



Original Contribution

Physical Activity and Common Mental Disorder: Results from the Caerphilly Study

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The authors examined associations between leisure-time and occupational physical activity and common mental disorder (CMD), defined as anxiety and depression, using data from a cohort of middle-aged men in Caerphilly, South Wales, United Kingdom, who were followed for 5 years (1989–1993) and 10 years (1993–1997). CMD was measured using the General Health Questionnaire. Total leisure-time activity and percentage of time spent in heavy-intensity activity were estimated from self-reports (Minnesota Leisure Time Physical Activity Questionnaire). Men were classified into four classes of occupational activity. Among 1,158 men with complete data, those who participated in any heavy-intensity leisure-time activity had reduced odds of CMD 5 years later (below median vs. none: adjusted odds ratio (OR_{adj}) = 0.61, 95% confidence interval (CI): 0.40, 0.93); median or above vs. none: OR_{adj} = 0.54, 95% CI: 0.35, 0.83). Analyses using multiple imputation to deal with missing data found weaker evidence for an association (OR_{adj} = 0.79 (95% CI: 0.54, 1.15) and OR_{adj} = 0.73 (95% CI: 0.49, 1.09), respectively). There was little evidence that men in the most physically demanding jobs had reduced odds of CMD after 5 years, and there was no association between physical activity and CMD 10 years later. Among these men, heavy-intensity leisure-time physical activity was associated with a small reduction in CMD over 5 years.

anxiety; depression; exercise; mental disorders; physical fitness

Abbreviations: CI, confidence interval; GHQ-30, 30-item General Health Questionnaire; MICE, multiple imputation by chained equation; OR, odds ratio.

In addition to the established benefits of physical activity for chronic diseases (1), increased activity improves subjective well-being (2). Despite the increasing burden of common mental disorders (anxiety and depression) in society (3), there are few data on the relation between physical activity and mental health. The authors of several reviews have concluded that physical activity is associated with a reduction in depressive symptoms (4–6), but these reviews included cross-sectional studies, from which the temporal

nature of the association could not be determined, and experimental studies examining only short-term effects.

Longitudinal epidemiologic studies have produced conflicting results (7–14). In the First National Health and Nutrition Examination Survey, engaging in little or no recreational activity was associated with twofold increased odds of incident depression after 8 years in women, but no such increase was seen for men (7). In the Alameda County Study, men and women who reported low levels of physical

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activity had 70 percent increased odds of incident depression over a period of 9 years (8), with greater physical activity reducing depressive symptoms later in life (14). Similarly, in an older Finnish cohort, persons who became more active over a period of 8 years had fewer depressive symptoms (11). Former female college athletes have been found to be at lower risk of depression in later life than nonathletes (13), but such findings may not be generalizable. In a study of college alumni, Paffenbarger et al. (9) also reported a reduced risk of depression among the more physically active. In another study, Morgan and Bath (10) reported a very small effect, but they did not exclude prevalent cases of depression at baseline, which would have resulted in underestimation of any true benefit of physical activity. Sexton et al. (12) observed an association only among persons with sedentary occupations. In the Upper Bavarian Field Study, Weyerer (15) found a cross-sectional association between low levels of physical activity and depressive disorder, but this was not supported by analysis of 5-year follow-up data. Similarly, in the Rancho Bernardo Study, Kritz-Silverstein et al. (16) did not find a longitudinal association over a period of 8 years. In a study of former medical students, Cooper-Patrick et al. (17) found no evidence for a link between physical inactivity and future depression over 2 or 15 years of follow-up.

While differences in follow-up, adjustment for confounders, and selection bias may contribute to the conflicting evidence, the most significant limitation of previous studies has been the measurement of physical activity. Often the measurement of physical activity is restricted to only one or two questions (7, 12, 15–17), and it is frequently confined to leisure-time activities (8–10, 14, 15). Accurate measurement of physical activity should comprise information on the frequency, duration, and intensity of all such activity (18), including both occupational and leisure-time activities. Paffenbarger et al. (9) recorded more detailed activity information that was converted into energy expenditure, which provided some evidence for a dose-response effect, suggestive of causality, but adjustment for confounders was limited to age.

