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Part G. Section 8: Mental Health

Introduction

Poor mental health, including diseases of the central nervous system (CNS), reduces the quality of life and adds a burden on public health. People with anxiety or depression disorders are more likely to have chronic physical conditions (1), and depression and dementia were among the 10 leading risk factors of disability-adjusted life expectancy in high-income nations worldwide during 2001 (2). They are projected to rank first and third by the year 2030 (3). In the United States, dementia and other CNS disorders are a leading cause of death, and mental disorders are estimated to account for more than 40% of years lost to disability (4).

The scientific evidence from prospective cohort studies and randomized controlled trials (RCTs) supports the overall conclusion that regular participation in moderate-to-vigorous physical activity is associated with improved aspects of mental well-being and reduced symptoms of several mental health disorders.

Review of the Science

Overview of Questions Asked

This chapter addresses 7 general questions about physical activity and mental health conditions. Each question includes subsections that focus on whether physical activity can protect against the onset of, or reduce, symptoms; whether the effects of physical activity on the symptoms differ by age, sex, race/ethnicity, or medical condition; and whether the effects of physical activity differ by the type, intensity, or timing of the physical activity. The general questions are:

1. Is there an association between physical activity and depression?
2. Is there an association between physical activity and anxiety?
3. Is there an association between physical activity and distress and well-being?
4. Is there an association between physical activity and cognitive function and dementia?
5. Is there an association between physical activity and sleep?

6. Is there an association between physical activity and other aspects of mental health?

7. Is there an association between physical activity and adverse psychological events?

The chapter also considers a final question dealing with mechanisms that could plausibly explain the association between physical activity and mental health.

Data Sources and Process Used to Answer Questions

To provide evidence-based answers to the above questions, the Mental Health subcommittee obtained data from a search of the *Physical Activity Guidelines for Americans* Scientific Database (see ***Part F: Scientific Literature Search Methodology,*** for a full description of the Database), which contains studies published in 1995 and later. Conclusions regarding the evidence-based review were restricted to results of RCTs and observational studies that used a prospective cohort design. Findings from selected cross-sectional, observational studies are presented when they provided additional information for questions that had a limited number of RCTs and prospective cohort studies (e.g., anxiety disorders and sleep). Studies of physical activity and mental health published since 1995 were evaluated using meta-analytic or otherwise systematic reviews when they were available. When such reviews were not available or were not sufficiently current, a systematic quantitative synthesis of results from published studies was conducted using a random effects model that weights results by the size of each study and variation in the effects across studies. Odds ratios in observational studies and standardized effect sizes in RCTs were retrieved from the published papers, or they were otherwise estimated from data and test statistics reported in the papers (5).

Question 1: Is There an Association Between Physical Activity and Depression?

Introduction

The American Psychiatric Association (6) recognizes 4 types of mood disorders: (1) *depression*, (2) *bipolar or manic-depressive disorder*, (3) mood disorders due to a *medical condition*, and (4) *substance-induced* mood disorders. Depression has an annual prevalence of about 8% among women and 4% among men worldwide and in the United States. The annual cost of depression in the United States is estimated at $83 billion per year (7). This condition includes a mild chronic form, *dysthymia*, and a more severe form, *major depressive disorder*. The rate of major depression has increased steadily during the past 50 years, with a lifetime prevalence of about 16%; the rate is higher among Hispanics than whites, and lowest, though still substantial, among African Americans. The lifetime rate of depression among adults aged 30 to 60 years is about twice the rate among people older than age 60 years (8).

People have a major depressive episode when they have depressed mood or lose interest or pleasure in normal activities most of the time for at least 2 weeks. Other symptoms include abnormalities in appetite, libido, sleep, energy levels, concentration and, often, suicidal thoughts. In some cases, anxiety and motor agitation can be more prominent symptoms than depressed mood. Also, mood disturbance can be less apparent than other features such as irritability, abuse of alcohol, and worsening of comorbid phobias, obsessions, or preoccupation with physical symptoms. Depression is not considered a major depressive episode if it is caused by grief (less than 2 months), drug abuse or medication, or a medical condition such as hyperthyroidism, heart disease, diabetes, multiple sclerosis, hepatitis, or rheumatoid arthritis. Many older patients with symptoms of depression do not meet the full criteria for major depressive disorder. If they have similar, but fewer, symptoms they may have *minor depression*, a sub-syndromal form of depression.

Does Physical Activity Protect Against the Onset of Depression Disorders or Depression Symptoms?

Conclusions

Population-based, prospective cohort studies provide substantial evidence that regular physical activity protects against the onset of depression symptoms and major depressive disorder. Evidence is insufficient to draw conclusions about bipolar disorder and other mood disorders.

Rationale

An association between physical activity and reduced symptoms of depression among adults has been generally supported in more than 100 population-based observational studies published since 1995, including nationally representative samples of nearly 190,000 Americans (9-15). Most of the studies looked at cross-sectional associations, which indicated that active people on average had nearly 45% lower odds of depression symptoms than did inactive people. In the national samples of Americans, active people had approximately 30% lower odds of depression.

Twenty-eight of the studies used a prospective cohort design, which reduces the likelihood that the association is explainable by people becoming less active after they experience depression symptoms. The median follow-up was about 4 years, and the range was 9 months to 37 years. The studies came from 11 nations (Australia, Canada, China, England, Finland, Germany, Israel, Italy, Netherlands, Japan), including 13 studies from the United States. In the cohort studies, the average odds of elevated symptoms were about 25 to 40% lower among active compared with inactive people, without adjustments for depression risk factors that might have differed between the active and inactive groups (OR = 0.67, 95% CI = 0.59 to 0.77). After adjustment for risk factors, such as age, sex, race, education, income, smoking, alcohol use, chronic health conditions, and other social and psychological variables, the odds remained nearly 15 to 25 percent lower among active people (OR = 0.82, 95% CI = 0.78 to 0.86).

Nearly all the comparisons (66 of 67) in the cohort studies showed less depression among physically active than inactive adults, but half the results did not reach statistical significance, often because the sample sizes were not big enough. The average number of people for each comparison was about 1,100 people, but a fourth of the comparisons included 500 people or fewer. Studies of 8 cohorts (16-23) used a clinical diagnosis to measure depression symptoms, reporting a reduction in the odds of incident cases of depression that averaged 30 percent (OR = 0.71, 95% CI: 0.61 to 0.77) among active people compared to inactive or low active people. In those studies, 18 of 19 comparisons favored active people, and nearly half the comparisons were statistically significant. Thus, the protective effect of physical activity is not limited to self-rated symptoms measured by questionnaires. Figures G8.1a and G8.1b illustrate crude and adjusted odds ratios and 95% confidence intervals from the 28 prospective cohort studies of physical activity and depression in nearly 40,000 adults from 11 countries, including 11 studies from the United States.

Does Physical Activity Reduce Symptoms of Depression?

Conclusions

The results of RCTs indicate that participation in physical activity programs reduces depression symptoms in people diagnosed as depressed, healthy adults, and medical patients without psychiatric disorders.

Rationale: Depressed Patients

A meta-analysis of 14 RCTs of chronic exercise among people diagnosed with depression (24) reported a cumulative, mean reduction in depression symptoms of 1.1 SD (95% CI: 1.5 to 0.60). However, the studies had scientific weaknesses that made it hard to conclude that the reduced depression symptoms were the independent result of exercise, and only 2 of the studies had been published after 1995 (25;26). Since that review, at least 11 RCTs have used exercise training to reduce depression symptoms in about 500 depressed patients. In 3 studies (27-29), depression was identified using cut-point scores on symptom questionnaires that have good predictive validity as screening tests to detect depression. In another 8 studies (30-37), patients were identified by diagnostic interview as having major depressive disorder, minor depression, or dysthymia.

In the studies published since the Lawlor & Hopker review (24), the average effect of exercise for symptom reduction was 1.1 SD (95% CI: 1.55 to 0.64) compared to a no treatment control group, virtually identical to the Lawlor & Hopker results. These recent studies compared the effects of exercise to a placebo (29;32-34;36;38) or to drug therapy (30;38) or bright light therapy (35). The reductions, on average, favored exercise over placebo (0.35 SD, 95% CI: 0.49 to 0.22), and 6 of 14 comparisons were statistically significant. The average sample size was 58 people, but 25% of the studies had 25 people or fewer. Symptom reduction after exercise was similar to drug therapy and similar or superior to bright light therapy. Four of the studies reported that reductions in symptoms met criteria

Figure G8.1a Depression Symptoms: Prospective Cohort Studies, 1995 Through 2007: Crude Odds

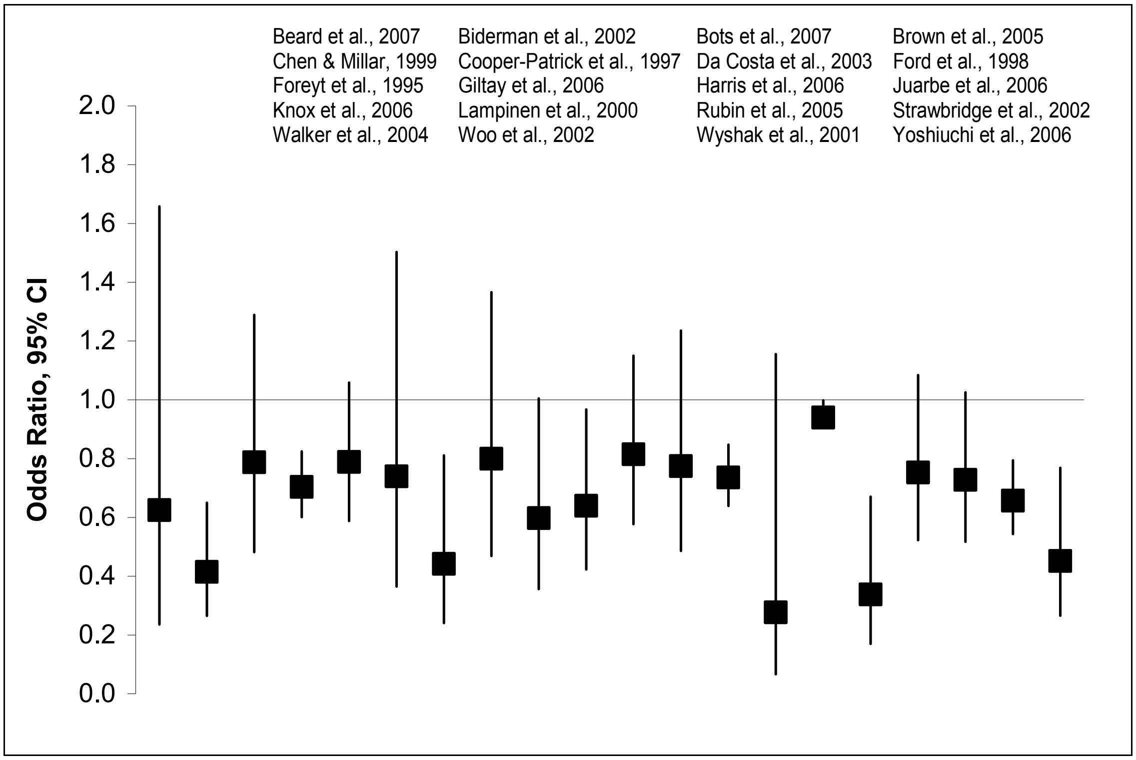

Figure G8.1a Data Points

Author/Date	High	Low	Odds Ratio
Beard et al., 2007	1.658	0.236	0.625
Biderman et al., 2002	0.6504	0.265	0.415
Bots et al., 2007	1.289	0.4819	0.788
Brown et al., 2005	0.8251	0.6011	0.704
Chen & Millar, 1999	1.0587	0.588	0.789
Cooper-Patrick et al., 1997	1.5026	0.365	0.74
Da Costa et al., 2003	0.8115	0.2407	0.442
Ford et al., 1998	1.3663	0.4686	0.8
Foreyt et al., 1995	1.0047	0.3562	0.598
Giltay et al., 2006	0.9678	0.4232	0.64
Harris et al., 2006	1.1502	0.577	0.815
Juarbe et al., 2006	1.2356	0.4861	0.775
Knox et al., 2006	0.848	0.6394	0.736
Lampinen et al., 2000	1.1555	0.0666	0.277
Rubin et al., 2005	0.9982	0.9229	0.94
Strawbridge et al., 2002	0.6709	0.1698	0.338
Walker et al., 2004	1.0842	0.523	0.753
Woo et al., 2002	1.0253	0.5173	0.728
Wyshak et al., 2001	0.7946	0.5432	0.657
Yoshiuchi et al., 2006	0.7689	0.2658	0.452

Figure G8.1b Depression Symptoms: Prospective Cohort Studies, 1995 Through 2007: Adjusted Odds

