The Effect of Exercise Training on Anxiety Symptoms Among Patients

A Systematic Review

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Background: Anxiety often remains unrecognized or untreated among patients with a chronic illness. Exercise training may help improve anxiety symptoms among patients. We estimated the population effect size for exercise training effects on anxiety and determined whether selected variables of theoretical or practical importance moderate the effect.

Methods: Articles published from January 1995 to August 2007 were located using the Physical Activity Guidelines for Americans Scientific Database, supplemented by additional searches through December 2008 of the following databases: Google Scholar, MEDLINE, PsycINFO, PubMed, and Web of Science. Forty English-language articles in scholarly journals involving sedentary adults with a chronic illness were selected. They included both an anxiety outcome measured at baseline and after exercise training and random assignment to either an exercise intervention of 3 or more weeks or a comparison condition that lacked exercise. Two co-authors independently calculated the Hedges *d* effect sizes from studies of 2914 patients and extracted information regarding potential moderator variables. Random effects models were used to estimate sampling error and population variance for all analyses.

Results: Compared with no treatment conditions, exercise training significantly reduced anxiety symptoms by a mean effect Δ of 0.29 (95% confidence interval, 0.23-0.36). Exercise training programs lasting no more than 12 weeks, using session durations of at least 30 minutes, and an anxiety report time frame greater than the past week resulted in the largest anxiety improvements.

Conclusion: Exercise training reduces anxiety symptoms among sedentary patients who have a chronic illness.

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ANXIETY, AN UNPLEASANT mood characterized by thoughts of worry, is an adaptive response to perceived threats that can develop into a maladaptive anxiety disorder if it becomes severe and chronic.[1] Anxiety symptoms and disorders are common among individuals with a chronic illness,[2-8] yet health care providers often fail to recognize or treat anxiety and may consider it to be an unimportant response to a chronic illness.[9]

Anxiety symptoms can have a negative impact on treatment outcomes in part because anxious patients can be less likely to adhere to prescribed medical treatments.[10,11] Personal costs of anxiety among patients include reduced health-related quality of life[12] and increased disability, role impairment,[13] and health care visits.[14]

Adequate evidence is available to justify screening for anxiety problems in primary care settings and prescribing effective treatments for those likely to benefit.[9,14] While pharmacological and cognitive behavioral therapies are both efficacious in reducing anxiety,[15,16] there continues to be interest in alternative therapies such as relaxation and exercise.[17-19]

Exercise training is a healthful behavior with a minimal risk of adverse events that could be an effective and practical tool for reducing anxiety among patients.[20-22] Meta-analytic reviews have summarized the association between exercise and anxiety symptoms both in samples of primarily healthy adults[23-26] and exercise training studies of patients with fibromyalgia and cardiovascular disease, but these analyses did not focus on the best available evidence.[27-29]

We used the results from randomized controlled trials to evaluate the effects of exercise training on anxiety. One goal was to estimate the population effect size for anxiety outcomes. A second goal was to learn whether variables of theoretical or practical importance, such as features of the exercise stimulus and the method for

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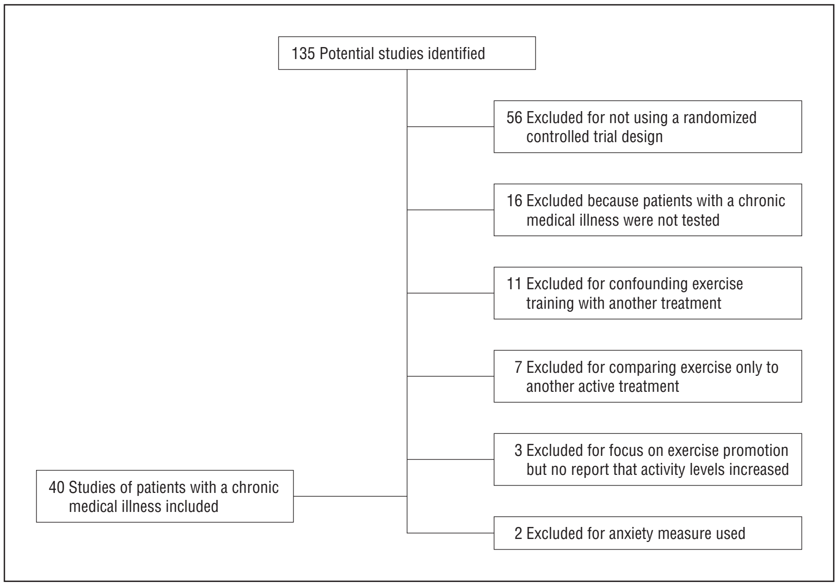

Figure 1. Flowchart for selection of studies

measuring anxiety, account for variation in the estimated population effect.