In previous studies, investigators have used self-report measures of common mental disorders (10, 12), with a focus on depressive symptoms (7, 8, 16) or recall of physician diagnoses (9, 13, 17). Because many persons with psychiatric problems have symptoms of both anxiety and depression, we use the term “common mental disorder” to refer to both depressive disorders and anxiety disorders. We aimed to examine the association between physical activity and common mental disorder in a longitudinal population-based cohort study of men with detailed leisure and occupational physical activity data and to determine whether there was any evidence for a dose-response effect.

MATERIALS AND METHODS

Caerphilly Study cohort

We used data from the Caerphilly Prospective Study, a cohort study of middle-aged men in Caerphilly, South Wales, United Kingdom. Detailed information on the cohort is

available elsewhere (<http://www.epi.bris.ac.uk/caerphilly/caerphillyprospectivestudy.htm>) (19). Briefly, in the initial survey (phase I: 1979–1983), men aged 45–59 years living in Caerphilly and the surrounding area were invited to participate in a study of the determinants of coronary heart disease. Eighty-nine percent of those eligible ($n = 2,512$) took part. In phase II (1984–1988), men who had taken part in phase I were recontacted, and men who had moved into the study area were invited to participate (total $n = 2,398$). The phase II cohort was subsequently followed at 5-year intervals (phase III: 1989–1993; phase IV: 1993–1997). In each phase, participants attended a clinic at which they completed a questionnaire, had anthropometric measurements and an electrocardiogram taken, and provided fasting blood samples. Measurements from the phase II assessment were used for the cross-sectional analyses and formed the baseline data for the longitudinal analyses presented here.

Phases I–III of the Caerphilly Study were approved by the Cardiff Local Research Ethics Committee, and later phases were approved by the Gwent Research Ethics Committee.

Measurement of common mental disorder

Common mental disorder was measured in phases II–IV using the 30-item General Health Questionnaire (GHQ-30) (20), a screening instrument for psychiatric disorders. In a validation study ($n = 97$), men with common mental disorder were identified using the Clinical Interview Schedule, which was administered by a psychiatrist blinded to GHQ-30 scores (21). On the basis of receiver operating characteristic curves, a case of common mental disorder was defined as having a GHQ-30 score greater than or equal to 5 (sensitivity = 71.4 percent; specificity = 71.0 percent).

Measurement of physical activity

In phase II (baseline), data on leisure-time physical activity were collected using questions derived from the Minnesota Leisure Time Physical Activity Questionnaire (22). Participants were asked whether they had undertaken a variety of activities during the last 12 months, as well as the frequency and average duration of each activity. Each activity was assigned an intensity code, and therefore energy expenditure was calculated both in total and for each level of intensity (light, moderate, and heavy) (19). The percentage of energy expended in heavy-intensity activity (e.g., running, playing soccer) was also calculated.

Physical activity at work was assessed on the basis of self-report questions (time spent walking, sitting, and lifting/carrying) modified from the Health Insurance Plan questionnaire (23). Each participant was categorized into one of four occupational physical activity classes based on quartiles (class 1 = least active; class 4 = most active). In phase II, 53 percent of the men in the study were employed. For the remaining men, these questions referred to physical activity in the last job held. No data were collected on how long a participant had been out of work or retired. For the main analyses, all men with data on work-related physical activity (current/last job) were included in order to maximize the number of participants in the analyses and to ensure

that the sample remained representative of the population of middle-aged men from which the sample was drawn. Sensitivity analyses were restricted to those employed at baseline.

Statistical analysis

All analyses were conducted in Stata, version 8.2 (24).

For leisure-time physical activity, total energy expenditure (kcal/day) was divided into tertiles (low, medium, and high). The percentage of leisure-time physical activity of heavy intensity was divided into three categories: none, low, and high (for the latter, dichotomizing at the median). Occupational physical activity was modeled in four job classes (as described above).