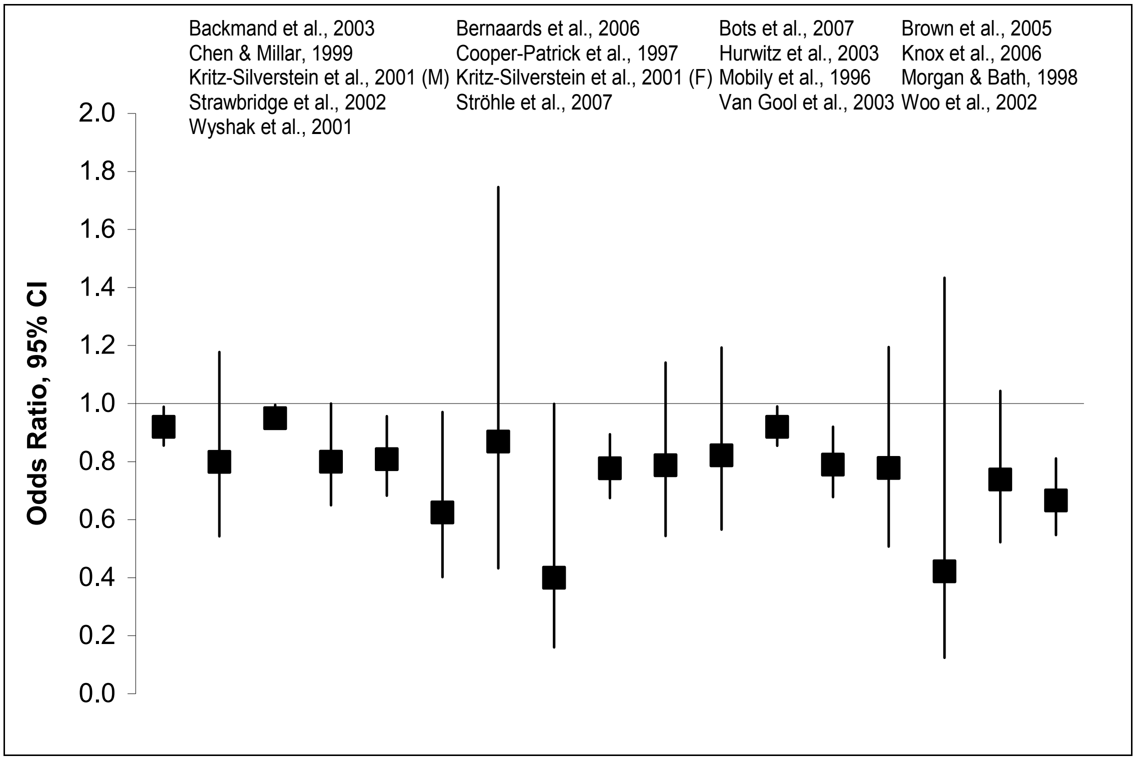

Figure G8.1b Data Points

Author/Date	High	Low	Odds Ratio
Backmand et al., 2003	0.9892	0.8556	0.92
Bernaards et al., 2006	1.1774	0.5429	0.7995
Bots et al., 2007	0.9956	0.9554	0.95
Brown et al., 2005	1	0.65	0.8
Chen & Millar, 1999	0.957	0.6831	0.8086
Cooper-Patrick et al., 1997	0.9714	0.4021	0.625
Hurwitz et al., 2003	1.7464	0.4326	0.8692
Knox et al., 2006	0.999	0.1602	0.4
Kritz-Silverstein et al., 2001 (M)	0.8946	0.6746	0.7769
Kritz-Silverstein et al., 2001 (F)	1.141	0.5439	0.7878
Mobily et al., 1996	1.1928	0.5659	0.8216
Morgan & Bath, 1998	0.99	0.855	0.92
Strawbridge et al., 2002	0.9205	0.678	0.79
Ströhle et al., 2007	1.1945	0.5072	0.7784
Van Gool et al., 2003	1.4337	0.1242	0.422
Woo et al., 2002	1.0435	0.5224	0.7383
Wyshak et al., 2001	0.8114	0.5472	0.6663

for a clinically meaningful decrease in symptoms (50%) or remission (32;35;37;38). Long-term reductions in symptoms were examined in a few studies and were generally favorable after supervised exercise training ended, especially when people maintained regular physical activity (28;29;36;39). The trial by Dunn and colleagues. (2005) was a placebo trial that controlled for social interaction and sunlight exposure (2 confounders common in other studies) and reported response and remission rates after exercise training that were 40 to 50% better than placebo (32).

Rationale: Healthy Adults and Adults With Medical Conditions

At least 42 RCTs since 1995, including more than 2,600 people, have examined the effects of exercise on depression symptoms in healthy adults or adults with medical conditions other than depression or disabling conditions that severely limit physical activity (i.e., spinal cord injury, multiple sclerosis, and stroke or traumatic head injury). Most of the medical patients studied had cardiovascular diseases, arthritis, chronic pain, obesity, or were cancer survivors. The mean effect of exercise compared to a control condition was 0.35 SD (95% CI: 0.24 to 0.46). The outcomes favored exercise in 90% (34 of 38) of the comparisons with control conditions, of which 60% (23 of 38) reached statistical significance. The average sample size was about 65 people, but in about a fourth of the studies it was less than 35, which was too small to detect an effect smaller than a half standard deviation (SD). When compared to a placebo (usually stretching or health education), the effect of exercise was halved to 0.15 SD (95% CI: 0.24 to 0.06). Although exercise effects exceeded placebo effects in 19 of 22 comparisons, only 4 reached statistical significance. The average sample size in the placebo studies was nearly 100 people, but samples more than 4 times that size would be needed to detect an effect that small.

Do the Effects of Physical Activity on Depression Symptoms Differ According to Age, Sex, Race/Ethnicity, or Medical Condition?

Conclusions

The available evidence supports the conclusion that regular physical activity reduces depression symptoms regardless of age, sex, race/ethnicity, or medical condition. Whether these factors modify the association between physical activity and depression has been understudied. Also, race and ethnicity have been poorly represented or not described in most studies.

Rationale: Cohort Studies

Few prospective cohort studies reported findings according to sex or age groups. Just 1 study reported results for men and women, finding that lower levels of depression symptoms were associated with more physical activity in both men and women (40). Only 11 studies had separate results for men or women. Reductions were smaller for active men (OR = 0.96, 95% CI = 0.93 to 0.99) than women (OR = 0.72, 95% CI = 0.68 to 0.77), but men were less studied. Five studies totaled fewer than 4,000 men, while 6 studies totaled more than 14,000 women. After adjusting for the number of comparisons made in each of the other cohort studies, in which men and women were represented evenly, effects for men and women did not differ. Crude odds reduction among active people were greater for people aged 55 years or older (OR = 0.58; 95% CI = 0.46 to 0.72) than people younger than age 55 year (OR = 0.72; 95% CI = 0.64 to 0.81), but physical activity was protective for all age groups, regardless of sex.

Most of the prospective cohort studies were population-based, but only a third specified the proportions of racial and ethnic groups included, and only 4 studies had evidence of good representation of African Americans and/or Hispanics/Latinos (41-44). One study reported that the odds of depression symptoms were similarly lower among white and African American adults who were active (42). Other studies had poor or no representation of other minority groups.

Rationale: Randomized Controlled Trials

In RCTs of people without depression, the average effect of exercise compared to a control condition is 0.35 SD in people with medical conditions (24 studies; 95% CI: 0.47 to 0.23) and 0.35 SD in people who have not been diagnosed with a medical condition (7 studies; 95% CI: 0.59 to 0.11). Figure G8.2 illustrates effect sizes and 95% confidence intervals comparing exercise with a control condition from the RCTs of depression in adults with or without medical conditions.

These trials reported similar reductions in depression for groups of varying ages from 28 to 83 years, but the studies were not designed to compare groups according to sex, race/ethnicity, or age. Only 1 of the trials compared men and women (45) and none compared effects between people of different ages or race/ethnicities. Seven of 11 studies of Americans described the racial/ethnic composition of their samples, but only 5 studies included African Americans (46-50); 3 studies included small numbers of Hispanics, Asian Americans or American Indians (49-51). Effects were larger in 6 studies of men (mean = 0.86 SD, 95% CI = 0.45 to 1.26), compared to 9 studies of women (mean = 0.27 SD, 95% CI = 0.04 to 0.51) and to 23 studies that combined results of men and women (mean = 0.27 SD, 95% CI = 0.16 to 0.37). Thus, it is likely that other features of the studies of men might explain the larger effects.

Reductions in depression symptoms were larger in 8 studies of heart patients (mean = 0.60 SD, 95% CI = 0.33 to 0.86) than in studies of other medical conditions (mean = 0.23 SD, 95% CI = 0.11 to 0.34) and were largest in the 3 studies of heart patients that included only men (52-54) (mean = 1.0 SD, 95% CI = 0.50 to 1.5). The small number of studies precluded meaningful comparisons among the other medical conditions.

Figure G8.2 Depression Symptoms: Randomized Controlled Trials, 1995 Through 2007

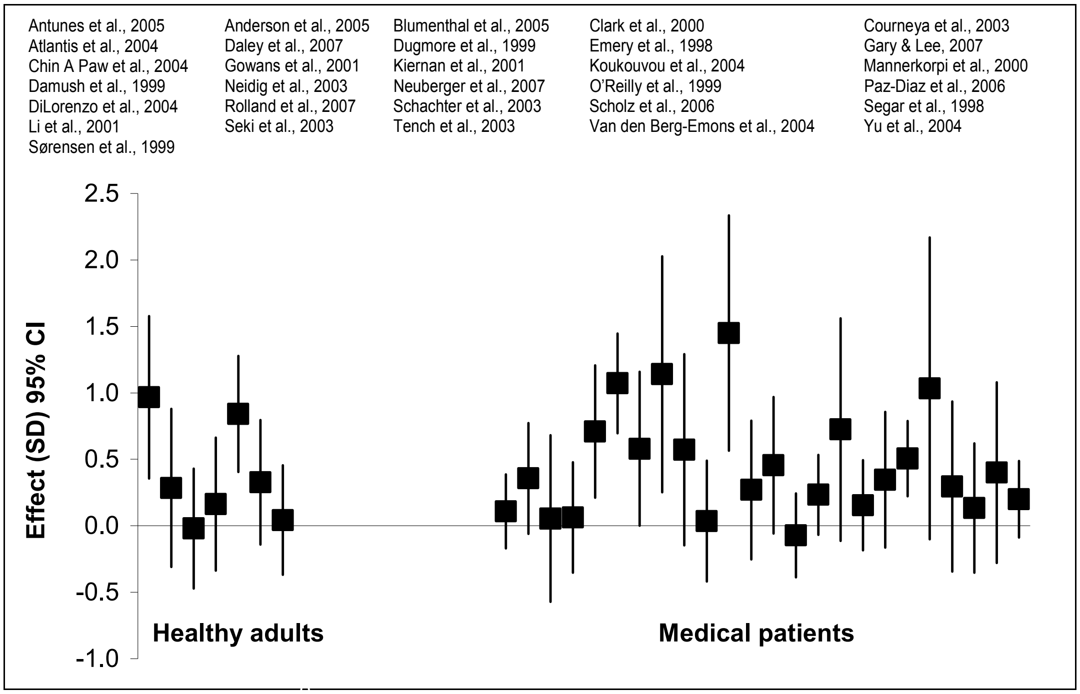

Figure G8.2. Data Points

Healthy Adults	High	Low	Effect Size
Antunes et al., 2005	1.5775	0.3545	0.966
Atlantis et al., 2004	0.8808	−0.3108	0.285
Chin A Paw et al., 2004	0.4298	−0.4718	−0.021
Damush et al., 1999	0.6628	−0.3368	0.163
DiLorenzo et al., 2004	1.2781	0.4039	0.841
Li et al., 2001	0.7952	−0.1406	0.3273
Sørensen et al., 1999	0.4545	−0.3687	0.0429

Medical Patients	High	Low	Effect Size
Anderson et al., 2005	0.3863	−0.1703	0.108
Blumenthal et al. 2005	0.7735	−0.0615	0.356
Clark et al., 2000	0.6815	−0.5729	0.0543
Courneya et al., 2003	0.4774	−0.3524	0.0625
Daley et al., 2007	1.2058	0.2102	0.708
Dugmore et al., 1999	1.4473	0.6947	1.071
Emery et al., 1998	1.1587	0.0003	0.5795
Gary & Lee, 2007	2.0279	0.2521	1.14
Gowans et al., 2001	1.2908	−0.1478	0.5715
Kiernan et al., 2001	0.4897	−0.4197	0.035
Koukouvou et al., 2004	2.3344	0.5646	1.4495
Mannerkorpi et al., 2000	0.7909	−0.2519	0.2695
Neidig et al., 2003	0.97	−0.059	0.4555
Neuberger et al., 2007	0.2436	−0.3876	−0.072
O'Reilly et al., 1999	0.5329	−0.0669	0.233
Paz-Diaz et al., 2006	1.561	−0.1128	0.7241
Rolland et al., 2007	0.4932	−0.185	0.1541
Schachter et al., 2003	0.8583	−0.1649	0.3467
Scholz et al., 2006	0.7897	0.2233	0.5065
Segar et al., 1998	2.1691	−0.1017	1.0337
Seki et al., 2003	0.935	−0.3452	0.2949
Tench et al., 2003	0.6196	−0.3542	0.1327
Van den Berg-Emons et al., 2004	1.0801	−0.2801	0.4
Yu et al., 2004	0.4876	−0.0886	0.1995

Do the Effects of Physical Activity Vary According to Features of Physical Activity, Including Type, Intensity, or Timing (i.e., Session Duration, Weekly Frequency, and Length of Participation)?

Conclusions

The evidence from prospective cohort studies and RCTs published since 1995 suggests that moderate and high levels of physical activity similarly reduce the odds of developing depression symptoms compared to low levels of physical activity exposure, which is nonetheless more protective than inactivity or very low levels of physical activity. The minimal or optimal type or amount of exercise for reducing depression symptoms is not yet known, but it appears that an increase in physical fitness is not required.

Rationale

Epidemiologic studies typically use a variety of criteria and methods to classify people into 2 or more activity groups. This limits the evaluation of the dose-response relation across the full range of reported physical activity and can misclassify people who overestimate or underestimate their activity. Only 7 prospective cohort studies of depression symptoms included the 3 or more levels of physical activity necessary to determine whether the association of physical activity with lower odds of depression has a dose-gradient with increased levels of exposure (16;18;21;22;55-57). After adjustment for age, sex, and other risk factors, the reduction of odds was smaller for the lowest level of physical activity (OR = 0.86, 95% CI = 0.79 to 0.94) compared to the next 2 levels of physical activity, which did not differ (OR = 0.77, 95% CI = 0.72 to 0.82). Thus, the highest levels of participation did not confer more protective benefits than did more moderate levels. Each was more protective than the lowest levels in the studies.

Figure G8.3 shows the odds ratios and 95% CI in prospective cohort studies that examined the dose-response association between levels of physical activity and depression symptoms.

