

Inverse Association between Physical Inactivity and Mental Health in Men and Women

DANIEL I. GALPER¹, MADHUKAR H. TRIVEDI¹, CAROLYN E. BARLOW², ANDREA L. DUNN³, and JAMES B. KAMPERT²

¹Mood Disorders Research Program and Clinic, University of Texas Southwestern Medical Center at Dallas, Dallas, TX; ²The Cooper Institute, Dallas, TX; and ³The Cooper Institute, Denver, CO

ABSTRACT

GALPER, D. I., M. H. TRIVEDI, C. E. BARLOW, A. L. DUNN, and J. B. KAMPERT. Inverse Association between Physical Inactivity and Mental Health in Men and Women. *Med. Sci. Sports Exerc.*, Vol. 38, No. 1, pp. 173–178, 2006. **Purpose:** The Aerobics Center Longitudinal Study (ACLS) provides the opportunity to evaluate associations between measures of physical activity and mental health in a large and well-characterized population of men and women. **Methods:** Participants were 5451 men and 1277 women (20–88 yr) who completed a maximal fitness treadmill test and self-report measures of habitual physical activity, depressive symptoms (Center for Epidemiological Studies Scale for Depression; CES-D) and emotional well-being (General Well-Being Schedule; GWB). To evaluate the dose–response gradient of the association, we classified the sample, separately for men and women, into three levels of relative cardiorespiratory (CR) fitness (low, moderate, high) on the maximal treadmill test, and four levels on a physical activity index of weekly walking, jogging, and running. **Results:** In both men and women, there was a significant inverse graded dose–response relationship between maximal CR fitness and the CES-D score ($P < 0.0001$), and a significant positive graded dose–response relationship between CR fitness and the GWB score ($P < 0.0001$). We also observed dose–response associations between the level of physical activity and both CES-D and GWB scores ($P < 0.0001$) that peaked at 11–19 miles per week. **Conclusion:** Among men and women in the ACLS, relative increases in maximal CR fitness and habitual physical activity are cross-sectionally associated with lower depressive symptomatology and greater emotional well-being. Prospective epidemiological studies and controlled clinical trials are needed to identify the minimal and optimal levels of physical activity and CR fitness associated with various mental health benefits in different segments of the general population. **Key Words:** CARDIORESPIRATORY FITNESS, DEPRESSION, CES-D, WELL-BEING

Unipolar depression manifests along a continuum from normative subthreshold depressive symptoms to severe major depressive disorder (MDD) and imposes a substantial personal, social, economic, and health care burden (15,21). Depressive symptoms are associated with reduced functional status and impaired occupational performance, as well as multiple chronic health problems, including osteoporosis, diabetes, and cardiovascular disease (CVD) (10,18). Indeed, many epidemiological studies implicate depression as a risk factor for CVD morbidity and mortality, even after controlling for a wide range of covariates, such as age, body mass index (BMI), socioeconomic status, and medical burden (23,24).

Physical inactivity is one of the most important behavioral risk factors for CVD morbidity and mortality in adults (3,22,32). Moreover, maximal cardiorespiratory (CR) fitness, a valid surrogate for habitual physical activity in epidemiological research, is more strongly associated with CVD outcomes than self-reported physical activity (3,4,19). Many observational studies show an inverse graded dose–response relationship between self-reported habitual activity, or CR fitness, and adverse health outcomes (3,16). For instance, among men and women in the Aerobics Center Longitudinal Study (ACLS), low levels of physical activity and CR fitness are strongly predictive of CVD morbidity and mortality, and participants with modest increases in physical activity and CR fitness exhibit a significantly reduced incidence of CVD and CVD and all-cause mortality at follow-up (3,4).

In the general population, physical activity may be inversely associated with psychiatric morbidity and psychosocial function, including depression and emotional well-being (6,11,13,32). For instance, a number of cross-sectional studies found lower depressive symptomatology among physically active men and women (1,28,34). Prospective studies have also found individuals who increase physical activity at reduced risk of exhibiting depressive symptoms or developing a depressive disorder (29,33). Moreover, several investigators reported significantly re-

Address for correspondence: Madhukar H. Trivedi, M.D., Mood Disorders Research Program and Clinic, Department of Psychiatry, University of Texas Southwestern Medical Center at Dallas, Exchange Park Express, American General Tower, 6363 Forest Park, Suite 13.354, Dallas, TX 75235; E-mail: Madhukar.Trivedi@UTSouthwestern.edu.