Logistic regression was used to examine the cross-sectional relation between physical activity and common mental disorder. The independent effects of leisure-time and occupational physical activity were examined. Odds ratios and their 95 percent confidence intervals are reported. In univariable models, results were adjusted for the following possible confounders: age (years), social class (Registrar General's occupational classification (25); six groups), marital status (married, single, widowed, or divorced/separated), employment status (employed, unemployed, self-employed, or retired (due or not due to ill health)), smoking habits (never smoker, ex-smoker, cigar or pipe smoker, or current smoker by number of cigarettes smoked per day (<15, 15–24, or ≥ 25)), alcohol consumption (units/week; 1 unit = 8 g of ethanol), social support, body mass index (weight (kg)/height (m)²), job satisfaction, demands, and latitude (based on the method of Karasek (26)), and biologic measures (levels of high density lipoprotein cholesterol (mmol/liter) and triglycerides (mmol/liter)).

In longitudinal analyses, we examined the short-term (phases II–III; 5-year follow-up) and longer-term (phases II–IV; 10-year follow-up) effects of physical activity on mental health. Participants with prevalent common mental disorder in phase II (GHQ-30 score ≥ 5) and noncases (GHQ-30 score <5) who were taking antidepressant medication were excluded from the cohort for longitudinal analyses. As before, unadjusted and adjusted results (with additional adjustment for phase II GHQ-30 score and change in triglyceride level (phases II–III or phases II–IV)) were examined.

Analyses were repeated classifying persons who had a GHQ-30 score greater than or equal to 5 or were taking antidepressants in phase III (or IV) as incident cases and, similarly, classifying persons who were taking antidepressants or daytime (nonsedative) anxiolytics (often prescribed for common mental disorder in the 1980s/1990s) in phase III (or IV) as incident cases.

In sensitivity analyses, we examined the influence of missing data on the findings. The method of multiple imputation by chained equation (MICE) (27) was used to impute the missing data (Stata *ice* procedure v.30.08.05). The imputation model included physical activity measurements, all potential confounders, GHQ-30 scores, and use of antidepressants/daytime anxiolytics at all time points. We generated 25 data sets and undertook 10 switching procedures.

Data sets

Of the phase II cohort ($n = 2,398$), 2,201 persons (91.8 percent) had completed the GHQ-30. A total of 1,995 men had data on both leisure-time and occupational physical activity in phase II and complete data on confounders, thus comprising the data set for cross-sectional analyses.

Of the 2,201 men who completed the phase II GHQ-30, 498 men were excluded (GHQ-30 score ≥ 5 or use of antidepressants), leaving 1,703 men to form the cohort for longitudinal analyses. A total of 1,158 men completed the GHQ-30 in phases II and III, had data on leisure-time and occupational physical activity, and had complete data on confounders (short-term outcome). A total of 1,016 men comprised the data set for longer-term outcome (phases II–IV).

RESULTS

Description of cohort

In phase II, the men were, on average, aged 57 years (standard deviation, 4.5); 87.5 percent were married, and two thirds were from the lower social classes (III–V). Just over half of the men were employed, 15 percent were unemployed, and 32 percent were retired.

The men expended a median of 254 kcal/day on leisure-time physical activity (interquartile range, 122–476), and 68 percent participated in heavy-intensity leisure-time physical activities. However, among those undertaking heavy-intensity activity, this only accounted for a median of 8.7 percent (interquartile range, 2.6–24.0) of their total leisure-time energy expenditure.

Cross-sectional analysis

Men in the highest third of total leisure-time physical activity had 34 percent reduced odds of common mental disorder compared with those in the lowest third (table 1). After adjustment for confounders, men who undertook any heavy-intensity leisure-time physical activity were approximately 30 percent less likely to report common mental disorder (table 1). There was no evidence of a dose-response effect. Men in the most active jobs (class 4) were less likely to report common mental disorder, although the 95 percent confidence interval spanned unity (table 1). In analyses that used multiple imputation to deal with possible bias due to missing data, the effect estimates did not differ substantively.