Those studies used different measures and criteria for defining levels of physical activity, so it is not possible to convert their findings to a standard estimate (e.g., MET-hours or kilocalories per kilogram) of the amount of physical activity at each level. However, about half the prospective cohort studies provided enough information to determine whether active people were meeting existing public health recommendations (58;59) for participation in moderate or vigorous physical activity (i.e., moderate-intensity aerobic [endurance] physical activity for a minimum of 30 minutes on 5 days per week, or vigorous-intensity aerobic physical activity for a minimum of 20 minutes on 3 days per week). Odds reduction favored people who met or exceeded recommendations for moderate or vigorous participation (OR = 0.64, 95% CI = 0.57 to 0.73) compared to active people who did not meet either recommended level (OR = 0.70, 95% CI = 0.58 to 0.82). Odds were not different between vigorous and moderate participation, but it was possible to distinguish moderate from vigorous participation in only a few studies. After adjustment for other risk factors, a similar

Figure G8.3 Depression Symptoms: Prospective Cohort Studies 1995 Through 2007: Dose Response

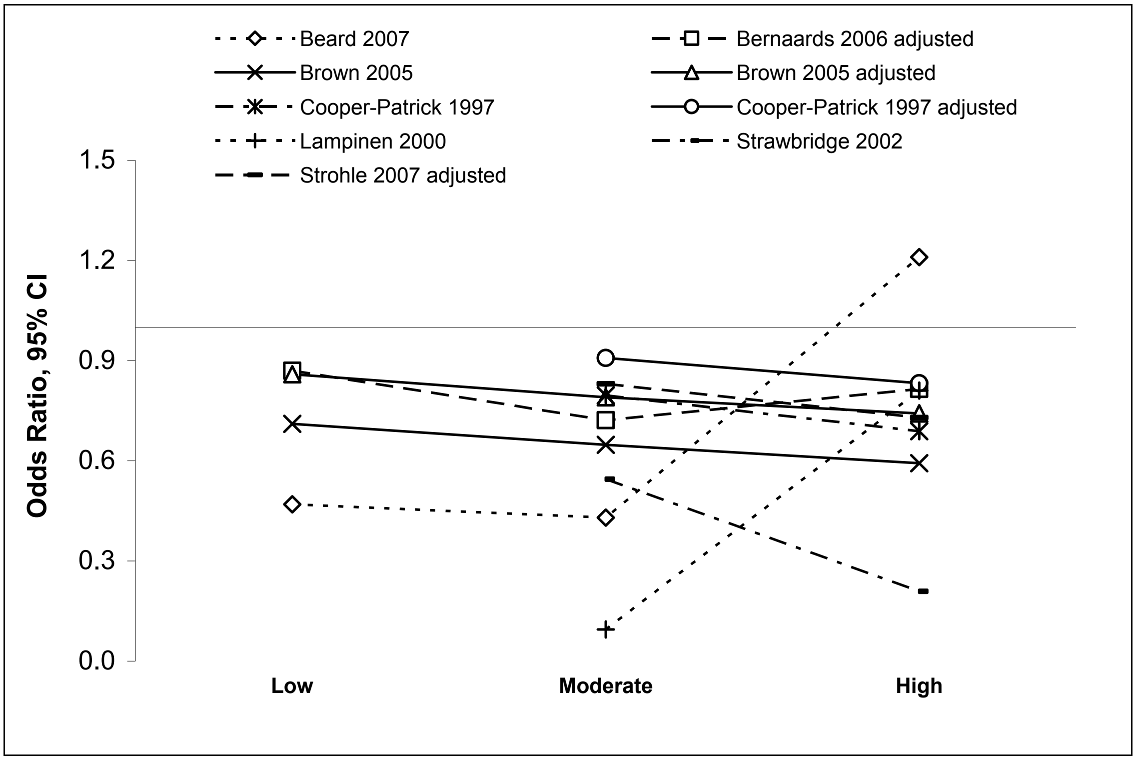

Figure G8.3 Data Points

Author/Year	Low	Moderate	High
Beard 2007	0.47	0.43	1.21
Bernaards 2006 adjusted	0.8694	0.7218	0.8151
Brown 2005	0.711	0.648	0.593
Brown 2005 adjusted	0.859	0.79	0.742
Cooper-Patrick 1997	0.796	0.689	
Cooper-Patrick 1997 adjusted	0.908	0.832	
Lampinen 2000	0.095	0.81	
Strawbridge 2002		0.545	0.209
Strohle 2007 adjusted	0.8303	0.7298	

protective benefit favored regular participation in moderate or vigorous physical activity (OR = 0.77, 95% CI = 0.72 to 0.82) compared to participation at levels less than recommended (OR = 0.84, 95% CI = 0.78 to 0.90).

A few RCTs of people without depressive disorders have manipulated type (e.g., aerobic versus resistance or walking versus aquatic exercise or Qigong) or timing (i.e., continuous versus intermittent [the intermittent studies often used resistance, circuit, interval or mixed-mode exercise]), of exercise to examine whether those features modify the effects of exercise on symptoms of depression (60-64). However, these studies did not include a control group who did not exercise. Only a few studies have evaluated Eastern health practices that include exercise (65). About 40 percent of the studies used an aerobic exercise intervention such as walking, jogging, cycling, or aquatic exercise, and another third of the studies combined aerobic activity with resistance exercise. Only 3 studies used resistance exercise alone, and none compared aerobic versus resistance exercise. On average, reductions in depression have been similar regardless of the mode of activity used. About two-thirds of the studies used continuous exercise. Regardless of mode, a larger reduction in depression tends to occur after continuous exercise (0.45 SD, 95% CI = 0.63 to 0.27) than intermittent exercise (0.18 SD, 95% CI = 0.30 to 0.06), but differing features of the studies other than timing might explain this finding.

Three-fourths of the RCTs of healthy adults and non-psychiatric medical patients used a moderate-to-vigorous exercise intensity of 60-80% of people's aerobic capacity or maximum strength that occurred 3 days per week. Intensity was lower or the frequency was 2 days per week in the other studies. The average duration of each session was about 35 minutes, but it was less than 30 minutes in a fourth of the studies and more than 1 hour in another fourth of the studies. However, fewer than half the studies were clear about how the time was partitioned into warm-up, exercise, and cool down. Nonetheless, reductions in depression symptoms did not differ across these varying features of exercise. Studies lasted an average of 6 months, and a fourth of the studies lasted less than 3 months. Length of the exercise program also was unrelated to symptom outcome. About half the studies measured cardiorespiratory fitness, which was increased significantly in 16 of 24 comparisons. Only 3 studies measured strength. In each study, fitness increases and symptom reduction were not associated when changes were defined by statistical significance, which depends on both the size of change and the sample size. After adjusting for sample sizes, the magnitude of depression reduction was moderately correlated with the magnitude of fitness increase ($r = 0.40$). However, that relation was not independent of increases in primary outcomes other than fitness in the studies of medical patients.

Perhaps the clearest experimental evidence for a dose-dependent effect of exercise on symptom reduction comes from the dose study (32). Adults aged 20 to 45 years diagnosed with mild to moderate major depressive disorder expended either 7.0 or 17.5 kilocalories per kilogram per week at a frequency of 3 or 5 days per week or engaged in 3 days per week of stretching exercises as a placebo control. Physician-rated symptoms after 12 weeks were reduced 47% from baseline for the higher dose, compared with 30% for the lower dose and 29% for control, regardless of whether exercise frequency was 3 days or 5 days each week.

Question 2. Is There an Association Between Physical Activity and Anxiety?

Introduction

Anxiety is characterized by apprehensive or worrisome thoughts and is typically accompanied by agitation, feelings of tension, and activation of the autonomic nervous system. A distinction is made between transient anxiety symptoms, termed *state anxiety*, persistent symptoms, termed *trait anxiety*, and a group of disabling conditions characterized by excessive, chronic anxiety that are known as *anxiety disorders*. The anxiety disorders, listed from most to least common, are:

- *Specific phobia* — an intense fear of an object, place, or situation that poses little or no actual danger.
- *Social phobia* — an overwhelming fear of scrutiny and embarrassment in social situations, leading to avoidance of potentially enjoyable activities.
- *Generalized anxiety disorder* — recurrent or persistent excessive worry about everyday, routine life events and activities, lasting at least 6 months.
- *Panic disorder* — repeated episodes of intense fear and physical symptoms that strike without warning and without an obvious source, often producing fear of being alone or going into public places (*agoraphobia*) and persistent fear of an attack.
- *Obsessive-compulsive disorder* — repeated, unwanted thoughts or compulsive behaviors that seem impossible to stop, typified by repetitive acts or rituals to relieve anxiety.
- *Post–traumatic stress disorder* — a delayed or prolonged response (including flashbacks, dreams, insomnia, hypervigilance) to a stressful event or situation (either short- or long-lasting) that was especially threatening or catastrophic (6).

Anxiety disorders are common, affecting more than 16 million people in the United States each year (roughly 4% of women and 2% of men). More than 80 million people in the United States at some point in their lives suffer from an anxiety disorder (8). Anxiety disorders begin at a median age of 15 years, often persist throughout life and are associated with numerous physical and mental co-morbidities, especially depression (66). People aged 15 to 24 years experience episodes of anxiety about 40% more often than people aged 25 to 54 years, regardless of race. Although less than 30% of those who suffer from anxiety disorders seek treatment, they strain the health care system because of direct psychiatric and nonpsychiatric treatment costs. Additional indirect costs of anxiety disorders are incurred from reduced work productivity. The total annual costs in 1990 of all anxiety disorders were estimated to be $42 billion to $47 billion dollars (67;67;68), and they likely cost double that amount today.

Does Physical Activity Protect Against the Onset of Anxiety Disorders or Anxiety Symptoms?

Conclusions

The weight of evidence from a small number of nationally representative and population-based cross-sectional and prospective cohort studies supports that regular physical activity protects against the onset of anxiety disorders and anxiety symptoms.

Rationale

At least 4 population-based cross sectional studies published since 1995, including data from nationally representative samples of nearly 121,000 Americans, show that regular physical activity is associated with lower odds of anxiety symptoms (13;69-71). Results of the US National Co-Morbidity Study found that regular physical activity reduced the odds of a diagnosed anxiety disorder (i.e., specific phobia, social phobia, generalized anxiety, panic, and agoraphobia) by an average of 43% (10). After controlling for sociodemographic and illness variables, regular physical activity reduced the odds of an anxiety disorder by an average of 28% (10).

At least 2 population-based studies used a prospective cohort design. The odds of developing any anxiety disorder were reduced by an average of 53% among Australians who reported more than 3 hours per week of vigorous physical activity compared to those reporting no activity (16). The effect was not statistically significant, in part due to the small number of participants who developed an anxiety disorder (n=67). The second study, which adjusted for age and sex and had more participants who developed an anxiety disorder (n=228), found that regularly active young adults (representative of Munich, Germany) on average had a statistically significant, 48% lower odds of developing any anxiety disorder compared to those reporting no activity (22).

Does Physical Activity Reduce Anxiety Symptoms?

Conclusions

The results of RCTs conducted with medical patients and healthy adults indicate that participation in physical activity programs reduces anxiety symptoms.

Rationale

Before 1995, no reports of RCTs of anxiety disorder patients had been reported. Since then, 2 RCTs have been conducted with anxiety disorder patients and reported statistically large effects. One trial conducted with 46 panic disorder patients found that those who completed a 10-week (3 times per week) walking or jogging program reported, on average, a large reduction in anxiety symptoms (1.1 SD) compared to those who took daily placebo capsules (72). The other trial involved 74 patients with social phobia, generalized anxiety, or panic disorder. The addition of a moderate intensity home-based exercise program to 8 to 10 weeks of group cognitive-behavioral therapy (GCBT) resulted in a large reduction in anxiety symptoms (1.36 SD) compared to the control condition (GCBT + nutrition education) after statistically controlling for potential confounding variables (73).

Before 1995, at least 40 quasi-experimental and experimental exercise training studies of varying quality had reported a cumulative effect on reducing anxiety symptoms of approximately 0.40 SD (74). Since 1995, at least 46 RCTs involving more than 3,550 people have examined the effects of chronic exercise on anxiety symptoms among inactive adults who were healthy or had a medical condition other than anxiety disorders or disabling CNS disorders including multiple sclerosis, traumatic head injury, stroke or spinal cord injury. The effect of exercise compared to control conditions in reducing anxiety symptoms was 0.38 SD (95% CI: 0.30 to 0.46). Outcomes favored exercise in 84% (67 of 80) of the comparisons with control conditions, and 28% (22 of 80) reached statistical significance. In 6 studies that compared moderate-to-vigorous exercise to a placebo-type condition (usually low intensity exercise such as stretching) the effect of moderate-to-vigorous exercise on reducing anxiety symptoms was 0.19 SD (95% CI: 0.05 to 0.33). Exercise effects were favorable in 90% (9 of 10) of the placebo-type comparisons, and 30% reached statistical significance. The average study included about 60 people, but a fourth of the studies had less than 40 participants, too few to detect small but possibly meaningful effects.

Do the Effects of Physical Activity on Anxiety Symptoms Differ According to Age, Sex, Race/Ethnicity, or Medical Condition?

Conclusions

The weight of the evidence supports the conclusion that regular physical activity reduces anxiety symptoms regardless of age, sex or medical condition. No published data address whether race or ethnicity modifies the effects of physical activity on anxiety symptoms.

Rationale

In the 46 RCTs of healthy adults and medical patients, the mean age of the samples was weakly related to anxiety reductions after exercise training. Two of the trials compared men and women and found no sex-related difference in the effect of exercise on anxiety symptoms (45;75). The average effect of exercise training on reduced symptoms of anxiety was larger in those studies that involved only men (mean = 0.62 SD, 95% CI: 0.34 to 0.89, n=7) compared to those that included only women (mean = 0.33 SD, 95% CI: 0.16 to 0.50, n=12) and those that included similar proportions of men and women (mean = 0.42 SD, 95% CI: 0.28 to 0.57, n=19). It is likely that other features of the studies of men might explain the larger effects. Regardless, exercise benefited both men and women.

