible explanations for this phenomenon. Suggested biologic mechanisms focus on the fact that strenuous exercise has been shown to result, at least in the short term, in increased cortical blood flow (1), release of endorphins, and increased epinephrine and norepinephrine synthesis (2–5). It also has been hypothesized that strenuous exercise allows for a discharge of hostility (6), reducing emotional strain and perhaps also serving as a buffer against stressful events (7, 8). Others have suggested that regular participation in physical exercise programs gives the individual a sense of mastery that contributes to greater self-esteem (9, 10), that it provides a distraction from negative preoccupations (9), or that the social approval accorded those who engage in exercise programs helps to elevate mood (11).

Overall, the empiric evidence for a link between exercise and one form of mental dysfunction, depression, is very mixed. There is ample testimony from runners and joggers as to the improved mood, sometimes even euphoria, that immediately follows an aerobic exercise session and that may continue for several hours after. Both human (2, 4, 12) and animal studies (5) have been

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Abbreviations: CES-D scale, Center for Epidemiologic Studies depression scale; 95 percent CI, 95 percent confidence interval; HPL, Human Population Laboratory; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio.

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able to show exercise-induced metabolic changes that might account for this effect, although there is some conflicting evidence as well (13). The longer-term effects are less clear, especially in psychopathology-free groups. Carr et al. (12) studied women volunteers and found that training augmented the effects of exercise on plasma levels of endorphins. However, Howlett et al. (14) found that while treadmill exercise sessions produced significant release of β-endorphins in 15 normal women, neither the pattern nor the amount of release was affected by an intensive program of exercise training.

There are a number of experimental studies that report improved mood or morale among subjects who have participated in exercise programs over a period of weeks or months (7, 15, 16) and some studies that fail to find this effect (17–19). The strongest evidence comes from studies of patient groups: exercise programs have been used as part of the therapeutic program for clinically depressed persons with rather consistently good results (9, 20, 21). However, in many of these, as in most of the experimental studies, lack of adequate control groups and the presence of other methodological problems render the findings inconclusive. (See de Coverley Veale (6), Taylor et al. (8), and Simons et al. (22) for excellent reviews of experimental literature.)

There have been only a few epidemiologic studies examining the association between regular exercise and mental health in nonpatient populations. While some of these studies find strong evidence for a link between exercise and mood (7, 11, 23, 24), all but one are based on cross-sectional data, allowing for the interpretation that depression leads to lack of exercise, rather than the reverse. In general, these studies also suffer from other methodological limitations, including small sample size and lack of adequate controls for potential confounding variables, particularly physical health.

The one prospective study produced somewhat equivocal results. Using data from the National Health and Nutrition Examination Survey (NHANES), Farmer et al. (25) found that baseline recreational physical activity was an independent predictor of depression levels 8 years later for white women who were not depressed at baseline, with adjustment for age, chronic conditions, education, employment, income, and length of follow-up. There was no such significant association for the nondepressed white men in the sample although, among the depressed men, a low level of physical activity was a strong predictor of continued depression at follow-up (25).

Additional study of community-based longitudinal data, such as those of the NHANES, is important to help clarify the nature of the relation between exercise and depression. The fact that most research on this subject to date has been done on patient, volunteer, or other limited samples and without adequate control for a number of potentially confounding factors may well account for the conflicting evidence thus far. For example, the cross-sectional associations observed may indicate only that depressed people are unlikely to engage in physical exercise. It also may be that physical activity is actually associated with depression, not directly, but indirectly through its association with other related characteristics. The most obvious of these potentially confounding variables is physical health status, since persons suffering from physical impairment are more likely to be depressed and less likely to engage in physical activities. It also has been suggested that the mood-enhancing properties of exercise actually derive from the social interaction that accompanies most of the physical activities in which people engage (17). Other characteristics that may complicate the exercise-mental health link include socioeconomic status, other health practices such as smoking and drinking, and stressful life events. Finally, it may be that the mood-enhancing properties of activity are operative only at certain levels of existing depression, i.e., that there is an interaction effect involving depression and physical activity.