Employment status, job decision latitude, demands, and satisfaction, and social class were the main contributors to the change in odds ratio observed from the unadjusted analysis to the fully adjusted analysis. Unemployed men and men who had retired because of ill health were less active at heavy intensity in their leisure time but had been more physically active in their last job and had increased odds of common mental disorder.

In analyses restricted to men who were employed ($n = 1,091$), there was some evidence that those who were most physically active at work had reduced odds of common

TABLE 1. Results of a cross-sectional analysis (phase II) assessing the independent effects of leisure-time and work-related physical activity on common mental disorder (GHQ-30* score ≥ 5) among participants in the Caerphilly Study, South Wales, United Kingdom†

Physical activity measure	No. of participants	Unadjusted‡ estimate (n = 1,995)		Fully adjusted§ estimate from complete case analysis (n = 1,995)		Fully adjusted§ estimate using the MICE* method to impute missing values (n = 2,201)	
		OR*	95% CI*	OR	95% CI	OR	95% CI
Total leisure-time activity							
Low	648	1.00		1.00		1.00	
Medium	676	1.01	0.77, 1.30	0.96	0.72, 1.27	0.94	0.72, 1.23
High	671	0.78	0.59, 1.03	0.66	0.49, 0.89	0.64	0.48, 0.86
Percentage of leisure time spent in heavy-intensity activity							
None	614	1.00		1.00		1.00	
Low	696	0.64	0.49, 0.84	0.68	0.51, 0.91	0.70	0.53, 0.93
High	685	0.58	0.44, 0.76	0.65	0.49, 0.88	0.66	0.50, 0.88
Job class (increasing activity ↓)							
Class 1	578	1.00		1.00		1.00	
Class 2	534	1.11	0.83, 1.49	1.11	0.81, 1.53	1.01	0.74, 1.37
Class 3	453	1.25	0.92, 1.68	1.20	0.85, 1.69	1.19	0.86, 1.65
Class 4	430	0.97	0.71, 1.34	0.78	0.54, 1.13	0.76	0.54, 1.08

* GHQ-30, 30-item General Health Questionnaire; MICE, multiple imputation by chained equation; OR, odds ratio; CI, confidence interval.

† Data were obtained as part of the Caerphilly Study, a cohort study (based in Caerphilly, South Wales, United Kingdom) of the determinants of coronary heart disease in middle-aged men. The cohort was established in 1979–1983, and data on physical activity were collected in phase II (1984–1988). Data on common mental disorder were collected in phase II and after 5 years (phase III: 1989–1993) and 10 years (phase IV: 1993–1997).

‡ Three physical activity exposure variables were entered in one regression model, but results were not adjusted for any other factors.

§ Adjusted for age, social class, marital status, employment status, smoking habits, alcohol consumption, social support, body mass index, high density lipoprotein cholesterol and triglyceride levels, and phase II Karasek (26) job demand variables (job decision latitude, job demands, and job satisfaction).

mental disorder (class 4 vs. class 1: odds ratio (OR) = 0.63, 95 percent confidence interval (CI): 0.34, 1.18). Total leisure-time physical activity was not important (medium vs. low: OR = 1.05, 95 percent CI: 0.69, 1.58; high vs. low: OR = 0.91, 95 percent CI: 0.57, 1.45), and only those who undertook high levels of leisure-time physical activity at a heavy intensity had reduced odds of common mental disorder (low vs. none: OR = 0.92, 95 percent CI: 0.58, 1.45; high vs. none: OR = 0.64, 95 percent CI: 0.41, 1.01).

Longitudinal analysis

5-year follow-up. In the short term, after adjustment for confounders, men who undertook any heavy-intensity leisure-time physical activity were less likely to report common mental disorder (table 2). There was little evidence of a dose-response effect. Total leisure-time physical activity was not associated with a reduction in the odds of common mental disorder. Persons in the most physically active jobs (class 4) had slightly reduced odds of common mental disorder, but the 95 percent confidence interval was wide (table 2). Restricting analyses to those who were employed

at baseline produced similar results ($n = 707$; data not shown).