None of the available investigations was designed to determine whether the effect of chronic exercise was moderated by race or ethnicity. The racial or ethnic composition of the samples was described in 17% of the reviewed studies (25;51;76-81). Of the 3,550 people who participated in the RCTs, approximately 89% were whites and approximately 11% were African Americans or Hispanics. Statistical analyses by race or ethnic category were not presented in any of the studies.

Of the RCTs, about 40% (19 of 46) were conducted with healthy adults, and 60% (27 of 46) involved patients with various medical conditions. The most frequently studied conditions were cancer and cardiovascular diseases. The average effect of exercise compared to a control condition was 0.40 SD in healthy adults (40 comparisons; 95% CI: 0.27 to 0.53) and 0.36 in people with medical conditions (40 comparisons; 95% CI: 0.26 to 0.47). The reduction in anxiety symptoms was somewhat larger than average in studies of cardiovascular conditions (mean = 0.53 SD, 95% CI: 0.15 to 0.92, n=6), but too few studies are available to conclude that the effect of exercise training on anxiety symptoms is modified by medical condition. Figures G8.4a and G8.4b summarize the findings from the RCTs of physical activity and anxiety symptoms in healthy adults and medical patients.

Epidemiologic studies have not yet examined race/ethnicity or medical condition as potential modifiers of the effect of exercise on anxiety disorders or symptoms. One cross-sectional study of 41,914 participants in the 2001 Behavioral Risk Factor Surveillance System found low anxiety symptoms among physically active people compared to inactive people across young (age 18 to 40 years), middle-aged (aged 41 to 60 years) and older adult (aged 61 years and older) categories, but the inactive younger adults were approximately 20% more likely to experience anxiety symptoms than inactive middle-aged and older adults (13). In a population-based cross sectional study of 19,288 twins and their families, potential interactions of exercise and age, exercise and sex and exercise, age and sex on anxiety symptoms were statistically non-significant (69).

Do the Effects of Physical Activity Vary According to Features of Physical Activity Including Type, Intensity, or Timing (i.e., Session Duration, Weekly Frequency, and Length of Participation)?

Conclusions

Limited cross-sectional, observational evidence suggests that the odds of an anxiety disorder may be reduced by higher weekly frequency of exercise bouts. However, there is an absence of evidence from prospective cohort studies or RCTs that examine whether anxiety symptoms vary according to features of physical activity exposure.

Rationale

One large population-based study found a dose-response relation between cross-sectional measures of physical activity frequency and lower prevalence of anxiety disorders (i.e., specific phobia, social phobia, generalized anxiety, panic, and agoraphobia) (10). The

Figure G8.4a Anxiety Symptoms: Randomized Controlled Trials of Healthy Adults 1995 Through 2007

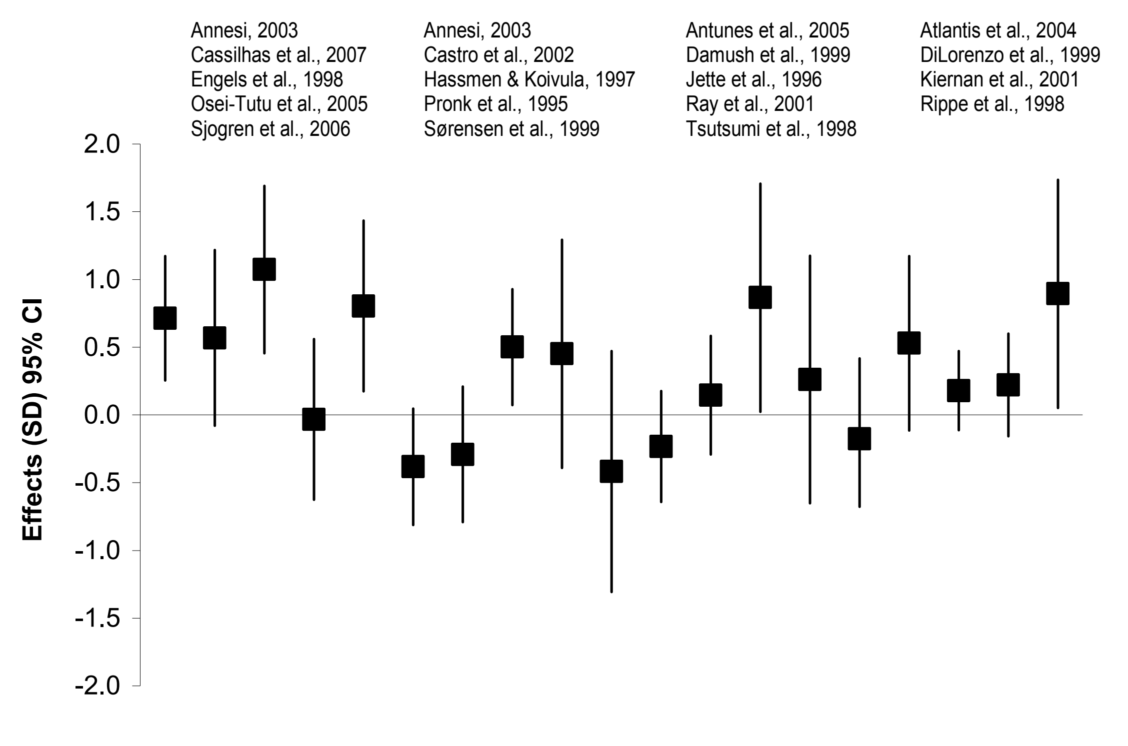

Figure G8.4a Data Points

Author	Year	High	Low	Effect Size
Annesi	2003	1.1726	0.2534	0.713
Annesi	2003	1.2184	−0.0811	0.5687
Antunes et al.	2005	1.6922	0.4556	1.0739
Atlantis et al.	2004	0.5596	−0.6273	−0.0339
Cassilhas et al.	2007	1.4338	0.1748	0.8043
Castro et al.	2002	0.047	−0.8126	−0.3828
Damush et al.	1999	0.2104	−0.7926	−0.2911
DiLorenzo et al.	1999	0.9291	0.072	0.5006
Engels et al.	1998	1.2926	−0.3902	0.4512
Hassmen & Koivula	1997	0.4711	−1.3073	−0.4181
Jette et al.	1996	0.1764	−0.6431	−0.2334
Kiernan et al.	2001	0.5843	−0.2918	0.1463
Osei-Tutu et al.	2005	1.7087	0.0233	0.866
Pronk et al.	1995	1.1766	−0.6525	0.262
Ray et al.	2001	0.4161	−0.6794	−0.1767
Rippe et al.	1998	1.1732	−0.1149	0.5292
Sjogren et al.	2006	0.472	−0.1135	0.1792
Sørensen et al.	1999	0.6008	−0.159	0.2209
Tsutsumi et al.	1998	1.7363	0.052	0.8946

Figure G8.4b. Anxiety Symptoms: Randomized Controlled Trials of Medical Patients 1995 Through 2007

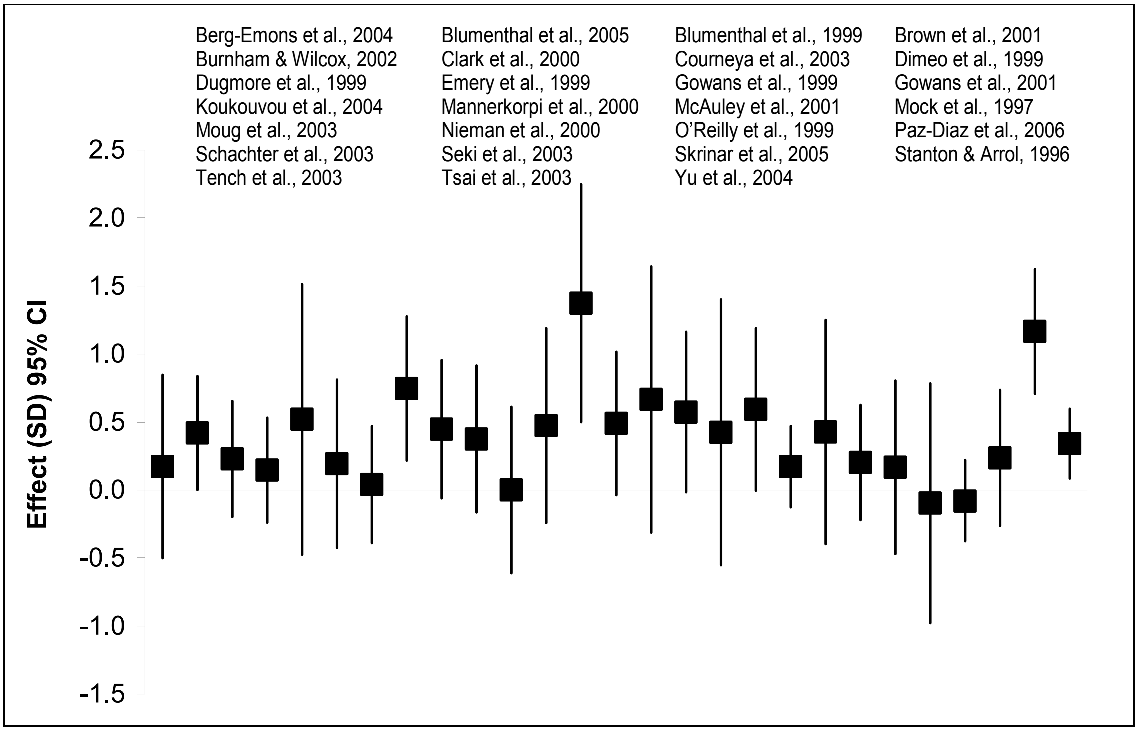

Figure G8.4b Data Points

Author	Year	High	Low	Effect Size
Berg-Emons et al.	2004	0.8471	−0.5021	0.1725
Blumenthal et al.	2005	0.8372	0	0.4186
Blumenthal et al.	1999	0.6547	−0.1989	0.2279
Brown et al.	2001	0.532	−0.2394	0.1463
Burnham & Wilcox.	2002	1.5144	−0.4748	0.5198
Clark et al.	2003	0.812	−0.4264	0.1928
Courneya et al.	2000	0.471	−0.3913	0.0399
Dimeo et al.	1999	1.2758	0.2166	0.7462
Dugmore et al.	1999	0.9564	−0.0625	0.447
Emery et al.	1999	0.9157	−0.1661	0.3748
Gowans et al.	1999	0.6123	−0.6124	0
Gowans et al.	2001	1.1875	−0.2423	0.4726
Koukouvou et al.	2004	2.2472	0.4995	1.3733
Mannerkorpi et al.	2000	1.0158	−0.039	0.4884
McAuley et al.	2001	1.6432	−0.3133	0.665
Mock et al.	1997	1.1626	−0.0178	0.5724
Moug et al.	2003	1.3995	−0.5531	0.4232
Nieman et al.	2000	1.1882	−0.004	0.5921
O'Reilly et al.	1999	0.4695	−0.1279	0.1708
Paz-Diaz et al.	2006	1.25	−0.3972	0.4264
Schachter et al.	2003	0.6268	−0.2207	0.2031
Seki et al.	2003	0.8051	−0.4711	0.167
Skrinar et al.	2005	0.7841	−0.9789	−0.0974
Stanton & Arrol.	1996	0.2212	−0.3778	−0.0829
Tench et al.	2003	0.7356	−0.2636	0.236
Tsai et al.	2003	1.6238	0.7053	1.1645
Yu et al.	2004	0.5979	0.0852	0.3415

percentage of adults with these anxiety disorders was highest among those who reported no physical activity and was reduced in a step-wise fashion among those who reported rare, occasional, and regular physical activity (10).

Prospective cohort studies show mixed results as to whether participation in sports, activities that often involve high-intensity exercise, has a protective effect against anxiety symptoms. Some show a protective effect (23) and others show no protection (82). One nationally representative cross-sectional study found that a group of regularly physically active (i.e., met or exceeded the *Healthy People 2010* physical activity guidelines) people reported a higher frequency of anxiety symptoms compared to those who were physically active but not active enough to meet the *Healthy People 2010* recommendations (13).

Few RCTs of healthy adults or people with medical conditions have manipulated any feature of an exercise intervention to learn whether those features causally modify anxiety symptoms. No exercise training studies have manipulated exercise program length or exercise type for the purpose of examining anxiety symptom outcomes.

About 43% (20 of 46) of the studies used a single aerobic exercise intervention such as walking, jogging, or cycling, 13% (6 of 46) used resistance exercise alone, and 9% (4 of 46) combined aerobic with resistance exercise. The magnitude of anxiety reduction has been similar across these 3 categories of studies. Regardless of mode, anxiety reductions also were similar after continuous (0.36 SD, 95% CI: 0.27 to 0.45) and intermittent (0.39 SD, 95% CI: 0.16 to 0.63) exercise (about 60% of studies used continuous exercise).

Three investigations manipulated exercise session duration and found no significant differences in anxiety symptom outcomes among exercise training studies that used bouts of varying session durations (80;83;84). Across all trials, the average duration of the exercise sessions was approximately 40 minutes. In a fourth of the studies, the duration was less than 25 minutes, and in another fourth the duration was more than 60 minutes. The effects of exercise training on anxiety symptoms were similar across studies of all durations. Imprecise descriptions of exercise duration contributed to the difficulty in determining whether session duration has a true effect. For example, less than half of the studies were specific regarding how time was partitioned into warm-up, exercise, and cool down.

Only 2 exercise training experiments manipulated exercise intensity to examine whether it modifies the effects of exercise on anxiety symptoms. Statistically non-significant differences in anxiety symptoms were found between moderate- and high-intensity resistance exercise conditions on the anxiety symptom outcomes (81;85). About 55% (44 of 80) of the comparisons from all the trials used moderate-to-vigorous exercise intensity (i.e., 60 – 80% of aerobic capacity or maximum strength) with a weekly frequency of 3 or more days per week. Reductions in anxiety symptoms were similar across variations in exercise intensity.