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duced CR fitness among men and women with depressive symptoms or disorders (14,20). Yet there is conflicting evidence for a graded dose–response association between physical activity or CR fitness and depressive symptoms (11,32).

In contrast to depression, emotional well-being is a subjective state of wellness, happiness, and life satisfaction (9). Emotional well-being is a primary component of health-related quality of life (HRQOL) that may be independently associated with morbidity and mortality (7,9,32). It is therefore critical to determine whether physical activity is related to emotional well-being within different segments of the population. Furthermore, from a public health perspective, it is important to establish the gradient of the association between physical activity, or CR fitness, and measures of positive psychosocial function, including emotional well-being (22,32).

There are currently insufficient data suggesting the minimal or optimal levels of habitual physical activity, or CR fitness, associated with mental health benefits to inform public health policy and research. To our knowledge, no observational studies have examined the gradient of the association between CR fitness and either depressive symptoms or emotional well-being in a community-based population of healthy men and women. Therefore, in the present study, we evaluated cross-sectional associations between established measures of physical activity and maximal CR fitness with depressive symptoms and emotional well-being in a sample of participants from the ACLS. We specifically sought to provide data that address the following two questions: 1) Is physical activity, or maximal CR fitness, significantly associated with depressive symptoms or emotional well-being in men and women? 2) Is there evidence of a dose–response relationship between physical activity, or maximal CR fitness, and depressive symptoms or emotional well-being?

METHODS

Study Population

ACLS population. The ACLS is an ongoing NIH-funded cohort study examining morbidity and mortality in relation to physical activity and physical fitness (3,4,8). The ACLS data come from patients who receive comprehensive health examinations at the Cooper Clinic, a specialty preventive medicine practice in Dallas, TX, serving anyone who elects to come for an examination. All patients receive a maximal treadmill test, provide a complete medical history, and are followed for morbidity and mortality. The ACLS cohort is a well-characterized population, and numerous papers have described associations between physical fitness, physical activity, and various diseases (3–5,8,17). The Cooper Clinic has a marketing department that broadly promotes its services through mass media and occupational groups. Patients come from all 50 states; they are generally well-educated (80% college graduates), non-Hispanic whites (>97%) from middle to upper socioeco-

omic strata. Individuals from lower SES strata and ethnic minorities are underrepresented in the ACLS database because relatively few are patients at the Cooper Clinic. Most patients are self-referred, although a substantial (but unknown) number are referred by their employers. The ACLS includes adults (at least 18 yr of age) who are sufficiently motivated and able-bodied to come to the Cooper Clinic for an examination. The health status of ACLS participants is reportedly better than that of the general population (4,18). The ACLS study is approved annually by The Cooper Institute's institutional review board.

All participants provided written informed consent before their examination to allow their examination data to become part of the ACLS. During the examination at the Cooper Clinic, participants complete a maximal exercise treadmill test to estimate CR fitness, as well as self-report measures of physical activity, depressive symptoms, and emotional well-being. The sample in this report includes all men ($N = 5451$) and women ($N = 1277$) from ACLS who received an examination between 1986 and 1994 and achieved at least 85% of their age-predicted maximal HR during the treadmill test ($220 - \text{age (yr)}$). Due to missing data on the self-report questionnaires, the analysis for physical activity includes 5307 men and 1248 women, and the analysis for CR fitness includes 5230 men and 1222 women. Further details about the methods and procedures of the ACLS are reported elsewhere (3,4).

Measures

Physical activity. Physical activity was assessed using a questionnaire that measures participation in 18 common leisure-time, recreational, and sports activities over the past 3 months (17). Walking, jogging, and running are the predominant types of physical activity reported by participants in the ACLS and the general population (8,22). Indeed, less than 2% of participants in the ACLS (1% of men and 2% of women) engage in leisure-time or sports activities other than walking, jogging, or running. Therefore, we operationalized physical activity exposure using a physical activity index (PAI) that classifies walking, jogging, and running into four mutually exclusive categories: 1 = walking, jogging, and running <1 mile per week (inactive); 2 = walking, jogging, and running 1–10 miles per week (insufficiently active); 3 = walking, jogging, and running 11–19 miles per week (sufficiently active); and 4 = walking, jogging, and running ≥ 20 miles per week (highly active). Slightly different physical activity categories have been used by other investigators to evaluate dose–response relationships and health outcomes (11,32); however, we elected to use the PAI because it has proven to be a valid and sensitive measure of habitual physical activity within the ACLS population (5,17).