10-year follow-up. There was no association between leisure-time physical activity and common mental disorder at 10 years of follow-up (table 3). Greater physical activity at work was associated with approximately 70 percent increased odds of common mental disorder at 10 years after adjustment for confounders, and this relation was evident, although attenuated, in the analysis that included imputed data. Restricting the analyses to men who were employed at baseline showed that those in the more physically active jobs had slightly elevated odds of common mental disorder, but there were no other differences ($n = 652$; data not shown).

Similar results were obtained when the incident case definition included persons who were taking antidepressants/anxiolytics (data not shown).

Missing data

From the longitudinal cohort ($n = 1,703$), 442 and 606 participants were missing outcome data in phases III and IV,

TABLE 2. Independent effects of leisure-time and work-related physical activity in phase II on common mental disorder (GHQ-30* score ≥ 5) at 5 years among participants in the Caerphilly Study, United Kingdom†

Physical activity measure	No. of participants	Unadjusted‡ estimate (n = 1,158)		Fully adjusted§ estimate from complete case analysis (n = 1,158)		Fully adjusted§ estimate using the MICE* method to impute missing values (n = 1,703)	
		OR*	95% CI*	OR	95% CI	OR	95% CI
Total leisure-time activity							
Low	361	1.00		1.00		1.00	
Medium	385	1.29	0.86, 1.93	1.34	0.88, 2.03	1.23	0.85, 1.79
High	412	1.18	0.78, 1.78	1.16	0.75, 1.80	1.04	0.70, 1.56
Percentage of leisure time spent in heavy-intensity activity							
None	320	1.00		1.00		1.00	
Low	419	0.59	0.40, 0.88	0.61	0.40, 0.93	0.79	0.54, 1.15
High	419	0.56	0.37, 0.83	0.54	0.35, 0.83	0.73	0.49, 1.09
Job class (increasing activity ↓)							
Class 1	344	1.00		1.00		1.00	
Class 2	309	1.20	0.79, 1.84	1.33	0.83, 2.13	1.23	0.80, 1.91
Class 3	250	1.18	0.75, 1.86	1.11	0.67, 1.84	1.18	0.75, 1.85
Class 4	262	0.91	0.57, 1.45	0.81	0.47, 1.39	0.94	0.59, 1.48

* GHQ-30, 30-item General Health Questionnaire; MICE, multiple imputation by chained equation; OR, odds ratio; CI, confidence interval.

† Data were obtained as part of the Caerphilly Study, a cohort study (based in Caerphilly, South Wales, United Kingdom) of the determinants of coronary heart disease in middle-aged men. The cohort was established in 1979–1983, and data on physical activity were collected in phase II (1984–1988). Data on common mental disorder were collected in phase II and after 5 years (phase III: 1989–1993) and 10 years (phase IV: 1993–1997).

‡ Three physical activity exposure variables were entered in one regression model, but results were not adjusted for any other factors.

§ Adjusted for age, social class, marital status, employment status, smoking habits, alcohol consumption, social support, body mass index, phase II GHQ-30 score, phase II high density lipoprotein cholesterol level, change in triglyceride level between phase II and phase III, and phase II Karasek (26) job demand variables (job decision latitude, job demands, and job satisfaction).

respectively. Imputation of missing data using the MICE method suggested that persons whose data were imputed were more likely to have higher GHQ-30 scores in phases III and IV and to be taking antidepressants/anxiolytics (table 4). Analyses including imputed data suggested a more conservative estimate for the effect of participating in any heavy-intensity leisure-time physical activity on common mental disorder at 5 years (in complete-case analysis, the reduction in the odds of common mental disorder was approximately 40 percent; with inclusion of imputed data, the reduction was approximately 20 percent). The evidence in support of an association was also weaker, as the 95 percent confidence interval included the null value (table 2).