About 63% (29 of 46) of the trials measured fitness, 7 studies measured strength, and 22 studies measured cardiorespiratory fitness. Cardiorespiratory fitness was increased significantly in 36% (13 of 36) of the comparisons and strength was increased significantly in 25% (2 of 8) of the comparisons. Those studies that defined changes by statistical significance showed no association between fitness increases and anxiety symptom reduction. After adjusting for sample sizes, the magnitude of anxiety reduction was weakly correlated with the magnitude of fitness increase ($r = .24$). This relation was independent of increases in primary outcomes other than fitness in the studies.

Question 3: Is There an Association Between Physical Activity and Psychological Distress and Well-Being?

Introduction

Psychological distress is a risk factor for psychiatric disorders (86;87) and coronary heart disease (88), and it is negatively associated with quality of life. Conversely, a feeling of well-being can reduce psychiatric risk and is an important feature of high life quality and health (89). People frequently experience feelings of distress during the normal course of living and during challenging life events, including chronic medical conditions. Thus, it is important to understand the association between physical activity and feelings of distress or well-being because they bear not only on disease risk but also on overall mental health. Measures in this area are not uniform, but most studies have used a scale that assessed the presence of distress (e.g., combined symptoms of anxiety and depression or perceived stress) or the absence of distress (e.g., well-being or positive mental health). Findings of physical activity studies have not differed when measures of distress or well-being were used, so the following results apply regardless of the direction of odds (i.e., decrease in distress or increase in well-being).

Does Physical Activity Protect Against the Onset of Feelings of Distress or Enhance Well-Being?

Conclusions

The available evidence from prospective cohort studies indicates a small-to-moderate association that favors people who are physically active.

Rationale

The association between physical activity and reduced feelings of distress or enhanced well-being among adults was virtually unstudied in large groups of people before 1995 (90). Since then, more than 30 population-based observational studies have been published, including nationally representative samples of more than 175,000 Americans (91-95). Most of the studies looked at cross-sectional associations, which indicated that active people on average had more than a 30% lower odds of feeling of distress or 30% higher odds of enhanced well-being than did inactive people. In the national samples of Americans, the odds favored active people by approximately 25%.

Thirteen studies of adults in Australia, Canada, Denmark, England, Netherlands, Scotland, Wales, and 3 studies of Americans (18;23;94) used a prospective cohort design. In those studies, the average odds of reduced feelings of distress or of enhanced well-being favored active people by about 30% compared with inactive people, without adjustments for risk factors (OR = 0.69, 95% CI = 0.61 to 0.78). After adjustment for risk factors, such as age, sex, race, education, social class, occupation, income, smoking, alcohol use, substance abuse, chronic health conditions, disability, marital status, life events, job stress, and social support, the odds still favored active people by nearly 20% (OR = 0.82, 95% CI = 0.77 to 0.86). About 80% of the comparisons (58 of 70) favored active adults, but half the results did not reach statistical significance, often because of too small sample sizes. The average number of people for each comparison was approximately 1,300 people, but a fourth of the comparisons had 700 people or less. Figure G8.5 illustrates 18 crude and/or adjusted odds ratios and 95% confidence intervals from the 13 prospective cohort studies of physical activity and distress or well-being in more than 100,000 adults from 8 countries, including 67,000 American women (23;94).

Does Physical Activity Reduce Feelings of Distress or Enhance Feelings of Well-Being?

Conclusions

The effects of RCTs indicate small benefits of physical activity that often do not exceed the effects of placebo control conditions, such as health education or stretching.

Rationale

Since 1995, at least 26 RCTs, including nearly 3,000 people, have examined the effects of exercise on feelings of distress or well-being in healthy adults or adults with medical conditions other than psychiatric disorders or disabling conditions that severely limit physical activity (i.e., spinal cord injury, multiple sclerosis, and stroke or severe head trauma). The average effect of exercise compared to a control condition was 0.27 SD (95% CI = 0.16 to 0.38). The outcomes were favorable after exercise in nearly 80 percent of the comparisons (26 of 33) with control conditions, but only 13 of 33 comparisons reached statistical significance. The average sample size was about 60 people, but a fourth of the studies had less than 45, a much smaller number than the 200 or so people needed to detect an effect as small as one-third SD. When compared to a placebo (usually stretching or health education), the effect of exercise was reduced to 0.10 SD (95% CI: −0.12 to 0.32) and was significant in just 2 of 9 comparisons.

Figure G8.5 Feelings of Distress/Well-Being: Prospective Cohort Studies, 1995 Through 2007: Crude and Adjusted Odds

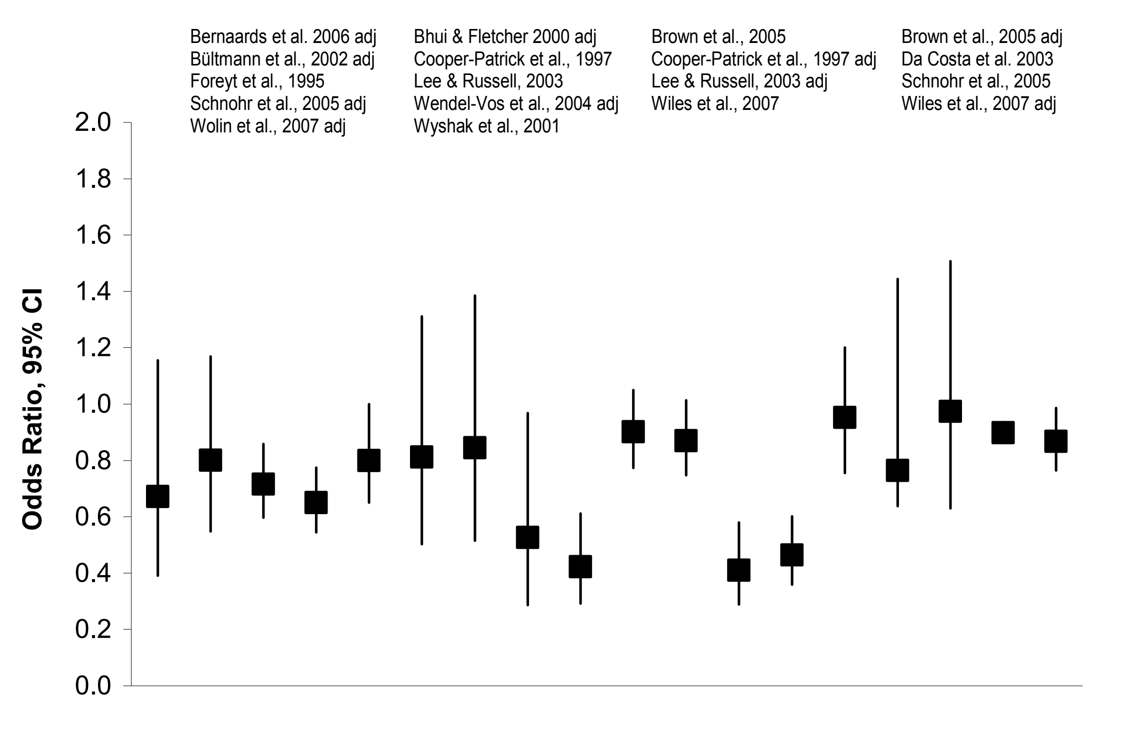

Figure G8.5 Data Points

Author	Year	High	Low	Odds Ratio
Bernaards et al.	2006 adj	1.155	0.391	0.6719
Bhui & Fletcher	2000 adj	1.169	0.548	0.8008
Brown et al.	2005	0.858	0.597	0.716
Brown et al.	2005 adj	0.775	0.545	0.65
Bültmann et al.	2002 adj	1	0.65	0.8
Cooper-Patrick et al.	1997	1.311	0.503	0.8118
Cooper-Patrick et al.	1997 adj	1.385	0.515	0.8444
Da Costa et al.	2003	0.968	0.287	0.527
Foreyt et al.	1995	0.611	0.292	0.4221
Lee & Russell	2003	1.05	0.774	0.9015
Lee & Russell	2003 adj	1.014	0.747	0.8699
Schnohr et al.	2005	0.58	0.289	0.4099
Schnohr et al.	2005 adj	0.601	0.359	0.4648
Wendel-Vos et al.	2004 adj	1.201	0.755	0.9521
Wiles et al.	2007	1.444	0.638	0.764
Wiles et al.	2007 adj	1.507	0.63	0.9741
Wolin et al.	2007 adj	0.935	0.863	0.8985
Wyshak et al.	2001	0.986	0.764	0.868

Do the Effects of Physical Activity on Distress or Well-Being Differ According to Race/Ethnicity, Sex, Age, or Medical Condition?

Conclusions

The available evidence supports that regular physical activity is associated with reduced feelings of distress and enhanced feelings of well-being regardless of age, sex, race/ethnicity, or medical condition. However, whether these factors modify those associations has not been studied. Race and ethnicity have been poorly represented or not described in most studies.

Rationale

Cross-sectional samples of Americans in the National Health Interview Survey (92), the Behavioral Risk Factor Surveillance Survey (93;95), and the National Physical Activity and Weight Loss Survey (91) included African American, Hispanics, and small numbers of Asian Americans and American Indians, but results were not compared between groups. Most of the prospective cohort studies were conducted in Europe or Australia and did not describe minority representation of the sample. The US Nurses' Health Study includes minority women, but their representation was not described in the study of physical activity and well-being in the cohort (94).

Similarly, it is unclear whether sex and age modify the protective effect of physical activity on distress/well-being. Only 4 cohort studies reported findings separately for males and females, with mixed results (96-99), and none compared age groups. Across cohort studies, findings were similar for men and women. However, age was inversely related to reduced odds of distress or increased odds of enhanced well-being regardless of sex. After adjustment for other risk factors, odds were 0.65 (95% CI = 0.61 to 0.72) for men and women younger than age 55 years and 0.90 (95% CI = 0.86 to 0.97) for men and women aged 55 years and older. In RCTs, the average effect of exercise compared to a control condition is similar in both healthy adults (0.28 SD, 95% CI = 0.16 to 0.41) and people with non-psychiatric medical conditions (0.26, 95% CI: 0.10 to 0.41). Figure G8.6 illustrates effect sizes and 95% confidence intervals feelings of distress or well-being in studies comparing exercise with a control condition from the RCTs of adults with or without medical conditions.

These trials reported similar effects of exercise in both men and women and in groups varying in mean aged 31 to 74 years. However, the studies were not designed to compare groups according sex, race/ethnicity, or age. Only 1 of the trials compared men and women (45), and results were mixed across the 3 studies of men (0.49 SD, 95% CI = −0.11 to 1.08). Ten studies reported results for women (0.21 SD, 95% CI = 0.02 to 0.40), and 15 studies combined results for similar proportions of men and women (0.26 SD, 95% CI = 0.12 to 0.41). None compared effects between people of different ages or race/ethnicities. Seven of 16 studies of Americans described the racial/ethnic composition of their samples, but only 2 studies included a substantial portion of African Americans

Figure G8.6 Feelings of Distress/Well-Being: Randomized Controlled Trials 1995 Through 2007

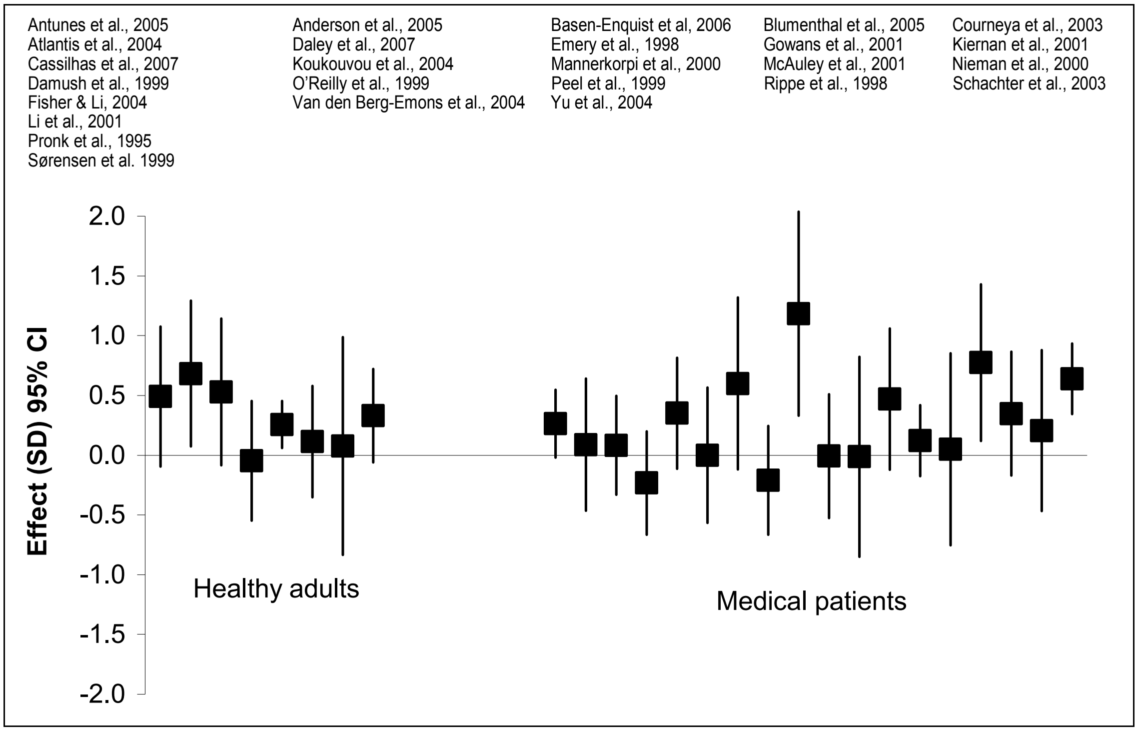

Figure G8.6 Data Points

Healthy Adults	Year	High	Low	Effect Size
Antunes et al.	2005	1.077	−0.095	0.491
Atlantis et al.	2004	1.293	0.073	0.683
Cassilhas et al.	2007	1.144	−0.084	0.53
Damush et al.	1999	0.453	−0.547	−0.047
Fisher & Li	2004	0.455	0.059	0.257
Li et al.	2001	0.58	−0.353	0.114
Pronk et al.	1995	0.987	−0.835	0.0758
Sørensen et al	1999	0.721	−0.059	0.331

Medical Patients	Year	High	Low	Effect Size
Anderson et al.	2005	0.549	−0.019	0.265
Basen-Enquist et al.	2006	0.641	−0.465	0.088
Blumenthal et al.	2005	0.496	−0.332	0.082
Courneya et al.,	2003	0.2	−0.666	−0.233
Daley et al.	2007	0.817	−0.115	0.351
Emery et al.	1998	0.566	−0.566	0
Gowans et al.	2001	1.319	−0.119	0.6
Kiernan et al.	2001	0.246	−0.666	−0.21
Koukouvou et al.	2004	2.037	0.331	1.1837
Mannerkorpi et al.	2000	0.511	−0.527	−0.008
McAuley et al.	2001	0.825	−0.85	−0.0123
Nieman et al.	2000	1.06	−0.121	0.4695
O'Reilly et al.	1999	0.42	−0.176	0.122
Peel et al.	1999	0.854	−0.754	0.05
Rippe et al.	1998	1.43	0.12	0.775
Schachter et al.	2003	0.866	−0.17	0.348
Van den Berg-Emons et al.	2004	0.88	−0.468	0.206
Yu et al.	2004	0.934	0.344	0.639

(46;100). Three studies included small numbers of Hispanics and/or Asian Americans (51;78;100). The small number of studies precluded meaningful comparisons among the medical conditions.