Cardiorespiratory fitness. CR fitness is defined as the time to volitional exhaustion (in seconds) on a maximal treadmill test using a modified Balke protocol (4). The treadmill speed began at $88 \text{ m}\cdot\text{min}^{-1}$ (3.3 mph), with a 0% grade for the first minute, a 2% grade for the second minute, and 1% increases in grade each minute thereafter until the

25th minute. For participants who remained after 25 min, the speed was increased by 5.4 m·min⁻¹ (0.2 mph) each minute until the test was completed. This treadmill protocol is highly correlated with direct measures of maximal oxygen uptake in both men ($r = 0.92$ (25)) and women ($r = 0.94$; (26)). Hence, this measure of CR fitness is equivalent to maximal aerobic power (4). Using the same approach as previous studies (3), we classified the ACLS participants, separately for men and women, into three levels of relative CR fitness within decades of age: 1 = lowest 20% of participants (low CR fitness); 2 = next 40% of participants (moderate CR fitness); and 3 = highest 40% of participants (high CR fitness).

Depressive symptoms. The Center for Epidemiologic Studies Depression Scale (CES-D) was used to quantify depressive symptoms experienced by participants during the previous week (2,28). This 20-item self-report scale generates a total severity score ranging from 0 to 60. Although it is not diagnostic, the CES-D is a valid and reliable measure of depressive symptomatology among adults in the general population (2,24).

Emotional well-being. The General Well-Being Schedule (GWB) (12) was used to quantify emotional well-being over the past month. This 18-item self-report scale was developed by the National Center for Health Statistics to measure life satisfaction, freedom from health concerns, positive affect, and an absence of negative affect in population surveys. Total GWB scores range from 0 to 110, with higher scores marking an expression of positive feelings and an absence of negative feelings (28). This measure has been found to have good to excellent reliability and construct validity (12,30).

Statistical Analysis

Descriptive statistics were calculated for each variable. To examine dose–response relationships, the exposure measures (PAI and CR fitness) were treated as discrete categorical variables and the mental health outcomes (CES-D and GWB scores) were treated as continuous variables. Mean differences in CES-D and GWB scores among each of the physical activity and CR fitness categories were tested using ANCOVA, separately for men and women. In these models, physical activity (four levels of PAI: inactive, insufficiently active, sufficiently active, highly active) and CR fitness (three levels: low, moderate, high) were the independent variables, CES-D and GWB scores were the dependent variables, and age, body mass index (BMI), and years of participation in the ACLS were included as covariates. Subsequently, we evaluated group differences in least-squares adjusted mean CES-D and GWB scores across levels of physical activity and CR fitness with a series of planned pairwise comparisons.

RESULTS

Participant characteristics. Characteristics of the men ($N = 5451$) and women ($N = 1277$) in the study sample are presented in Table 1. Additionally, among the men, 6%

TABLE 1. Characteristics of men and women in the sample.

Variable	Men ($N = 5451$)	Women ($N = 1277$)
Age (yr)	49.5 (10.4)	48.1 (11.1)
Physical activity (miles per week)	6.7 (11.4)	2.8 (8.2)
Treadmill time (s)	1179.7 (306.3)	855.1 (297.1)
BMI ($\text{kg}\cdot\text{m}^{-2}$)	26.0 (3.5)	23.0 (3.8)
CES-D* score	7.0 (6.8)	9.6 (8.6)
GWB† score	72.4 (14.0)	77.7 (16.7)
SBP (mm Hg)	121.6 (13.6)	113.5 (14.6)
DBP (mm Hg)	80.8 (9.2)	75.9 (9.5)
Total cholesterol ($\text{mg}\cdot\text{dL}^{-1}$)	213.1 (53.6)	207.9 (42.6)
HDL cholesterol ($\text{mg}\cdot\text{dL}^{-1}$)	48.9 (14.4)	64.9 (15.6)

* CES-D, Centers for Epidemiologic Studies Depression Scale.

† GWB, National Center for Health Statistics General Well-Being Schedule.

(310) exhibited low CR fitness, 25% (1348) exhibited moderate CR fitness, and 69% (3694) exhibited high CR fitness. A similar pattern was observed among women: 8% (97) exhibited low CR fitness, 27% (344) exhibited moderate CR fitness, and 65% (805) exhibited high CR fitness. Based on the PAI, 27% (1454) of the men were classified as inactive, 35% (1892) as insufficiently active, 26% (1396) as sufficiently active, and 13% (709) as highly active; likewise, 33% (422) of the women were classified as inactive, 35% (443) as insufficiently active, 22% (283) as sufficiently active, and 10% (129) as highly active.