The purpose of the analyses presented here is to address these issues by examining

the longitudinal relation between physical activity and depression in a heterogeneous population, using multivariate analysis to adjust for a number of factors that could confound this relation. We use a large community sample that has been followed for two decades with measurements of the relevant variables at three points in time (26).

Our analyses are designed to address the following questions. 1) Is there an association, in a nondepressed population, between baseline physical activity and risk of subsequent depression? 2) Is there an association between *changes* in physical activity during the first follow-up period and risk of subsequent depression? 3) Do adjustments for physical health, social isolation, socioeconomic status, or other measures known to predict depression alter the associations observed in question 1 or 2, above?

MATERIALS AND METHODS

The study sample

The data are taken from ongoing studies conducted by the Human Population Laboratory in Alameda County, California. In 1965, 8,023 noninstitutionalized adults (aged 20 years and over or ever married) in 4,452 housing units were selected on the basis of a stratified systematic sample of Alameda County housing units. The sampling procedures are discussed in greater detail in the publications by Berkman and Breslow (26) and Hochstim (27). The sample subjects were asked to complete an extensive questionnaire about behavioral, social, and psychologic aspects of their lives, as well as about their physical health. Completed questionnaires were received from 6,928 of the designated respondents.

The first round of follow-up interviews was conducted in 1974. After ascertainment of vital status of the 1965 respondents by computerized record linkage, all but 4.4 percent of the 6,235 respondents not known to be dead were located; of these, 81.6 percent completed a follow-up questionnaire, providing information on the same set of physical, behavioral, and psychosocial parameters as in 1965. A third wave of data collection was completed in 1983, in which a 50 percent random sample of the 1974 respondents was recontacted. Of the 2,184 designated respondents not known to be dead, 94 percent were located, and 87 percent of these (1,799 respondents) completed questionnaires in this second follow-up. The first portion of this analysis will be done using those interviewed in 1965 and 1974; the second portion, in which we examine change in physical activity in relation to risk of subsequent depression, will use only those subjects who responded at all three waves. (Missing data result in actual sample sizes very slightly smaller than those presented above.)

Measure of depressive symptoms

The measure of depressive symptoms used here has been utilized in several other studies (28, 29). It was constructed in the following manner. A set of 40 items ostensibly relating to depression was selected from a larger pool of questionnaire items dealing with varied aspects of psychologic distress. Items were selected that deal with mood disturbance, negative self-concept, loss of energy, problems with eating and sleeping, trouble with concentration, and psychomotor retardation or agitation (30). A further criterion for selection was that the items be contained in all three questionnaires. These 40 items then were rated independently by 10 clinical researchers (psychiatrists and psychologists) in terms of their presumed usefulness in ascertaining whether a subject was depressed. From their ratings, half of the items were eliminated. The homogeneity of the remaining set of items was assessed by item-total correlations and measures of internal consistency reliability (31). From these results, two of the remaining 20 items were eliminated. The remaining 18 items have item-total correlations ranging from 0.18 to 0.45 and acceptable internal consistency reliability. Coefficient α was 0.77 for the total sample, 0.75 for males, and 0.77 for females. Reliabilities using the Spearman-Brown split-half

procedure were 0.77 for the total sample, 0.74 for males, and 0.79 for females (28). For a comparison of these items with those contained in other brief symptom checklists, such as the Center for Epidemiologic Studies depression scale (CES-D scale), see Kaplan et al. (29).

The questionnaire items used here were phrased to elicit information on current symptom status; respondents were asked to indicate whether or not they experience particular feelings and symptoms, and, in some cases, how often. The score is generated by assigning one point for each answer that is indicative of a "depressed" response. In the analyses presented here, we contrast respondents who reported four or fewer symptoms with those who reported five or more. Thus, the term "depressed," as used in describing these analyses, should always be understood to mean a high (5+) level of *depressive symptoms*.