METHODS

This systematic review and meta-regression analysis was conducted in a manner consistent with guidelines set forth in the QUOROM statement.[30]

DATA SOURCES AND SEARCHES

Articles published from January 1995 to August 10, 2007, were located using the Physical Activity Guidelines for Americans Scientific Database, developed and maintained by the Division of Nutrition, Physical Activity, and Obesity at the Centers for Disease Control and Prevention's National Center for Chronic Disease Prevention and Health Promotion.[20] That search was supplemented by additional searches through December 2008 of the following databases: Google Scholar, MEDLINE, PsycINFO, PubMed, and Web of Science. We used the keywords "exercise," "physical activity," "anxiety," "tension, "randomized trial," and "randomized controlled trial." Supplemental searches of the articles retrieved and those supplied by colleagues were performed manually.

STUDY SELECTION

Inclusion criteria included (1) English-language articles, (2) sedentary adult participants with a chronic illness, (3) random assignment to either an exercise intervention of at least 3 weeks or a comparison condition that lacked exercise training, and (4) an anxiety outcome measured at baseline and after exercise training.

Investigations were excluded that (1) included exercise as one part of a multicomponent intervention but did not include the additional component (eg, stress management) in a comparison condition, (2) compared exercise only with an active treatment (eg, cognitive behavioral therapy, medication, another mode of exercise), (3) focused on education promotion interventions aimed at increasing physical activity but failed to show that physical activity levels were increased, and (4) used anxiety outcome measures focused on a specific phobia. **Figure 1** provides a flowchart of study selection.

DATA EXTRACTION AND QUALITY ASSESSMENTS

Study Characteristics

Seventy-five effects were derived from 40 studies[31-70]: 21 from patients with cardiovascular disease, 15 from patients with fibromyalgia, 10 from patients with multiple sclerosis (MS), 9 from patients with psychological disorders, 8 from patients with cancer, 4 from patients with chronic obstructive pulmonary disease (COPD), 4 from patients with chronic pain (eg, knee osteoarthritis, back pain), and 4 from patients categorized as having "other medical illnesses" (ie, obesity, lupus, and epilepsy). The mean (SD) age was 50 (10) years. The mean percentage of women was 59% (33%). Exercise training averaged 3 (1) sessions per week, 42 (22) minutes per session, and was of 16 (10) weeks' duration. The exercise training adherence rate averaged 78% (14%). Adherence was reported for 51 of 75 (68%) of the effects.

Study Quality Assessment

Two of us (M.P.H. and P.J.O.) independently assessed study quality according to randomization methods, baseline differences between treatment groups, the quality of the anxiety outcome measure, adherence, and exercise program descriptions.

Effect Size Calculation

Effect sizes were calculated by subtracting the mean change in the comparison condition from the mean change in the experimental condition and dividing the difference by the pooled standard deviation of baseline scores.[71] Effect sizes were adjusted for small sample size bias and calculated such that a decrease in anxiety resulted in a positive effect size.[71] When exact means and standard deviations were not provided (n=3), effect sizes were estimated[72] from exact P values[60,62] and from a figure shown in the study.[70] When a standard deviation was not reported (n=1[51]), it was estimated from the largest other study that used the same anxiety measure.[34]

Data Synthesis and Analysis

Random effects models were used to aggregate mean effect size delta (Δ) and to test variation in effects according to selected moderator variables.[71,73] The number of unpublished or unretrieved studies of null effect that would diminish the significance of observed effects to $P > .05$ was estimated as fail-safe N+.[74] A 2-way (effects × raters) intraclass correlation coefficient (ICC) for absolute agreement was calculated to examine interrater reliability for the calculation of effect sizes. The initial ICC was 0.93, and discrepancies were resolved.