Cardiorespiratory fitness and depressive symptoms. ANCOVA demonstrated an inverse association between CR fitness and estimated mean CES-D scores for both men ($F(5, 5229) = 28.45, P < 0.0001$) and women ($F(5, 1221) = 13.27, P < 0.0001$). Planned pairwise contrasts demonstrated significant differences in CES-D scores (all P values < 0.005) between the low, moderate, and high CR fitness groups among men and women (Fig. 1). Thus, we observed an inverse graded dose–response relationship between CR fitness and depressive symptomatology for both men and women.

Physical activity and depressive symptoms. ANCOVA demonstrated an inverse association between physical activity and estimated mean CES-D scores for both men ($F(6, 5306) = 20.93, P < 0.0001$) and women ($F(6, 1247) = 11.80, P < 0.0001$). As depicted in Figure 2, inactive men exhibited greater depressive symptom severity than insufficiently active men ($P < 0.0001$) and highly active men ($P < 0.0001$). Moreover, insufficiently active men exhibited

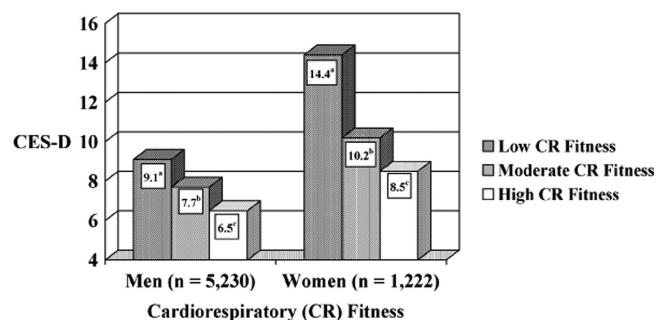


FIGURE 1—Mean scores for depressive symptoms by CR fitness level, adjusted for age, BMI, and years of participation. Superscripts indicate significant differences between CR fitness groups (all P values < 0.005).

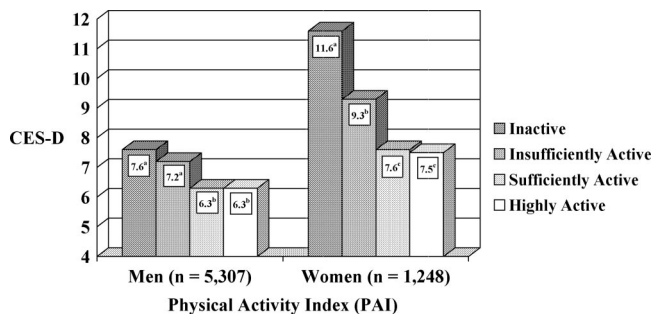


FIGURE 2—Mean scores for depressive symptoms by physical activity level (PAI), adjusted for age, BMI, and years of participation. Superscripts indicate significant differences between physical activity groups (all P values < 0.007). PAI levels: inactive, < 1 mile per week of walking, jogging, and running; insufficiently active, 1–10 miles per week; sufficiently active, 11–19 miles per week; highly active, ≥ 20 miles per week.

greater depressive symptom severity than sufficiently active men ($P < 0.0001$) and highly active men ($P < 0.0014$). There were no other statistically significant differences between physical activity groups among the men.

Inactive women exhibited greater depressive symptom severity than insufficiently active women ($P < 0.0001$), Sufficiently active women ($P < 0.0001$) and highly active women ($P < 0.0001$). Furthermore, insufficiently active women exhibited greater depressive symptomatology than sufficiently active ($P < 0.0067$) and highly active women ($P < 0.0001$). There were no other statistically significant differences between physical activity groups among the women.

Cardiorespiratory fitness and emotional well-being. ANCOVA demonstrated a positive association between CR fitness and estimated mean GWB scores among both men ($F(5, 5224) = 97.09, P < 0.0001$) and women ($F(5, 1221) = 28.41, P < 0.0001$). As presented in Figure 3, planned pairwise contrasts showed significant differences (all P values < 0.0001) in emotional well-being between low, moderate, and high CR fitness groups in men and women. Thus, we observed a positive graded dose–response relationship between CR fitness and emotional well-being among both men and women.