Measure of physical activity

Baseline physical activity and change in physical activity level were assessed using information from 1965 and 1974 responses to the question, "Here is a list of things that people do in their free time. How often do you do any of these things?" The physical activity index was computed based on the reported frequency and presumed strenuousness of the leisure-time participation in active sports, swimming or walking, doing exercises, and gardening; for the first three of these activities, a report of "often" participation was given four points, a report of "sometimes" was given two points, and a report of "never" received zero points; for the gardening item, which is presumed to be less strenuous, the corresponding points were two, one, and zero. The points received for all items were summed to produce the final index with actual scores ranging from zero to 14. This index has been used in a large number of Human Population Laboratory (HPL) studies and has been shown to be prospectively associated with morbidity and mortality risk in this sample (26). For the two-wave analysis, this score was trichotomized into low (0–4 points), medium (5–8 points), and high (9–14 points) activity levels. Based on preliminary analysis of the two-wave data which showed that only the low-activity category carried a consistent risk of depression, the index was dichotomized into low (0–4) versus moderate or high (5–14, referred to hereafter as "high") for the three-wave analysis, resulting in a four-category change score (low-low, low-high, high-low, and high-high).

Adjustment variables

Previous HPL analyses have identified a number of psychosocial predictors of depression that might confound the relation of physical activity (29); these include education, physical disability, chronic conditions, physical symptoms, perceived health, social isolation, feelings of anomy, and five stressful life events (residential move, loss of job, separation or divorce, death of spouse, and financial difficulties). In addition, based on evidence from other studies of depression, we include age, income, race, marital status, smoking status, alcohol consumption, and relative weight for height as adjustment variables. Descriptions of these variables and their scoring are presented in Kaplan et al. (29).

Analysis

All analyses were performed using logistic regression procedures in which the presence of a high level of depressive symptoms, the dependent variable, was regressed on physical activity and a variety of other covariates. Using a series of logistic models, we first examined the risk of depression associated with different levels of physical activity with adjustment for age only, and then with additional adjustments for potential confounder variables from a number of domains.

The first set of analyses was performed on all members of the two-wave panel who reported four or fewer depressive symptoms at baseline and who had nonmissing data

on all relevant variables (n = 3,789; exclusions due to missing data = 438, or 10.4 percent of eligible respondents). Independent variables were baseline (1965) measures (except for the retrospective recall of 1966–1973 life events obtained in 1974), with depression (five or more depressive symptoms) in 1974 as the outcome. The trichotomous physical activity score was entered as two dummy variables representing low and moderate activity levels, respectively, with high activity as the reference. These analyses were performed separately for men and women.

The analyses of activity change and depression were performed on all members of the three-wave panel who reported fewer than four depressive symptoms at the 1974 follow-up and who had nonmissing data for all relevant variables (n = 1,275; additional exclusions due to missing data in the 1974 follow-up = 142 or 10.0 percent of eligible respondents). We repeated the same series of logistic models as in the two-wave analysis, with depression (5+ symptoms) in 1983 as the outcome variable and 1965–1974 physical activity change as the predictor. Activity change, based on the dichotomous form of the physical activity index, was entered into the model as three dummy variables representing low levels at both 1965 and 1974, change from high level in 1965 to low level in 1974, and change from a low level in 1965 to a high level in 1974, respectively; the risk associated with each of these groups was compared to the reference group of persons with high levels of activity in both 1965 and 1974. Adjustment variables were entered with values for both 1965 and 1974, providing adjustment for 1965–1974 change in a given variable as well as for the absolute levels of the variable at the two points in time. Since respondents who reported high depression levels in 1965 but not in 1974 were not excluded from these analyses, all models also included adjustment for 1965 depression. Preliminary analyses had shown that there were no significant differences between men and women in terms of the effects of physical activity change on subsequent depression scores; therefore, the primary analyses of the three-wave data were performed on the entire group with adjustment for sex also entered into every model. For purposes of comparison with the NHANES results, one set of sex-specific models was also examined.

RESULTS

Effects of attrition

Persons lost to follow-up in 1974 (not known dead but not located or did not complete the follow-up questionnaire) were somewhat more apt to have been depressed at baseline than were those who completed the first follow-up (17 vs. 13 percent); the two groups did not differ on the baseline physical activity measure. Those who responded in 1965 and 1974 but were lost to follow-up in 1983 were more apt to have been depressed in 1974 than were those who were three-time respondents (21 vs. 13 percent) and also more apt to have been inactive (38 vs. 28 percent).