Primary Moderators

To provide focused research hypotheses about variation in effect size,[75] 6 primary moderator variables were selected (**Table 1**): exercise program length, session duration, and change in physical fitness[20,76]; type of comparison group and type of intervention used (single [exercise alone vs nonexercise comparison] vs multiple [eg, exercise + medication vs medication] interventions)[77]; and the time frame of anxiety report (eg, right now vs past week).[23,78]

Table 1. Definitions for Levels of Primary Moderators

Effect Moderator	Levels
Exercise session duration, min	10-20
	21-30
	31-45
	>45
	Not reported
Program length, wk	3-12
	13-26
	>26
Fitness change	*No change:* The confidence interval corresponding to the Hedges *d* effect size for fitness change encompassed zero
	Increased fitness: The confidence interval corresponding to the Hedges *d* effect size for fitness change did not encompass zero
	Not reported: Not enough information was reported to estimate whether the confidence interval corresponding to the Hedges *d* effect size for fitness change did or did not encompass zero
Intervention type	*Exercise alone:* The intervention compared exercise training with a no treatment, usual care, or wait list comparison condition
	Multicomponent intervention: The intervention compared exercise training plus a placebo (eg, placebo pill, stretching) with the same placebo, or exercise training plus a second treatment (eg, medication, diet, stress management) was compared with the same second treatment
Comparison type	*No treatment:* The comparison condition involved no treatment
	Usual care: The comparison condition involved usual medical care
	Wait list: The comparison condition involved waiting to participate in the intervention
	Placebo or second treatment: The comparison condition involved a placebo or a second treatment that was added to the exercise condition
Time frame of anxiety report	*Right now:* Reported anxiety symptoms at the moment of testing
	Past week including today: Reported anxiety symptoms recalled from the past week including the day of testing
	More than past week: Reported anxiety symptoms recalled across a time frame longer than the past week
	Not reported: Time frame not reported

Primary Moderator Analysis

Each primary moderator level was coded according to planned contrasts[79] ($P \leq .05$) among its levels when the number of effects (k) per level was at least 3. A two-way (effects × raters) mixed-effects model ICC with absolute agreement was calculated to assess interrater reliability for coding of moderator variables. The initial ICCs were at 0.92 or higher, and discrepancies were resolved. The 6 primary moderator variables and 2 interaction terms (program length × session duration and comparison group × intervention type) were included in mixed-effects multiple linear regression analysis with maximum-likelihood estimation,[71,73] adjusting for nonindependence of multiple effects contributed by single studies.[80] Tests of the regression model (Q_R) and its residual error (Q_E) are reported.

Secondary Moderators

Secondary moderator variables were selected for descriptive, univariate analyses based on a logical, theoretical, or prior empirical relation with anxiety. They were organized into general categories of patient characteristics (eg, age, sex, and illness), characteristics of the exercise intervention (eg, adherence, exercise mode, frequency, and relative intensity), and the specific anxiety measure used (**Table 2**).

Secondary Moderator Analysis

Mean effect sizes (Δ) and 95% confidence intervals (CIs) were computed for continuous and categorical variables using a random effects model to account for heterogeneity of moderator effects.[73]

RESULTS

Sixty-six of 75 effects were greater than zero. The distribution of the unweighted effects shown in **Figure 2** was positively skewed and leptokurtic. The mean effect size Δ was 0.29 (k=75 [95% CI, 0.23-0.36]; z=9.06; $P<.001$). The fail-safe number of effects was 1525, and a funnel plot (not shown) revealed a lack of publication bias.

PRIMARY MODERATOR ANALYSES

The overall multiple regression model was significantly related to effect size ($Q_{R(9)}=20.89$; $P=.01$; $R^2=0.27$; $Q_{E(65)}=56.29$; $P=.77$). Exercise program length (β=0.33; z=2.55; P=.01), session duration (β=0.27; z=2.14; P=.03), and time frame of anxiety report (β=0.25; z=2.01; P=.04) were independently related to effect size. In a follow-up regression model, 2-way interactions among these variables were statistically nonsignificant (exercise program length × session duration: P=.71, exercise program length × anxiety report time frame: P=.43, and session duration × anxiety report time frame: P=.95). Planned contrasts showed a larger effect in studies in which (1) exercise training duration was 3 to 12 weeks (Δ=0.39 [95% CI, 0.28-0.49]) compared with longer durations (Δ=0.23 [95% CI, 0.15-0.31]; z=2.38; P=.02), (2) the exercise session duration exceeded 30 minutes (Δ=0.36 [95% CI, 0.27-0.44]) compared with a combination of the shorter and unspecified session durations (Δ=0.22 [95% CI, 0.13-0.31]; z=2.09; P=.04), and (3) the time frame of anxiety report was greater than 1 week (Δ=0.44 [95% CI, 0.29-0.59]) compared with shorter time frames (Δ=0.26 [95% CI, 0.19-0.33]; z=2.78; P=.005).