DISCUSSION

Principal findings

In cross-sectional analyses, middle-aged men who undertook leisure-time physical activity at a heavy intensity and

those in the top third of total leisure-time physical activity had approximately 30 percent reduced odds of common mental disorder. There was also weak evidence suggesting that men in the most physically demanding jobs had slightly reduced odds of common mental disorder. In the short term (over 5 years), there was some evidence that the association between heavy-intensity leisure-time physical activity and common mental disorder persisted. There was no evidence to support a dose-response effect or an association between leisure-time physical activity and incident common mental disorder after 10 years.

Strengths and limitations

The Caerphilly Study cohort is a representative population-based sample of men residing in South Wales, United Kingdom, in the 1980s. The main strength of this cohort study is the collection of detailed data on leisure-time physical activity (based on the Minnesota Leisure Time Physical Activity Questionnaire (28)) together with data on physical

TABLE 3. Independent effects of leisure-time and work-related physical activity in phase II on common mental disorder (GHQ-30* score ≥ 5) at 10 years among participants in the Caerphilly Study, United Kingdom†

Physical activity measure	No. of participants	Unadjusted‡ estimate (n = 1,016)		Fully adjusted§ estimate from complete case analysis (n = 1,016)		Fully adjusted§ estimate using the MICE* method to impute missing values (n = 1,703)	
		OR*	95% CI*	OR	95% CI	OR	95% CI
Total leisure-time activity							
Low	306	1.00		1.00		1.00	
Medium	344	1.28	0.85, 1.93	1.34	0.87, 2.08	1.14	0.77, 1.70
High	366	1.17	0.77, 1.77	1.15	0.73, 1.79	1.06	0.71, 1.59
Percentage of leisure time spent in heavy-intensity activity							
None	267	1.00		1.00		1.00	
Low	370	1.04	0.69, 1.57	1.07	0.68, 1.67	1.12	0.76, 1.66
High	379	0.92	0.61, 1.40	0.96	0.60, 1.52	1.03	0.67, 1.58
Job class (increasing activity ↓)							
Class 1	317	1.00		1.00		1.00	
Class 2	273	2.14	1.39, 3.31	2.41	1.48, 3.92	2.10	1.37, 3.21
Class 3	227	1.50	0.93, 2.42	1.56	0.90, 2.69	1.40	0.86, 2.25
Class 4	207	1.87	1.17, 3.01	1.85	1.06, 3.23	1.65	1.00, 2.71

* GHQ-30, 30-item General Health Questionnaire; MICE, multiple imputation by chained equation; OR, odds ratio; CI, confidence interval.

† Data were obtained as part of the Caerphilly Study, a cohort study (based in Caerphilly, South Wales, United Kingdom) of the determinants of coronary heart disease in middle-aged men. The cohort was established in 1979–1983, and data on physical activity were collected in phase II (1984–1988). Data on common mental disorder were collected in phase II and after 5 years (phase III: 1989–1993) and 10 years (phase IV: 1993–1997).

‡ Three physical activity exposure variables were entered in one regression model, but results were not adjusted for any other factors.

§ Adjusted for age, social class, marital status, employment status, smoking habits, alcohol consumption, social support, body mass index, phase II GHQ-30 score, phase II high density lipoprotein cholesterol level, change in triglyceride level between phase II and phase IV, and phase II Karasek (26) job demand variables (job decision latitude, job demands, and job satisfaction).

activity at work (23). This contrasts with previous studies in which only information on leisure-time physical activity was collected, often using a single question. However, we acknowledge that activity levels could be measured more accurately using objective measures rather than self-reports.

We adjusted for a large number of potential confounders but cannot rule out residual confounding. For example, while we adjusted for social class (based on occupation), no data were available on other markers of socioeconomic position (e.g., housing tenure). Participants who were physically active in their leisure time may have led a healthier lifestyle, and unmeasured confounders could explain our findings.