Differences of this sort are frequently observed in longitudinal studies of community-based samples and do not necessarily mean that there is any systematic bias in the results based on a partial follow-up. Such bias would result only if the longitudinal associations being studied (in this case, the longitudinal association of physical activity and depression) were quite different for the respondent and dropout groups. While, by definition, this longitudinal relation cannot be measured in the dropout group, we were able to compare the cross-sectional associations in the two groups and make some inferences about what the longitudinal relation in the dropout group might be.

Table 1 shows the results of logistic regression analyses of the relevant cross-sectional associations, with adjustment for age, sex, and physical disability for study and dropout groups. Analysis of the association between 1965 depression and 1965 activity level for the 4,848 persons who constitute the two-wave respondent sample resulted in an odds ratio of 4.22 for those at the lowest level of activity and 2.14 at a moderate level (ad-

TABLE 1. Cross-sectional associations of physical activity/activity change and depression by response status: The Alameda County Study

	1974 Respondents*			1974 "Dropouts"*		
	OR†	95% CI†	*n*	OR	95% CI	*n*
Low activity	4.22	3.17–5.62	1,548	3.55	1.97–6.38	290
Moderate activity	2.14	1.61–2.86	2,001	1.80	1.02–3.21	379
High activity (reference)	1.0		1,299	1.0		205
	1983 Respondents‡			1983 "Dropouts"‡		
	OR	95% CI	*n*	OR	95% CI	*n*
Low activity, 1965 and 1974	3.76	2.57–5.50	294	2.83	1.31–6.16	84
Low activity, 1965, and high activity, 1974	2.12	1.35–3.34	209	2.44	1.02–5.83	42
High activity, 1965, and low activity, 1974	2.93	1.92–4.46	216	2.09	0.89–4.88	53
High activity, 1965 and 1974 (reference)	1.0		1,070	1.0		191

* Logistic regression of 1965 depression on 1965 physical activity level with adjustment for age, sex, and physical disability.
† OR, odds ratio; 95% CI, 95% confidence interval.
‡ Logistic regression of 1974 depression on 1965–1974 physical activity change with adjustment for age, sex, and physical disability.

justed for age, sex, and physical disability): the corresponding odds ratios for the 874 individuals who did not respond in the 1974 follow-up are 3.55 and 1.80. The cross-sectional associations of the two groups were very similar, and both displayed the same pattern as that observed in our longitudinal analysis of the two-wave respondent group below. We know of no reason to suspect that the unobserved longitudinal association in the dropout group would have departed from this overall pattern.

The results were similar when we compared the three-wave respondent group with those who dropped out between 1974 and 1983 with regard to the association of 1965–1974 physical activity change and depression status in 1974. The relation was somewhat stronger in the respondent group than in the dropout group, but the patterns were very similar, and the associations were clear in both cases. We regard this as reasonably strong evidence that there is no systematic bias due to loss to follow-up in either 1974 or 1983 in terms of the associations of interest, and that, had we been able to follow all members of the original sample for the full 18 years, the results would not have been significantly different from those presented here.

Associations of physical activity level and covariates

In table 2, we examine the cross-sectional relations between physical activity and a number of the covariates of depression identified above (29). The values in this table indicate the potential complexity of the physical activity-depression association: i.e., each of the covariates is associated with physical activity also and, in some cases, the association is quite strong. Adjusting for these variables in our analysis, one domain at a time, will allow us to investigate the possibility that the connection between physical activity and depression is derived from their common association with one or more of these other factors.