SECONDARY MODERATOR ANALYSES

The number of effects (k), mean Δ effect size, 95% CI, and P value for planned contrasts of each level of pri-

Table 2. Definitions for Levels of Secondary Moderators

Effect Moderator	Levels
Sample age, mean, y	25-54
	>54
Sex data	Female only
	Male only
	Mixed (samples that combined females and males)
Illness	Patients with cancer and survivors
	Patients with cardiovascular disease (eg, CHD, hypertension)
	Patients with COPD
	Patients with fibromyalgia
	Patients with multiple sclerosis
	Patients with psychological disorders (eg, major depression disorder, panic disorder)
	Patients not in categories above with chronic pain conditions (eg, osteoarthritis, back pain)
	Patients with chronic illnesses not categorized above (miscellaneous)
Exercise intensity	*Low:* Low relative intensity: <40% HRR, <64% MHR, <12 perceived exertion RPE, or <46% $\dot{V}O_2$ max
	Moderate: Moderate relative intensity: 40%-59% HRR, 64%-76% MHR, 12-13 RPE, or 46%-63% $\dot{V}O_2$ max
	Vigorous: High relative intensity: ≥60% HRR, ≥77% MHR, ≥14 RPE, or ≥64% $\dot{V}O_2$ max
	Not reported: Exercise intensity was inadequately reported
Exercise mode	*Aerobic:* Used exercise modes commonly described as aerobic (eg, walking, jogging, cycling)
	Resistance: Used weight lifting only
	Aerobic+ resistance: Used both aerobic and weight lifting modes
	Aerobic+: Used traditional aerobic exercise mode and a second type of physical activity (eg, flexibility, games)
	Resistance+: Used weight lifting and a second type of physical activity (eg, flexibility, games)
	Mixed: Used aerobic and weight lifting and another type of physical activity (eg, games)
	Other: Used a single type of exercise not categorized above (eg, tai chi chuan)
Frequency, training sessions/wk, No.	1
	2
	3
	4
	5
Author reported fitness significance	*No:* Authors reported that fitness was not significantly changed
	Yes: Authors reported that fitness was significantly changed
	Not reported: Significance of fitness change not reported
Physical activity recommendations	*Moderate:* Intervention met ACSM/CDC recommendation for moderate physical activity (moderate intensity exercise, ≥30 min/d, ≥5 d/wk)
	Vigorous: Intervention met ACSM/CDC recommendation for vigorous physical activity (vigorous intensity exercise, ≥20 min/d, ≥3 d/wk)
	Not meeting either: Intervention did not meet moderate or vigorous ACSM/CDC physical activity recommendation
	Not reported: Physical activity data were not obtained or were inadequately reported to determine whether ACSM/CDC recommendations were met
Anxiety measure	*STAI-State:* Used state scale of the State-Trait Anxiety Inventory
	POMS: Used tension scale of the Profile of Mood States
	HADS-A: Used anxiety scale of the Hospital Anxiety and Depression Scale
	SCL-90: Used anxiety scale of the Symptom Checklist-90
	STAI-Trait: Used trait scale of the State-Trait Anxiety Inventory
	Other: Used anxiety measure not categorized above and not commonly used

Abbreviations: ACSM/CDC, American College of Sports Medicine/Centers for Disease Control and Prevention; CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; HRR, heart rate reserve; MHR, maximal heart rate; RPE, rating of perceived exertion; $\dot{V}O_2$ max, maximal oxygen uptake.

mary and secondary moderators are presented in **Table 3**. Descriptive results for the remaining primary moderators from the overall regression model and for secondary moderators are reported as standardized regression coefficients in **Table 4**.