Only half of the men were employed at the time of the phase II survey; the remainder reported on physical activity in their last job, and no data were available on time since last employment. Those who were employed may have been a select group; thus, to maintain the representativeness of our sample, in our main analyses we included all men with data on physical activity (current/most recent job). We may

have underestimated these effects. However, sensitivity analyses restricted to participants who were employed at the baseline assessment suggested few differences for the longitudinal analyses.

The questions about occupational physical activity were relatively crude, and data on physical activity were only recorded at one time point, so misclassification in exposure status may have biased our estimates. Furthermore, common mental disorder frequently has a relapsing course, so our single measurement of mental disorder at 5 and 10 years is unlikely to have captured all cases that occurred during the intervening period. Assuming that such misclassification was nondifferential, this would have attenuated any association. Finally, since the cohort comprised only men, we cannot generalize our findings to women.

The finding of *increased* odds of common mental disorder in the longer term among persons in more physically demanding jobs was unexpected. In post-hoc analyses, we hypothesized that persons in more physically demanding occupations may have less control over the demands of their

TABLE 4. Results from comparison of observed and imputed data for the 1,703 participants forming the cohort for longitudinal analyses, Caerphilly Study, United Kingdom*

	Observed data		Imputed data†,‡	
	No. of participants§	Median	No. of participants§	Median
GHQ-30¶ score				
Phase III	1,261	1	442	1
Phase IV	1,097	1	606	1
GHQ-30 score ≥5 (%)				
Phase III	1,261	15.6	442	18.1
Phase IV	1,097	18.2	606	21.8
Use of antidepressants (%)				
Phase III	1,469	0.5	234	3.4
Phase IV	1,366	1.8	337	3.9
Use of anxiolytics (%)				
Phase III	1,469	1.1	234	5.8
Phase IV	1,366	0.9	337	3.8

* Data were obtained as part of the Caerphilly Study, a cohort study (based in Caerphilly, South Wales, United Kingdom) of the determinants of coronary heart disease in middle-aged men. The cohort was established in 1979–1983, and data on physical activity were collected in phase II (1984–1988). Data on common mental disorder were collected in phase II and after 5 years (phase III: 1989–1993) and 10 years (phase IV: 1993–1997).

† Value across 25 imputation data sets. The method of multiple imputation by chained equation (MICE) (27) was used to impute missing values.

‡ Additional variables included in the imputation model: alcohol consumption, body mass index, Karasek (26) job demand variables (job decision latitude, job demands, and job satisfaction), social class, employment status, smoking status, leisure-time and occupational physical activity, high density lipoprotein cholesterol and triglyceride levels, and phase II GHQ-30 score.

§ Number of persons with observed data or for whom data were imputed. Where fewer than 25 observations were imputed, data are not presented.

¶ GHQ-30, 30-item General Health Questionnaire.

work, which may adversely affect their long-term mental health and consequently counterbalance any benefit of greater physical activity; however, adjustment for indicators of job control did not substantially attenuate this effect. Alternatively, in persons who are physically active but who stop such activity, this change may have a greater influence on their mental health than having never undertaken such activity. However, we cannot explore this hypothesis given the lack of activity data in later years. This requires clarification in future studies.

Differences between participants who were followed in phases III and IV and those who were lost to follow-up may have biased the findings from the complete-case analysis. Therefore, in sensitivity analyses, we examined the influence of missing data on the findings. Comparing observed data and imputed data, we found that participants with missing data had higher GHQ-30 scores and were therefore more likely to have had common mental disorder at the time of follow-up. In order for our effect estimate to have been attenuated compared with findings from the complete-case data set, the effect of physical activity would have had to be

weaker in this group. The validity of the imputed data is dependent on correct specification of the imputation model, but this cannot be tested empirically. We included all of the variables that we believed would be strongly associated with the likelihood of a subsequent value's being missing, including age and severity of common mental disorder (GHQ-30 score) at earlier (and later) time points. The conclusions we have drawn from the analysis including imputed data and the complete-case analysis do not differ substantially. Heavy-intensity leisure-time physical activity was associated with a small reduction in the odds of common mental disorder in the short term (over 5 years). However, results from the analysis including data imputed by the MICE method suggested that the size of the effect was smaller (compared with the complete-case analysis) and, given that the 95 percent confidence interval surrounding the effect estimate included unity, provided weaker evidence to support an association. The possibility of no association cannot be ruled out. In order to obtain a more precise estimate of such a small effect, we would require a much larger sample.