Two-wave analysis

Table 3 shows the relative risks of depression in 1974 associated with low and moderate activity levels in 1965 for men and for women, with various other adjustments. In the first models, which are adjusted for age only, the risk of depression associated with the lowest level of baseline physical activity compared with the highest level was 2.48 (95 percent confidence interval (95 percent CI) 1.54–4.01) for men and 2.88 (95 percent CI 1.87–4.44) for women. For men only,

TABLE 2. Cross-sectional associations of physical activity score and covariates: The Alameda County Study, 1965

Covariates	Physical activity level (%)			Total	
	Low	Medium	High	*n*	%
Demographics					
Age (years)					
20–39	25.8	47.7	26.5	2,235	100.0
40–59	39.6	41.2	19.2	1,947	100.0
≥60	56.4	34.7	9.0	646	100.1
Sex					
Male	30.0	45.2	24.8	2,142	100.0
Female	39.8	41.9	18.3	2,686	100.0
Ethnic status					
Black	50.0	35.3	14.7	476	100.0
Other	33.9	44.2	21.9	4,352	100.0
SES*					
Adjusted income					
Lowest quartile	43.2	40.2	16.6	1,148	100.0
Other	32.4	44.6	22.9	3,501	99.9
Education					
0–8 years	56.9	34.4	8.7	689	100.0
>8 years	31.8	44.9	23.4	4,124	100.1
Physical health					
Disability					
Disabled ≥6 months	72.3	22.6	5.0	159	99.9
Not disabled	34.2	44.0	21.8	4,668	100.0
Chronic conditions					
≥2 chronic conditions	56.6	31.8	11.5	581	99.9
0–1 chronic condition	32.6	44.9	22.5	4,247	100.0
Symptoms					
≥2 symptoms	44.9	41.3	13.8	1,107	100.0
0–1 symptom	32.7	43.9	23.4	3,721	100.0
Perceived health					
In poor/fair health	56.8	35.6	7.6	725	100.0
In good/excellent health	31.6	44.8	23.7	4,093	100.1
Health habits					
Alcohol consumption					
Abstainer	47.5	35.8	16.7	953	100.0
Drinker	32.5	45.2	22.3	3,875	100.0
Relative weight					
>10% over- or underweight	39.7	41.7	18.7	2,592	100.1
≤10% normal weight	30.6	45.3	24.2	2,236	100.1
Social networks					
Group membership					
No memberships	46.2	39.2	14.6	1,661	100.0
≥1 memberships	29.8	45.5	24.7	3,167	100.0
Friends and relatives					
Little contact	45.9	38.3	15.9	1,097	100.1
More contact	32.0	45.0	22.9	3,648	99.9

* SES, socioeconomic status.

there was a significant, but smaller relative risk (odds ratio (OR) = 1.64, 95 percent CI 1.03–2.59) associated with moderate activity also.

After adjustment for physical health measures (model 2), the association of low activity and subsequent depression was weakened some for both men and women, but it re-

TABLE 3. Associations of 1965 physical activity level and 1974 depression with various adjustments: The Alameda County Study

Model	Adjustment	Men				Women			
		Low activity (n = 470)		Moderate activity (n = 819)		Low activity (n = 703)		Moderate activity (n = 890)	
		OR*	95% CI*	OR	95% CI	OR	95% CI	OR	95% CI
1	Age only	2.48	1.54–4.01	1.64	1.03–2.59	2.88	1.87–4.44	1.30	0.83–2.02
2	Age and health	2.21	1.36–3.60	1.55	0.98–2.46	2.34	1.51–3.65	1.23	0.79–1.93
3	Fully adjusted model†	1.76	1.06–2.92	1.46	0.91–2.34	1.70	1.06–2.70	1.00	0.63–1.59

* OR, odds ratio; 95% CI, 95% confidence interval.
† Adjusted for age, physical health, socioeconomic status, social supports, life events, anomy, alcohol consumption, smoking status, and relative weight.

mained sizable and significant. The risk associated with moderate activity was virtually unchanged from the original model. A number of other models, with adjustments for, one at a time, socioeconomic status, social supports, stressful life events, anomy, and health habits, were also tested (these models are not shown in table 3). In each case, the effect of the adjustment on the odds ratio associated with low activity levels was relatively small; the activity-depression association remained significant in each of these models and always with an odds ratio greater than 2.0. The adjustments had virtually no effect on the odds ratios associated with moderate activity. Finally, a "fully adjusted" model (model 3) was tested in which adjustment variables for all domains were included simultaneously (table 3). In this model, the odds ratios for low activity compared with high activity for men and women decrease to 1.8 and 1.7, respectively, indicative of the summation of the smaller decreases associated with each individual adjustment. However, the risk of depression for both men and women at this low activity level compared with those at high levels remained near twofold and significant at $p = 0.03$.