COMMENT

The analysis revealed that exercise training significantly decreased anxiety scores among patients with a chronic illness. The magnitude of the overall mean effect (Δ=0.29) is similar to the effect of exercise training on fatigue symptoms among patients (Δ=0.37)[77] and on cognitive function among older adults (g=0.30).[81]

PRIMARY MODERATORS OF THE EFFECT

Exercise Program Length

Given the importance for health care providers of knowing the minimum exercise stimulus needed to improve mental health outcomes among patients,[76] it is noteworthy that exercise programs of 3 to 12 weeks resulted in significantly larger decreases in anxiety (Δ=0.39; k=35) than programs lasting more than 12 weeks (Δ=0.23; P=.02; k=39). These results are generally consistent with meta-analytic reviews of the effect of exercise training on depression,[82] cognitive function in older adults,[81] and quality of life among patients with MS.[83] These results also are comparable with the generally expected response time of pharmacological treatments of 4 to 12 weeks for individuals with anxiety.[84]

It is uncertain why studies with shorter program lengths had larger

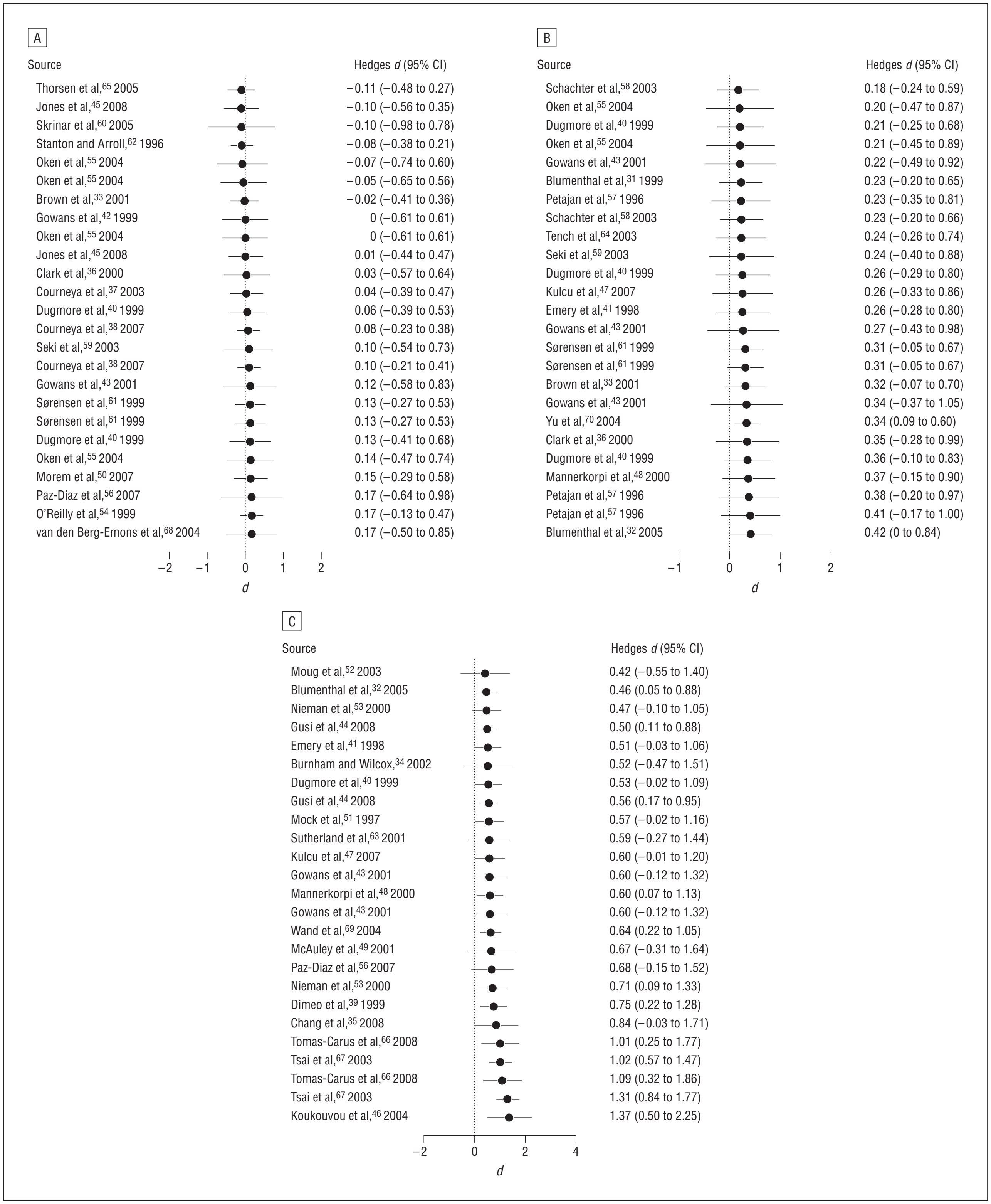

Figure 2. The distribution of the unweighted effects. Panels A-C represent a continuous forest plot. CI indicates confidence interval.

improvements in anxiety symptoms. One possibility is that the larger effect resulted from better adherence. A moderate inverse association was found between adherence and program length ($\rho = -0.42$; $P = .002$; k=50). The mean (SD) adherence values for program lengths of 3 to 12 weeks (83% [11%]; k=23) were significantly better ($t_{(48)} = 2.67$; $P = .01$) than values for program with lengths greater than 12 weeks (73% [15%]; k=27). A limitation, however, is that approximately one-third of the overall effects were derived from studies that did not provide information about adherence.