Comparison with existing data

In previous studies, investigators have found associations in persons with sedentary occupations (12) or have analyzed select groups (9, 13, 17) from which it is difficult to make generalizations. The evidence from previous population-based cohort studies (7, 8, 14–16) is mixed.

Two of four previous population studies supported an association between physical activity and mental health. In the First National Health and Nutrition Examination Survey, Farmer et al. (7) found that women had increased odds of incident depression over a period of 8 years (after adjustment for age, physical health, and markers of socioeconomic status, OR = 1.9, 95 percent CI: 1.1, 3.2), but no such increase was seen for men (adjusted OR = 1.3, 95 percent CI: 0.5, 3.1). More detailed information on leisure-time physical activity was recorded in the Alameda County Study (8). Men and women undertaking low levels of activity had 70 percent increased odds of incident depression after adjustment for confounders. A beneficial effect of physical activity on mental health over a period of 5 years was reported in later follow-up of this cohort when participants were, on average, aged 63 years (14). In contrast, among older persons (mean age = 71 years) in the Rancho Bernardo Study, change in Beck Depression Inventory score over 8 years was not significantly different for participants who had and had not undertaken regular strenuous exercise (16). Physical activity was assessed by means of a single question in the Rancho Bernardo Study, and thus misclassification of exposure status may have attenuated any effect. Weyerer (15) also found little longitudinal evidence to support an association over 5 years of follow-up, but detailed exposure data were lacking.

To our knowledge, only one previous study (7) considered nonrecreational physical activity, but this was limited to a single question. Women who undertook little or no activity apart from recreation had twofold increased odds of depression cross-sectionally, but there was little evidence to support an association for men (7). The role of nonrecreational activity was not explored in the longitudinal analyses.

Mechanisms underlying an association between physical activity and common mental disorder

Our findings are consistent with evidence from randomized controlled trials suggesting that physical activity is, in the short term, an effective treatment for mild-to-moderate depression (29). Possible biologic explanations for an association between physical activity and common mental disorder are poorly understood. Reductions in hippocampal volume and the number of glial cells in the prefrontal cortex and amygdala have been implicated in the pathophysiology of depression (30). Substances such as brain-derived neurotrophic factor promote cell survival, and indirect regulation of such substances may explain some of the effectiveness of antidepressants (30). Animal studies suggest that exercise raises levels of brain-derived neurotrophic factor (31), promotes cell proliferation (32), and stimulates 5-hydroxytryptamine release (33). There is also some evidence that physical activity reduces cortisol levels (34). Other investi-

gators have focused on the relation between physical activity and changes in psychosocial factors (e.g., body image (35), self-esteem (36)) which may affect mental health, and there is interest in the role of social support in physical activity (37).

Implications of this study

Official reports from both the United States (38) and the United Kingdom (1) recommend that people undertake at least 30 minutes of physical activity on at least 5 days of the week. Such guidance is particularly challenging, as many people who engage in physical activity do not maintain this. With sedentary occupations increasingly becoming the norm, the role of leisure-time physical activity is becoming increasingly important. The widespread encouragement to lead a physically active lifestyle in order to gain the recognized benefits for physical health may also have modest short-term benefits for mental health.

Conclusions and directions for future research

In summary, heavy-intensity leisure-time physical activity among these middle-aged men was associated with a small reduction in the likelihood of common mental disorder over 5 years. There was no evidence for an association over the longer term. In future research, investigators should examine cohorts of men and women followed regularly with repeated measures of both leisure-time physical activity and activity undertaken in the workplace, in order to ascertain the independent effects of these physical activity components on mental health. Investigators in future studies should also pay closer attention to the potential mechanisms underlying any possible association.

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