Three-wave analysis

Table 4 summarizes the analysis of change in activity level between 1965 and 1974 as a predictor of depression between 1974 and 1983. In the first model, with adjustments for age and sex only, persons with chronically low activity levels and those who had decreased from high to low were both seen to be at considerably increased risk of subsequent depression compared with those who had high levels of activity at both times (OR = 1.94, 95 percent CI 1.11–3.38; and OR = 2.02, 95 percent CI 1.09–3.75, respectively). The risk for those who had increased their activity between 1965 and 1974 was not significantly different from that of the reference group (those with high activity levels in both 1965 and 1974). These odds ratios changed very little when, in the second model, adjustment for 1965 depression was added.

In model 3, adjustment for physical health was added, resulting in a considerably smaller, nonsignificant odds ratio for those with chronically low activity levels, but only small changes in the odds ratios of those who changed from low to high or high to low (although the lower limit of the confidence interval for the latter ratio also fell below 1.0 in this model). In subsequent models (not shown here), adjustments in other domains were added one at a time. None of these adjustments had more than a small impact on the odds ratios associated with any of the physical activity change categories.

The final model in table 4 (model 4) shows the effects of simultaneous adjustment for covariates in all domains on the activity change-depression association. The odds ratio for those reporting low activity in both 1965 and 1974 declines to 1.22 (95 percent CI 0.62–2.38), a considerable difference from the value in the unadjusted model (1.94). The odds ratio for those who reported a decrease in activity between 1965 and 1974

TABLE 4. Association of physical activity change (1965–1974) and subsequent depression (1983) with various adjustments: The Alameda County Study

Model	Adjustment	Physical activity level						
		Low*				High*		
		Low (n = 194)†		High (n = 157)†		Low (n = 137)†		High (reference, n = 787),†
		OR‡	95% CI‡	OR	95% CI	OR	95% CI	OR
1	Age and sex	1.94	1.11–3.38	1.37	0.70–2.68	2.02	1.09–3.75	1.00
2	Age, sex, and 1965 depression	1.85	1.05–3.26	1.18	0.59–2.33	1.88	1.01–3.51	1.00
3	Age, sex, 1965 depression, and physical health	1.46	0.81–2.65	1.08	0.53–2.21	1.71	0.90–3.27	1.00
4	Fully adjusted§	1.22	0.62–2.38	1.11	0.52–2.36	1.61	0.80–3.22	1.00

* For 1965.
† For 1974.
‡ OR, odds ratio; 95% CI, 95% confidence interval.
§ Adjustment for age, sex, 1965 depression, physical health, socioeconomic status, social supports, life events, anomy, alcohol consumption, smoking status, and relative weight.

showed a much smaller decline with the additional adjustments, while that for subjects who changed from low to high activity remained virtually unchanged from the previous model.

In order to make a more precise comparison of these results with those of the NHANES study, we repeated the final models of this three-wave analysis separately for men and women. The results (not shown here) were very similar to those from our total sample; while no effect was statistically significant, the largest odds ratios were found among those who went from high to low activity levels. Interestingly, the ratio for men in this category (2.04) is larger than that for the total sample, suggesting a stronger relation between decrease in activity level and subsequent depression for men than for women. This is in contrast, although not necessarily contradiction, to the finding of the NHANES study in which, among those who were not depressed at baseline, low-activity women had a twofold risk of subsequent depression, while the ratio for men was only 1.3.

DISCUSSION

In this nondepressed population sample, men and women who reported a low activity level at baseline were at a significantly greater risk for depression at follow-up than were those who reported high activity levels at baseline. This association persisted but was somewhat diminished with adjustment for associated variables including physical health, socioeconomic status, social supports, life events, and other health habits. These findings suggest that the relation of physical activity to depression is complex. It does derive in part from the mutual association of activity and depression with a variety of other characteristics of the individual or his circumstances, yet it is not wholly attributable to the influence of any of these covariates or even the combination of all of them together. This complexity may help to account for the lack of uniformity of results in previous studies and carries important implications for the kind of controls that need to be included in future studies. There was no significant difference, after adjustment for covariates, between those who reported moderate activity and those who reported high activity.