Physical activity and emotional well-being. ANCOVA demonstrated a positive association between physical activity and estimated mean GWB scores in men ($F(6, 5306) = 78.65, P < 0.0001$) and women ($F(6, 1247) =$

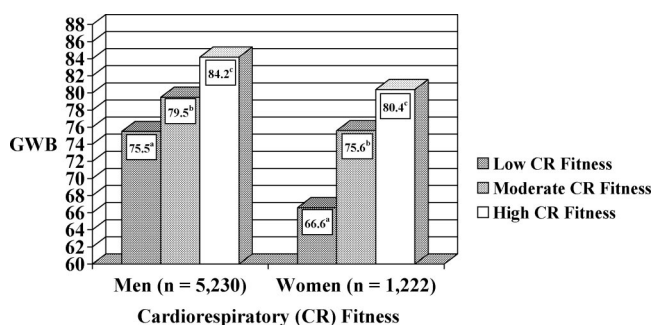


FIGURE 3—Mean scores for emotional well-being by CR fitness level, adjusted for age, BMI, and years of participation. Superscripts indicate significant differences between CR fitness groups (all P values < 0.0001).

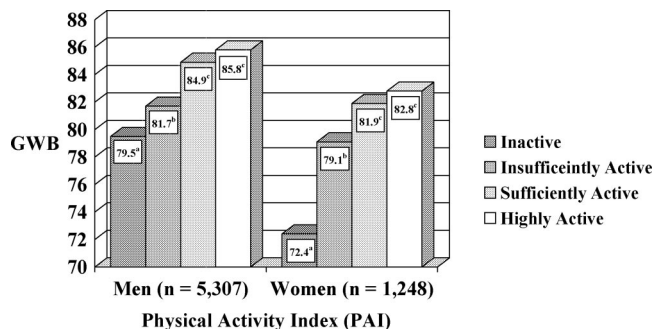


FIGURE 4—Mean scores for emotional well-being by physical activity level (PAI), adjusted for age, BMI, and years of participation. Superscripts indicate significant differences between physical activity groups (all P values < 0.03). PAI levels: inactive, < 1 mile per week of walking, jogging, and running; insufficiently active, 1–10 miles per week; sufficiently active, 11–19 miles per week; highly active, ≥ 20 miles per week.

24.82, $P < 0.0001$). As presented in Figure 4, inactive men exhibited lower emotional well-being than insufficiently active men ($P < 0.0001$), sufficiently active men ($P < 0.0001$), highly active men ($P < 0.0001$). Insufficiently active men also exhibited lower emotional well-being than sufficiently active men ($P < 0.0001$) and highly active men ($P < 0.0001$). There were no other statistically significant differences between physical activity groups among the men.

Inactive women exhibited lower emotional well-being than insufficiently active women ($P < 0.0001$), sufficiently active women ($P < 0.0001$), and highly active women ($P < 0.0001$). Moreover, as shown in Figure 4, insufficiently active women displayed lower emotional well-being than sufficiently active women ($P < 0.0240$) and highly active women ($P < 0.0224$). There were no other statistically significant differences between physical activity groups among the women.

DISCUSSION

The ACLS provides an excellent opportunity to evaluate cross-sectional associations between physical activity exposure, measured via a maximal treadmill test and a self-report questionnaire, and both depressive symptoms and emotional well-being in a large and well-characterized sample of men and women. To the best of our knowledge, this is the first community-based observational study to evaluate associations between maximal aerobic power and divergent components of mental health in men and women, and one of the few epidemiological studies to assess the gradient of the dose–response relationship between physical activity and either depressive symptoms or emotional well-being in healthy adults (11).

Our results showed clear graded dose–response relationships between maximal CR fitness and depressive symptomatology and emotional well-being in both men and women. Although some prior research suggests that depression may be independent of CR fitness (32), recent studies have reported significant negative associations between depressive symptoms and health-related fitness, when fitness was operationalized using measures of maximal aerobic power (14,20).

A series of prospective studies from the ACLS found men and women in the low CR fitness category (i.e., bottom 20% of ACLS participants) at significantly increased risk of CVD morbidity and mortality (3,4). Our results further indicate that this population segment is characterized by significantly more depressive symptomatology and significantly lower emotional well-being than men and women with moderate to high CR fitness. Indeed, the adjusted mean CES-D score of women with low CR fitness in the present sample was 14.4, which approaches the score of 16 that is often used to identify subclinical or minor depression, as well as to screen for MDD in the general population (2,23,24). Depressive symptoms of this magnitude have been independently associated with incident CVD and all-cause mortality (20,34), functional impairment, excess costs, and increased risk of MDD (15).