Do the Effects of Physical Activity Vary According to Features of Physical Activity Including Type, Intensity, or Timing (i.e., Session Duration, Weekly Frequency, and Length of Participation)?

Conclusions

Population-based studies indicate that participation in either moderate or high levels of physical activity is associated with reduced feelings of distress or enhanced well-being, when compared with inactivity or very low physical activity exposure. The minimal or optimal type or amount of exercise for reducing feelings of distress or enhancing feelings of well-being are not yet known, but it appears that an increase in physical fitness is not required.

Rationale

Seven prospective cohort studies of feelings of distress or well-being included 3 or more levels of physical activity, using inactivity or low activity as the reference group (18;55;56;94;96;97;101). Independently of age and sex, and with or without adjustment for other risk factors, a linear reduction in odds of about 10% occurred for each level of physical activity compared to people who were inactive or had very low activity. Similarly, odds favored people who met or exceeded recommendations for moderate or vigorous participation by about 5% compared to active people who did not meet either recommended level. No studies permitted a direct comparison of moderate and vigorous recommended levels, but unadjusted odds were lower for participation in moderate-to-vigorous physical activity (OR = 0.77, 95% CI = 0.70 to 0.84) compared to participation at levels less than recommended (OR = 0.84, 95% CI = 0.78 to 0.91). Figure G8.7 shows the odds ratios and 95% CI in prospective cohort studies that examined the dose-response association between levels of physical activity and feelings of distress or well-being.

A few RCTs manipulated type (walking versus aquatic exercise or Qigong) or timing (i.e., intermittent versus continuous) of exercise to examine whether those feature modify the effects of exercise on feelings of distress or well-being (60-62;64), but the studies did not include a control group who did not exercise. About 45 percent of the controlled studies used an aerobic exercise intervention such as walking, jogging, cycling, or aquatic exercise, and another 30 percent of the studies combined aerobic activity with resistance exercise. Only 3 studies used resistance exercise alone, and none compared aerobic with resistance exercise. About half the studies used continuous exercise, and a third used intermittent exercise. One study of home-based aerobic dance reported positive effects when daily exercise was a continuous 30-minute session but not when it was 2 sessions of 15 minutes each separated by 4 hours (80). Timing of the exercise could not be determined in the other studies. Effects of exercise did not differ according to the mode or timing of exercise.

Figure G8.7 Feelings of Distress/Well-Being: Prospective Cohort Studies 1995 Through 2007: Dose Response

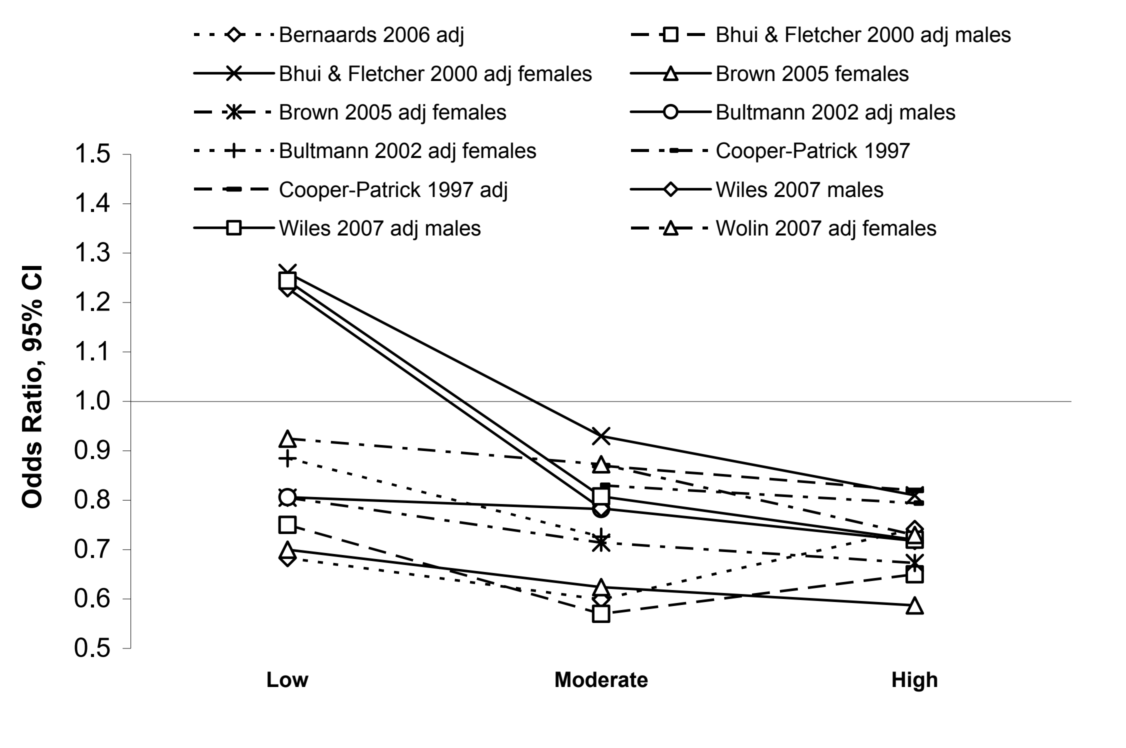

Figure G8.7 Data Points

Author/Year	Low	Moderate	High
Bernaards 2006 adj	0.6829	0.599	0.7416
Bhui & Fletcher 2000 adj males	0.75	0.57	0.65
Bhui & Fletcher 2000 adj females	1.26	0.93	0.81
Brown 2005 females	0.7	0.624	0.587
Brown 2005 adj females	0.805	0.714	0.673
Bultmann 2002 adj males	0.806	0.782	
Bultmann 2002 adj females	0.885	0.726	
Cooper-Patrick 1997		0.83	0.794
Cooper-Patrick 1997 adj		0.87	0.8196
Wiles 2007 males	1.2288	0.7833	0.7178
Wiles 2007 adj males	1.244	0.8079	0.72
Wolin 2007 adj females	0.9247	0.8729	0.7298

Three-fourths of the studies used a moderate-to-vigorous exercise intensity of 60% to 80% of people's aerobic capacity or maximum strength. The average session lasted 45 minutes and occurred 3 days per week, but studies had a wide range of session duration (10 to 85 minutes) and weekly frequency (1 to 7 days). Nonetheless, these features of exercise did not modify effects independently of each other. Studies lasted an average of 6 months, and a fourth of the studies lasted less than 3 months. Length of the exercise program was also unrelated to symptom outcome.

Eleven of 13 studies that measured cardiorespiratory fitness reported a significant increase that averaged 1 SD, or about 20%. Strength was significantly increased in each of 3 studies that measured strength. However, there was no association between fitness increases and changes in feelings of distress or well-being.

Question 4: Is There an Association Between Physical Activity and Cognitive Function and Dementia?

Introduction

Cognition can be conceptualized as processes involved in selecting, manipulating, and storing information derived from experiences and how these processes guide behavior. Cognitive abilities are functional properties of the individual that are not directly observed but are inferred from behavior. Researchers in the disciplines of psychometrics, cognitive psychology, and neuropsychology have developed more than 400 tests designed to assess specific types of mental processing (102). They range from those designed to evaluate specific processes (e.g., working memory, information-processing speed, inhibition) to those that assess global mental functioning involving multiple processes. Assessment methods include those designed specifically to evaluate the effects of injury and degenerative disease on cognitive function and those designed to evaluate individual differences in healthy individuals. The multidimensionality of cognitive function and the diversity of assessment methods present a special challenge for the interpretation of the evidence about the effect of physical activity and exercise on cognitive function.

Does Physical Activity Protect Against the Onset of Age-Related Decline in Cognitive Function or Dementia?

Conclusions

The weight of the available evidence from prospective cohort studies supports the conclusion that physical activity delays the incidence of dementia and the onset cognitive decline associated with aging.

Rationale: Prospective Cohort Studies

At least 17 prospective population-based cohort studies have been published since 1995 that have assessed the association of individuals' level of physical activity with the onset of age-related decline in cognitive functioning among healthy adults or with incident cases of dementia. Studies that confounded the measure of physical activity with other leisure or mental activities were not considered. Four studies showed protective effects against cognitive decline in healthy aging adults (103-106) and two studies did not find protective effects (107;108).

Of the 11 studies of dementia, 7 reported a protective effect of physical activity. Nine of 16 comparisons were statistically significant (mean OR = 0.63 95% CI = 0.50 to 0.80). Though limited in number, results were stronger for Alzheimer's disease than for other dementias, including vascular dementia. Figure G8.8 describes results from prospective cohort studies of physical activity and incident dementia or Alzheimer's disease.

The studies varied considerably in sample size, methods used to assess participant's physical activity level and mental function, and the duration between baseline and follow-up measurements. In general, most studies with sample sizes greater than 1,000 individuals report that physical activity delays the onset of cognitive decline or dementia. The results of studies conducted with smaller numbers of participants are inconsistent. The lack of agreement among the studies reviewed may be explained, at least in part, in terms of statistical power. An alternative explanation for the inconsistencies among the results of these studies is the confounding influence of cognitive stimulation derived while engaged in physical activities (108). In studies that report a relation between physical activity and delayed onset of dementia, the effects were detected using both clinical assessments and standardized measures of cognitive function. Further, early-life (103), mid-life (109), and current levels of physical activity all appear to postpone symptoms of dementia. Thus, although exercise does not prevent dementia, it may be associated with a delay in its onset, perhaps by maintaining a higher level of cognitive function for physically active adults than less physically active individuals as they age (110).

Rationale: Randomized Controlled Trials

A meta-analysis of 18 RCTs (111) indicated that aerobic exercise training produced an effect size (SD) of 0.48 for improving performance on all cognitive tasks, with the greatest effect size (0.68) for executive processing tasks that measure goal-oriented decision-making behavior, compared to 0.46 for controlled-processing tasks that assess attentional effort, 0.42 for visuospatial tasks that evaluate the perceptual organization, and 0.27 for speeded tasks that focus on rapid responses and movements. The results of 2 recently conducted experiments provide support for the facilitative effects of resistance exercise training on information-processing functions of cognitively healthy older adults (85;112), though one experiment found no significant effects of either yoga training or a walking program on older adults' memory or information-processing speed (113).