In general, the findings regarding activity change provide even stronger evidence for a direct link between activity level and subsequent depression. Those who had been inactive in 1965 but increased their activity levels by 1974 were at no greater risk for depression in 1983 than were those who had been highly active all along, suggesting that

the high risk of depression associated with that early inactivity is modified if the activity level is changed. On the other hand, those who had been active in 1965 but had fallen to a low activity level by 1974 were more than one and a half times as likely to become depressed by 1983 as were those who maintained high levels of activity. This latter finding is not conclusive, since in the adjusted models the association fails to reach significance at the 0.05 level; however, the odds ratio for this high-low group remains substantial in all models, relatively unaffected by the adjustments, suggesting that there may well be an increase in risk of future depression with cessation of regular activity.

A major exception to the overall pattern of the change analysis is found in the experience of the chronically inactive. While the unadjusted model shows them to be at significantly increased risk over the consistently active, adjustments, particularly for physical health, virtually eliminate this difference. In other words, for the long-term inactive, the apparent association of inactivity with depression is in fact a reflection of other characteristics of this group, primarily their physical health.

In evaluating our findings, particularly those having to do with changes in level of physical activity, it is important to be aware of the limitations of the measure used. The measure is based on respondent reports from two single points in time, 9 years apart, and does not include information on duration of change either during the interval before the report or in the subsequent follow-up period. Based as it is on self-reports about leisure or recreational activities, our indicator of the independent variable is imprecise, and its reliability and validity are unknown. Other community-based studies suffer from the same deficiency (11, 25). A more rigorous strategy would use measures incorporating data on duration of physical activity, strenuousness of the activity, and level of physical fitness of the subjects.

We also should point out that our measure of depression, similar to that used in other community-based studies (11, 25), is also potentially problematic. Our indicator of depression consists of reports of depressive symptoms. As we have noted elsewhere (29, 32), symptoms of depression may reflect a variety of heterogeneous mood states. In particular, checklists eliciting symptoms of depression do not permit differentiation among those subjects experiencing mild to severe dysphonic mood and those suffering from diagnosable episodes of clinical depression. Furthermore, they do not provide data on chronicity or degree of functional impairment. Data on onset and duration are particularly important, since studies have shown that symptoms of depression can fluctuate considerably over time (33, 34).

There is also evidence to suggest that these diverse depressive syndromes, which can occur in community populations, may also differ in their epidemiologic dimensions (32, 34–36). That is, mild dysphonic states may differ from more severe clinical depression in terms of prevalence and duration as well as causes and consequences. Given this, the question arises as to whether the relations observed by us and by Farmer et al. (25) hold for more severe forms of depressive disorder.

The analysis described here is only the second major longitudinal examination of the activity-depression association in a community sample. Our findings differ somewhat from those of the NHANES survey (25), providing stronger evidence that physical activity is in some way related to the risk of becoming depressed in a "normal" population and that, possibly, changing one's activity level can alter the risk of subsequent depression.

Based on these results and other recent community-based studies (11, 25), we conclude that there is a positive mental health benefit associated with increased levels of physical exercise. The exact mechanisms for this effect are still unclear. We believe two lines of research should be explored in future investigations. From an epidemiologic perspective, research is needed that explores whether there is a beneficial effect of exercise on more severe, clinical forms of depression

as well as more mild dysphoric states. In addition, more rigorous assessment of physical activity, along the lines noted above, would permit greater understanding of the role of exercise in affecting mental health status. From a community mental health perspective, the available evidence also suggests that physical activity should be considered as one possible strategy in community programs in which the objective is to prevent depression. As noted by Ross and Hayes (11), the effect of physical activity on psychologic well-being, while not dramatic, is large enough to suggest that community interventions are worth exploring.

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