Consistent with prior observational studies, we also found an inverse cross-sectional association between physical activity and depressive symptomatology (1,28,29) and emotional well-being (28,30). Taylor and colleagues (30) observed an inverse association between physical activity and the GWB score in overweight and obese African-American women, but they did not evaluate the dose–response relationship. The dose–response relationship found in our study is similar to data reported by Stephens (28) using a nationally representative cohort of men and women in the National Health and Nutrition Examination Survey I (NHANES I). Our results are also consistent with those of Brown et al. (6), who found dose–response relationships between physical activity and both the physical and mental components of HRQOL using a large sample ($N = 175,850$) of adults who participated in the 2001 Behavioral Risk Factor Survey Schedule (BRFSS).

Our study has several strengths that are unique to the literature. First, we measured CR fitness with a standardized maximal treadmill test, a valid and objective marker of habitual physical activity that is more reliable than the self-report measures of physical activity used in previous population-based studies (3,19). Second, the large sample of men and women enabled us to examine dose–response relationships. Third, we used well-established and validated measures of physical activity, depressive symptoms, and emotional well-being.

The major limitation of this study is the cross-sectional design that precludes us from inferring cause–effect relationships. Indeed, more active individuals may have reported lower depressive symptomatology and higher emotional well-being either because physical activity has a beneficial effect on these outcomes or because participants with better mental health tend to be more physically active. In addition, the association between physical activity and mental health could be mediated by one or more unknown common variables, including social support (1,11). However, relationships between physical activity and various mental health outcomes are undoubtedly complex and bidirectional; for instance, physical inactivity is likely to be both a cause and a consequence of depressive symptoms (11,24).

Although we used an index of habitual physical activity that has been validated against maximal CR fitness in the ACLS population (8,17), it is important to acknowledge the limitations of this measure. First, the PAI does not include physical activity other than walking, jogging, and running, and the PAI categories are fairly broad, so our results may not generalize to other types or measures of physical activity. The analyses presented here show that depression and emotional well-being reached a plateau at 11–19 miles per week of walking, jogging, and running on the PAI (see Figs. 2 and 4). It is noteworthy that this weekly dose of physical activity is equivalent to 1100–1900 kcal·wk⁻¹, or approximately 2–3 miles or 30 min of aerobic activity on most days of the week, which is “sufficiently active” to attain most health benefits according to current public health recommendations for physical activity in adults (22,32). However, some research suggests that the intensity, frequency, or duration of physical activity may be independently associated with health outcomes (7,16). We were not able to examine these parameters because they are not part of the PAI. If we had been able to investigate other measures or categories of physical activity, we may have found different dose–response relationships. For instance, our results may have been more consistent with evidence of a nonlinear dose–response relationship (7).

Third, the ACLS cohort, although large, is not representative of the general population; therefore, our results may not generalize beyond predominantly white and well-educated men and women from middle to upper socioeconomic strata. However, the internal validity of this research is not affected by the nature of the population (4). Fourth, with the exception of CR fitness, which is an objective measure of work capacity, the results of this study depend on the reliability and validity of self-report measures of physical activity, depressive symptoms, and emotional well-being. On the other hand, recent literature on depression has clearly emphasized the validity of self-rated assessments of depressive symptoms and emotional well-being (32).

In summary, this cross-sectional study, using a large sample of men and women from the ACLS, showed an inverse dose–response association between physical activity/maximal CR fitness and depressive symptomatology, and a positive dose–response association between physical activity/maximal CR fitness and emotional well-being. Additionally, the results suggest that modest volumes of weekly physical activity that have been prospectively associated with moderate to high levels of maximal CR fitness and reduced CVD morbidity and mortality in the ACLS (3,4) and elsewhere (16,19) are also associated with lower depressive symptomatology and greater emotional well-being. The external validity of our study is limited by the cross-sectional design and the relatively homogeneous sample of healthy men and women from middle to upper socioeconomic strata; yet, the associations are consistent with our conviction that physical activity is a particularly beneficial behavior for persons with chronic diseases, including MDD and CVD, due to the combined effects on both physical and mental health. Prospective epidemiological studies and con-

trolled clinical trials are needed to determine the minimal and optimal levels of physical activity associated with depression, emotional well-being, and other mental health outcomes in different segments of the general population.

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