Figure G8.8 Incident Total Dementia or Alzheimer's Disease: Prospective Cohort Studies, 1995 Through 2007: Crude and Adjusted Hazard

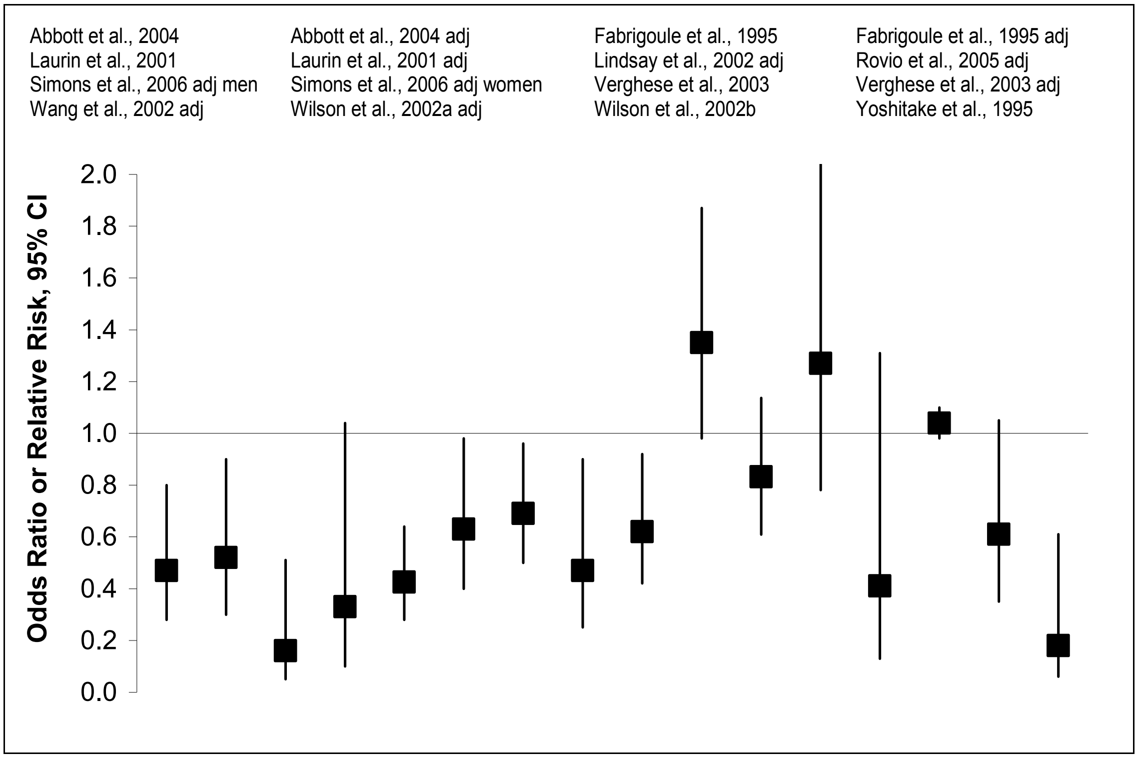

Figure G8.8 Data Points

Author/Date	High	Low	Odds Ratio or Relative Risk
Abbott et al. 2004	0.8	0.28	0.47
Abbott et al. 2004 adj	0.9	0.3	0.52
Fabrigoule et al. 1995	0.51	0.05	0.16
Fabrigoule et al. 1995 adj	1.04	0.1	0.33
Laurin et al. 2001	0.64	0.28	0.425
Laurin et al. 2001 adj	0.98	0.4	0.63
Lindsay et al. 2002 adj	0.96	0.5	0.69
Rovio et al. 2005 adj	0.9	0.25	0.47
Simons et al. 2006 adj men	0.92	0.42	0.62
Simons et al. 2006 adj women	1.87	0.98	1.35
Verghese et al. 2003	1.137	0.609	0.832
Verghese et al. 2003 adj	2.06	0.78	1.27
Wang et al. 2002 adj	1.31	0.13	0.41
Wilson et al. 2002a adj	1.1	0.98	1.04
Wilson et al. 2002b	1.05	0.35	0.61
Yoshitake et al. 1995	0.61	0.06	0.18

Does Physical Activity Reduce Symptoms Associated With Alzheimer's Disease or Other Dementias?

Conclusions

Evidence from RCTs of healthy older adults and people with Alzheimer's disease or other dementias support that regular participation in physical activity improves aspects of cognitive function or reduces symptoms of dementia.

Rationale

A meta-analytic review of 10 randomized controlled studies of older adults diagnosed with cognitive impairments (114) concluded that physical activity interventions benefit the cognitive function of older adults regardless of disease status. Similar to the finding of Colcombe and Kramer (111) with healthy older adults, older adults with impairments who participated in physical activity interventions show better cognitive function than those assigned to control conditions (ES = .57). However, concerns of the methodological integrity of many of the studies reviewed led the authors to recommend caution in the interpretation of these findings. The beneficial effects of physical activity on older adults with dementia have been reported in 2 recent experiments (115;116).

Although individuals with dementia benefit cognitively from participation in exercise training, it is not clear whether physical activity ameliorates symptoms of dementia or simply maintains the level of cognitive function for those who are active. In several experiments, differences in cognitive function and information-processing performance in older adults assigned to physical activity or control conditions was due to the degradation of performance by inactive individuals. Further, although relatively short-term exercise programs demonstrate improvements on older adults' cognitive function, the durability of the effect remains to be determined.

Do the Effects of Physical Activity on Cognitive Function Differ According to Genetics, Age, Sex, Race/Ethnicity, or Medical Condition?

Conclusions

The available evidence supports the benefits of physical activity for improving or maintaining cognitive function among healthy older adults, more so than for young adults whose cognitive health is normally near peak function. The smaller, but generally favorable effects of physical activity on cognitive function and symptoms among people with dementia may be modified by the severity of dementia and other health factors.

Rationale

The protein apolipoprotein E4 (ApoE4) is a known risk factor for Alzheimer's disease. Individuals who have two copies of the ApoE4 allele are at greatest risk for the disease, followed by individuals with one copy of the ApoE4 allele, followed by those who are non-carriers. Investigators have suggested that physical activity diminishes the effects of ApoE4 on the development of Alzheimer's disease. The evidence from prospective cohort studies has been inconsistent, however, with some reporting that physical activity benefits the cognitive functioning of ApoE4 non-carriers and has no effect for ApoE4 carriers (117), and others report that physical activity benefits cognitive functioning for ApoE4 carriers, but has no effect for ApoE4 non-carriers (117;118). Nevertheless, evidence that genetic factors may influence the relation between physical activity and cognition is important as it may help to explain some of the inconsistencies among studies that have examined the effects of physical activity on cognitive performance in the general population of older adults.

The results of one of 15 prospective cohort studies reviewed suggest that sex may modify the relation between physical activity experiences and cognitive function (103). Older Dutch men, but not women, who reported being physical active early in their lives (ages 15 to 25 years) had faster information-processing abilities than those who were less physically active during those years of their lives.

The benefits of physical activity on the cognitive function of older adults who have dementia may be reduced in individuals with cardiovascular risk factors. Daily walking or gardening reduced the 16-year combined risk of Alzheimer's and vascular dementia among elderly male residents of Dubbo, New South Wales in Australia but only daily gardening was protective among females (119). An evaluation of the changes in brain structure and function that accompany Alzheimer's disease and changes in cerebral metabolic processes that accompany ischemia led Eggermont and colleagues (120) to speculate that an individual's cardiovascular risk factors may attenuate or even reverse the positive effects of exercise on cognition and that participation in structured exercise programs may not be beneficial for all patients. Thus, while the bulk of scientific evidence obtained thus far provides compelling support for the benefits of physical activity for healthy older adults, the favorable effects of physical activity may be modified by cardiovascular health or risk. Additionally, the gains in cognitive function brought about by physical activity may be observed more clearly in older adults than young adults, whose level of cognitive health is near its peak and provides less room for exercise-related improvement (121).

Do the Effects of Physical Activity Vary According to Features of Physical Activity, Including Type, Intensity, or Timing (i.e., Session Duration, Weekly Frequency, and Length of Participation)?

Conclusions

Evidence from prospective cohort studies or RCTs is insufficient to determine whether cognitive function or symptoms of dementia vary according to features of physical activity exposure.

Rationale

Four of 6 prospective cohort studies of cognitive decline with aging in healthy people examined more than 2 levels of physical activity exposure. Three of them, including a large cohort of women from the Nurses' Health Study (105), found a dose-response relation, whereby the decline in risk was greater at higher levels of physical activity participation. Four of 10 prospective cohort studies of dementia risk examined more than 2 levels of physical activity exposure. Two of the 4 studies reported a dose-response relation such that higher levels of physical activity result in greater protection against dementia (122;123). The other 2 studies of dementia (124;125) reported similar trends, but the cohorts were too small to detect statistical significance.

The methods used to measure physical activity vary greatly, both among RCTs and prospective cohort studies, which makes it difficult to identify the effects of specific features of physical activity on cognitive function. The use of self-report measures of physical activity is a limitation of prospective studies in general, but it is a unique problem for studies of cognitive function when the measures of physical activity include leisure activities that involve social and cognitive activities but light physical exertion (e.g., crossword puzzles, card games).

Cognitive function has been associated with levels of and gains in cardiorespiratory fitness among healthy, older adults (126-128), and fitness also has been positively correlated with white matter integrity (129), brain volume (130;131), and hippocampal neurogenesis (132). However, the cumulative evidence does not provide clear support that cardiorespiratory fitness is associated with cognitive performance (133).

The sole randomized controlled experiment designed specifically to assess the dose-effect relation between resistance training and information processing in healthy older adults reported that similar benefits were derived from interventions that involved weight loads of either 50% or 80% of maximal strength (85). The results of a large prospective cohort study, led Podewils and colleagues (117) to conclude that, with respect to the onset of dementia, the number of different physical activities in which older adults engage may be more important than their frequency, intensity, or duration. At this time, the dose-response relation among mode, duration, and intensity of exercise training and changes in cognition remains unclear.

Question 5: Is There an Association Between Physical Activity and Sleep?

Introduction

Nearly one-third of the adult population in the United States experiences insomnia every year, and each year 50 to 70 million Americans experience some effects on their health from sleep disorders, sleep deprivation, and excessive daytime sleepiness (134). The financial cost is approximately $65 billion, $50 billion of which represents costs to industry from lost productivity. Approximately 70 sleep disorders exist, the most studied of which are insomnia and obstructive sleep apnea. Many neurological disorders are associated with poor sleep, and poor sleep itself can have important health-related outcomes. Only about 5% to

20% of people who suffer sleep disturbances will seek help from a primary care physician, and many will purchase over-the-counter sleep aids.

Does Physical Activity Protect Against the Onset of Insomnia or Other Sleep Problems?

Conclusions

A small number of observational, population-based studies provides initial evidence supporting a positive association of regular participation in physical activity with lower odds of disrupted or insufficient sleep, including sleep apnea.

Rationale

Population-based studies have found that physically active people report better sleep than inactive people (135), but most of the studies used a cross-sectional design and do not permit conclusions about the temporal sequence of physical activity and sleep. One prospective cohort study (136) found that those who reported more physical activity had nearly 40% lower odds of incident insomnia. Eleven of 13 cross-sectional studies show that the chances of having insufficient or interrupted sleep are lower (mean OR = 0.73 95% CI = 0.66 to 0.81) among adults who are engaged in more physical activity than among those who have less physical activity or are sedentary (136-146). At least 2 population-based, cross-sectional studies found that men and women who exercise at least 3 hours per week had lower odds of sleep apnea measured by polysomnography (147;148). Figure G8.9 shows odds ratios from population-based cross-sectional studies of physical activity and self-ratings of disrupted or insufficient sleep.

Does Physical Activity Reduce Sleep Problems and Enhance Sleep Quality?

Conclusions

The weight of the evidence from a small number of RCTs supports the conclusion that regular participation in physical activity has favorable effects on sleep quality and is a useful component of good sleep hygiene.

Rationale

Six RCTs, all published since 1995, show positive and large effects (more than 1 SD) of exercise training on symptoms of poor sleep and self-rated sleep quality (26;37;149-152). Acute aerobic exercise of varying intensities elicits small to moderate improvements (approximately 4 to 13 minutes) in several features of objectively measured sleep quality, including increases in time spent in slow-wave sleep, total sleep time, and latency for rapid eye movement (REM) sleep, and a decrease in REM sleep among normal sleepers (153). The effects for total sleep time are larger when the exercise lasts more than an hour but do not vary according to people's fitness levels or the intensity of the exercise. The effects of a

Figure G8.9 Physical Activity and Symptoms of Disrupted or Insufficient Sleep: 13 Cross-Sectional Studies (Total n=84,904)

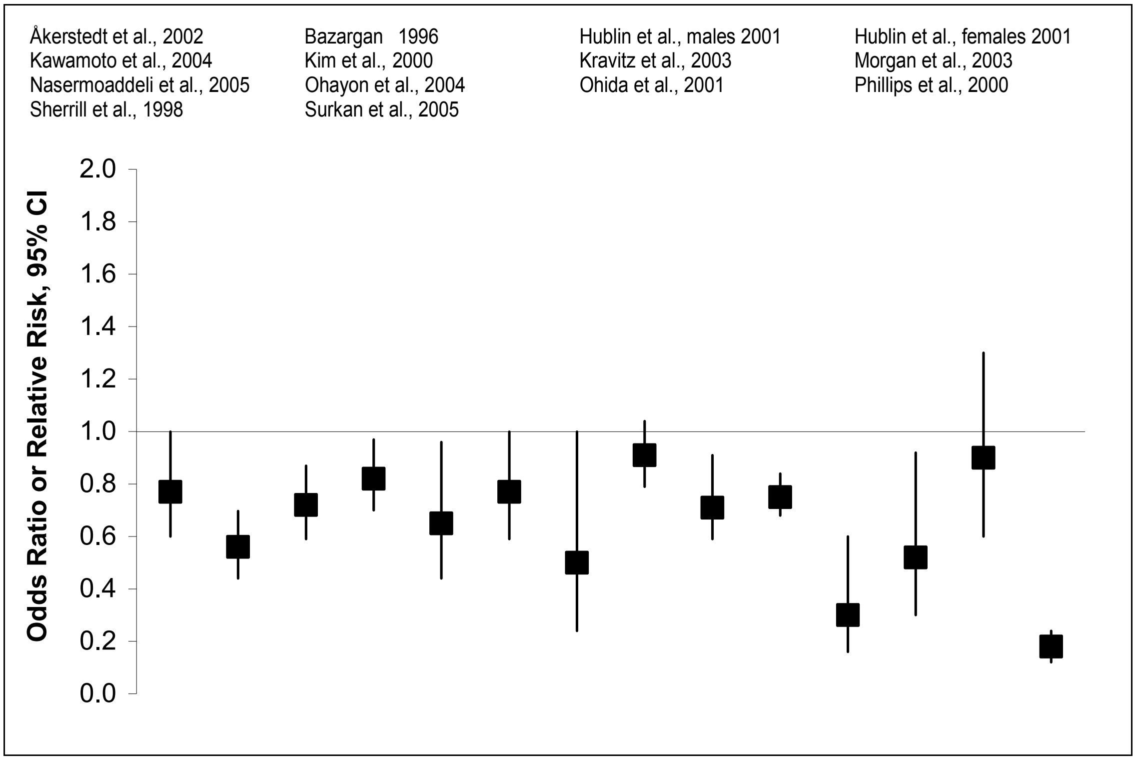

Figure G8.9 Data Points

Author/Date	High	Low	Odds Ratio or Relative Risk
Åkerstedt et al., 2002	1	0.6	0.77
Bazargan 1996	0.697	0.44	0.56
Hublin et al., males 2001	0.87	0.59	0.72
Hublin et al., females 2001	0.97	0.7	0.82
Kawamoto et al., 2004	0.96	0.44	0.65
Kim et al., 2000	1	0.59	0.77
Kravitz et al., 2003	1	0.24	0.5
Morgan et al., 2003	1.04	0.79	0.91
Nasermoaddeli et al., 2005	0.91	0.59	0.71
Ohayon et al., 2004	0.84	0.68	0.75
Ohida et al., 2001	0.6	0.16	0.3
Phillips et al., 2000	0.92	0.3	0.52
Sherrill et al., 1998	1.3	0.6	0.9
Surkan et al., 2005	0.61	0.06	0.18

single exercise session on the sleep of people with sleep disorders are not known. The long-term effects of exercise on objective measures of sleep among poor sleepers have not been studied much (154), and the results of a few RCTs (155-157) and quasi-experimental studies (158;159) of nursing home residents or patients with sleep apnea have been mixed.

Do the Effects of Physical Activity on Sleep Differ According to Age, Sex, Race/Ethnicity, or Medical Condition?

Conclusions

The few RCTs and the scarcity of prospective cohort studies do not permit conclusions about whether the effects of physical activity on sleep differ according to types of people, age, type of sleep disorder, or other medical conditions.

Rationale

Self-reports of exercise frequency and sleep problems were inversely related in a cross-sectional study of a thousand elderly African American residents of New Orleans (138). Older, sedentary adults without cardiovascular disease who complained of sleep problems reported improvements in self-rated sleep after a 16-week exercise program of moderate intensity consisting of 30 to 40 minutes of low-impact aerobics and brisk walking 4 times a week (150). Similarly, older, depressed adults with sleep problems who were not currently being medically treated reported improvements in self-rated sleep that was accompanied by a reduction in depression symptoms (160) after a 10-week, 3-days-per-week, moderately intense (80% of one maximum repetition) resistance training program (26).

Do the Effects of Physical Activity Vary According to Features of Physical Activity Including Type, Intensity, or Timing (i.e., Session Duration, Weekly Frequency, and Length of Participation)?

Conclusions

Evidence from prospective cohort studies or RCTs is insufficient to determine whether features of sleep quality vary according to features of physical activity exposure.

Rationale

In a year-long study of moderate intensity (60% to 85% maximal heart rate) walking or leg cycling exercise (45 minutes or more, 5 or more days each week) among postmenopausal, overweight or obese, sedentary women not taking hormone replacement therapy, morning exercisers who exercised at least 225 minutes per week reported less trouble falling asleep compared with those who exercised less than 180 minutes per week. In contrast, evening exercisers who exercised at least 225 minutes per week reported more trouble falling asleep compared to those who exercised less than 180 minutes per week (152). However, those differences might have been biased, as the timing of exercise sessions were self-selected and most evening exercisers were employed while the morning exercisers were mostly retired or not working. Regardless, increases in cardiorespiratory fitness were related to reduced odds of poor sleep quality, independently of changes in body mass index or time spent outdoors.

Fifteen, 60-minute sessions once a week that emphasized moderate-intensity recreational sports activities (e.g., softball, dance, self-defense, swimming, and athletics) were accompanied by a small increase in self-rating of total time spent sleeping among older, sedentary adults who were group-randomized according to age and socioeconomic status (161). Other studies of less vigorous exercises, such as walking or yoga, have reported smaller or statistically non-significant reductions in self-rated sleep (47;162;163).

Question 6: Is There an Association Between Physical Activity and Other Aspects of Mental Health?

Introduction

Physical activity and exercise may have the potential to reduce the onset or progression of central nervous system disorders other than dementia that contribute to disability and mortality risk, such as multiple sclerosis (164) and Parkinson's disease (165). They also may reduce the adverse impact of these disorders on quality of life. However, too few prospective cohort studies and RCTs have been conducted to allow conclusions about the protective effects of physical activity for CNS diseases other than Alzheimer's disease and other dementias.

Benefits of physical activity may also extend to other aspects of mental health that are less directly linked to disability and mortality risks but are important contributors to overall quality of life, such as self-esteem and feelings of energy/fatigue. Sufficient evidence exists to encourage more study in these areas, but presently not enough studies are available to draw conclusions about how the effects of physical activity or exercise might differ according to types of people or types and amounts of physical activity.

Self-Esteem

Enhanced self-esteem has significance for mental health because it conveys a feeling of value or self-worth and it is a generalized indicator of psychological adjustment and health risk (89). A meta-analysis of about 50, mostly small, RCTs of various types of exercise reported an average increase in self-esteem of about 0.25 SD among adults (166). Self-esteem is increased among adults (166) when physical fitness is increased. However, because features of physical activity exposure were not associated with self-esteem outcomes in the studies, it is difficult to conclude that fitness influences self-esteem independently of other diverse aspects of the studies' methods, social contexts, and participant expectations of benefit. Nonetheless, larger gains in self-esteem can be expected for individuals with low initial levels, and for whom physical attributes have a relatively high value as a part of global self-concept.

Chronic Fatigue

The literature on physical activity and chronic fatigue syndrome is small, and epidemiologic studies of this condition rarely have included measures of physical activity. Five relatively small RCTs all show a positive effect of exercise training on symptoms of chronic fatigue syndrome (167-171). A dozen population-based observational studies, including 4 prospective cohorts published since 1995, suggest a protective effect of physical activity against feelings of fatigue or low energy (OR = 0.61, 95% CI = 0.52 to 0.72) (172), and RCTs of groups of medical patients and other adults show a moderate reduction in symptoms of fatigue (173;174).

Question 7: Is There an Association Between Physical Activity and Adverse Psychological Events?

Some adverse psychological events have been reported among extremely active people, but whether they are causally influenced by physical activity exposure is not yet known. Clinical cases of "running addiction," were described 30 years ago (175), whereby motivation for running exceeded commitments to work, family, social relations, and medical advice. Similar cases have been labeled *positive addiction, runner's gluttony, fitness fanaticism, athlete's neurosis, obligatory running*, and *exercise abuse*.

However, little is understood about the origins, valid diagnosis, or mental health impact of exercise abuse (176;177). Though exercise abuse or addiction is a recognized problem for clinical medicine, its population prevalence is unknown but likely low. Likewise, it is not known whether excessive exercise and disordered eating share a common course that is motivated by common goals and followed by common medical outcomes. It has been proposed that anorexia athletica is a subclinical syndrome of anorexia nervosa (178), but the prevalence of disordered eating and the independent risk caused by sport and exercise have not yet been established by controlled epidemiologic and clinical studies. In most cases, the eating behaviors of athletes do not appear to signal anorexia nervosa or bulimia (i.e., bingeing and purging (179)), which have prevalence rates in the United States of about 1% and 4%, respectively. Cases of muscle dysmorphia, a proposed form of body dysmorphic disorder, in which a person develops a pathological preoccupation with his or her muscularity and has associated symptoms of severe subjective distress, impaired social and occupational functioning, and abuse of anabolic steroids and other substances, have been reported (180;181). No population-based studies have been conducted to determine the prevalence of muscle dysmorphia nor any prospective cohort studies or randomized clinical studies to determine whether muscle dysmorphia or body dysmorphia results from participation in resistance exercise training or whether people who have existing vulnerability to a distorted body image and self-concept are drawn to weightlifting.

Results from nearly 100 studies on these potential adverse events of participation in exercise training and sports are inconclusive because the studies described symptoms among different groups of active or inactive people without fully considering attributes other than activity history that might account for abusive exercise or eating problems (177). Risk profiles of exercise abusers or athletes have not been evaluated against those of non-athletes from the same academic, socioeconomic, or psychological backgrounds. The studies often lack standard definitions or valid measures of physical activity or disordered eating. Though anorexics often augment food restriction by hyperactivity, their aerobic fitness is well below average because of muscle wasting and anemia, in contrast to the above-average aerobic fitness of habitual runners and trained athletes. In addition, cross-sectional studies have not revealed a common psychopathology between obligatory (i.e., excessively committed) runners and anorexic patients.

Anxiety can be elevated slightly immediately after maximal exercise testing or heavy resistance exercise (i.e., approximately 80% of 1 repetition maximum (182;183)), but that elevation is temporary. Nonetheless, overall reductions in anxiety can be delayed by 1 or 2 hours after resistance exercise is completed. Evidence from 15 studies refutes the potential association between exercise and panic attacks; only 5 panic attacks were reported during exercise involving 444 exercise bouts performed by 420 panic disorder patients (184). Research has also shown that lactate accumulation resulting from exercise is not related to increased risk of panic attacks among patients with panic disorder (185) or postexercise anxiety in normal individuals (186). Moreover, a small, randomized clinical trial recently showed that 10 weeks of aerobic exercise training was effective in reducing symptoms of anxiety among patients with panic disorder and agoraphobia (72).

Question 8: What Mechanisms Can Plausibly Explain the Association Between Physical Activity and Mental Health?

Very limited evidence exists about biological mechanisms that can explain the effects of physical activity or exercise on mental health (187). It is accepted that the brain and the rest of the central nervous system regulate moods, emotions, cognitions, sleep, and neurological functions, and that social and environmental factors interact with genes to regulate the brain. Experimental animal studies show that both voluntary and forced running activate and produce adaptations in several aspects of brain neural circuits involved with learning, memory, motivation, and behaviors that mimic features of human depression, anxiety, and cognitive function. These include neurotransmitters (e.g., acetylcholine, glutamate, and gamma-aminobutyric acid), neuromodulators (e.g., dopamine, norepinephrine, and serotonin) and their receptors, neuropeptides that influence neurotransmission (e.g., galanin and neuropeptide Y), and neuronal growth factors (e.g., brain derived neurotrophic factor and VGF), all of which are targets of experimental treatments for depression and anxiety. However, only a few studies have used animal models of mental or neurological disorders, testing whether brain and behavior changes coincide as predicted after physical activity (e.g., 188-194). Likewise, the way in which exercise regulates sleep has received little study and is unknown. Indirect evidence suggests that acute bouts of exercise are positively associated with melatonin production in women (195) and can induce circadian phase shifts (196) including a phase delay in circadian melatonin rhythm (197), influence adenosine metabolism (198), and activate brain neurological circuits hypothesized to help people feel less anxious and depressed (154).

Unlike other chronic diseases, non-biological mechanisms also may explain the effect of physical activity on mental health. Cognitive explanations include increased self-esteem (e.g., 199), perceptions of social support, and efficacy beliefs about personal control. Similarly, acute responses to single exposures of physical activity, such as transient changes in moods (200;201) or feelings of energy; pleasant (e.g., enjoyment) or unpleasant (e.g., discomfort or pain) affective experiences during exercise; or nightly sleep (153), are likely to contribute to the accumulative psychological responses that typically are measured only after chronic exposure to physical activity. Also such responses might contribute indirectly by increasing exposure to physical activity (e.g. better adherence to exercise) or by influencing other factors important to mental health (e.g., social engagement). Tests of those contributions will require research designs and methodologies that are difficult to implement with tight control in clinical or public health settings (e.g., 202-206). Thus, continued experimental research on biological mechanisms and innovative tests of social or cognitive mediators of psychological responses are needed to confirm and explain the evidence from prospective observational studies and RCTs that physical activity and exercise promote mental health.

Overall Summary and Conclusions

The weight of the cumulative evidence from prospective cohort studies and RCTs of uneven quality supports the conclusion that physical activity has protective benefits for several aspects of mental health. The evidence is strongest for protection against symptoms of depression and cognitive decline associated with aging, including the onset of dementia. Substantial evidence also suggests that physical activity reduces symptoms of anxiety and poor sleep, as well as feelings of distress and fatigue, and enhances well-being. Physical activity generally appears equally beneficial for adults regardless of age, sex, race/ethnicity, or health status, but few studies have directly compared benefits or hazards of physical activity among those population segments. Minority groups have been poorly represented in most studies. A small number of prospective cohort studies suggest that health benefits for depression and dementia are greater with higher levels of physical activity exposure, but insufficient evidence precludes conclusions about the minimal or optimal types or amounts of physical activity for mental health. Benefits do not appear to depend on fitness or fitness gains. Current evidence supports the conclusion that regular participation in moderate-to-vigorous physical activity, consistent with current public health guidelines, confers mental health benefits when compared to participation in low levels of physical activity or a sedentary lifestyle.

Research Needs

This review of physical activity and mental health identified a number of research needs. First, more prospective cohort studies and tightly controlled RCTs are needed, especially for anxiety and sleep disorders. Specifically:

- More studies of under-represented groups and of people at high risk of mental health disorders are needed.
- Selection of potential confounders specific to mental health risks need to be included in prospective cohort studies.
- Reporting of adherence to and dropout from trials should be improved, particularly with respect to the impact on the trial's efficacy and likely population effectiveness.
- Investigators should strive for convergence of subjective and objective measures of physical activity and should specify the social and environmental contexts in which physical activity occurs.
- Valid outcome measures need to be selected, refined, and used uniformly.
- Physical activity exposures and outcomes need to be measured frequently to permit investigators to model change.
- It would be helpful to conduct additional RCTs comparing the effects of exercise with other preventive interventions.
- Novel designs that distinguish social moderators and mediators of outcomes from experimental contamination (i.e., placebo effects) would make a valuable contribution to the field.

A second important research need is studies that manipulate or directly compare standardized features of physical activity, including type, intensity, and timing, with the settings in which activity takes place (e.g., group vs. solitary, community vs. home, indoor vs. outdoor).

Finally, it would be helpful to accelerate the synergy between human brain imaging studies and neuroscience studies that use animal models of human disease. This improved synergy could help elucidate biological mechanisms underlying the benefits of physical activity to mental health. An increased emphasis on modeling of social-cognitive mediators of mental health outcomes and studies of gene-environment interactions also would be valuable additions to the field.

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