Table 3. Summary of Univariate Moderator Analysis

Effect Moderator[a]	Contrast Weights	Effects, k	Δ	95% CI	*P* Value
Fitness change					
No change	−1	26	0.25	0.14 to 0.36	<.001
Increased fitness	1	14	0.34	0.19 to 0.49	<.001
Not reported	0	35	0.31	0.22 to 0.40	<.001
Program length, wk					
3-12	1	35	0.39	0.28 to 0.49	<.001
13-26	−1/2	29	0.20	0.10 to 0.29	<.001
>26	−1/2	10	0.32	0.16 to 0.48	<.001
Exercise session duration, min					
10-20	−1/3	8	0.20	−0.01 to 0.41	.06
21-30	−1/3	15	0.20	0.06 to 0.35	.006
31-45	1/2	15	0.33	0.19 to 0.47	<.001
>46	1/2	25	0.37	0.26 to 0.48	<.001
Not reported	−1/3	12	0.25	0.10 to 0.40	.001
Comparison type					
No treatment	1	31	0.32	0.22 to 0.43	<.001
Usual care	−1/3	22	0.36	0.24 to 0.47	<.001
Wait list	−1/3	10	0.15	−0.05 to 0.35	.13
Placebo or second treatment	−1/3	12	0.21	0.07 to 0.36	.003
Intervention type					
Exercise alone	1	63	0.31	0.24 to 0.39	<.001
Multicomponent intervention	−1	12	0.21	0.07 to 0.36	.003
Time frame of anxiety report					
Right now	−1/2	19	0.33	0.20 to 0.46	<.001
Past week including today	−1/2	34	0.25	0.15 to 0.34	<.001
More than past week	1	15	0.44	0.29 to 0.59	<.001
Not reported	0	7	0.17	−0.03 to 0.36	.09
Age, y					
25-54	1	53	0.29	0.22 to 0.37	<.001
>54	−1	22	0.29	0.18 to 0.40	<.001
Sex					
Female	−1	16	0.33	0.21 to 0.46	<.001
Male	1	6	0.35	0.09 to 0.62	.01
Mixed	0	53	0.27	0.20 to 0.35	<.001
Illness					
CV	NA	21	0.32	0.21 to 0.44	<.001
Fibromyalgia	NA	15	0.29	0.13 to 0.45	<.001
MS	NA	10	0.19	−0.02 to 0.40	.07
Psychological	NA	9	0.32	0.16 to 0.47	<.001
Cancer	NA	8	0.19	0.01 to 0.37	.03
COPD	NA	4	0.40	0.06 to 0.74	.02
Pain	NA	4	0.30	0.06 to 0.55	.02
Miscellaneous	NA	4	0.47	0.14 to 0.79	.005
Exercise intensity					
Low	−1	11	0.19	0.01 to 0.36	.04
Moderate	1/3	31	0.28	0.18 to 0.38	<.001
Vigorous	1/3	10	0.28	0.13 to 0.43	<.001
Not reported	1/3	23	0.36	0.25 to 0.48	<.001
Exercise mode					
Aerobic	1	21	0.30	0.18 to 0.42	<.001
Resistance	0	1			
Aerobic + resistance	−1/4	7	0.32	0.12 to 0.53	.002
Aerobic+	−1/4	26	0.24	0.13 to 0.35	<.001
Resistance+	−1/4	3	0.12	−0.17 to 0.41	.42
Mixed	−1/4	11	0.31	0.14 to 0.49	<.001
Other	0	6	0.59	0.35 to 0.82	<.001

(continued)

Exercise Session Duration

Exercise session durations greater than 30 minutes showed larger effects (Δ=0.36; k=40) than durations of 10 to 30 minutes (Δ=0.22; k=35). Better mental health outcomes with longer exercise session durations also have been found in studies of exercise training effects on cognitive function in older adults,[81,85] and claudication pain reduction among patients with peripheral artery disease.[86]

As more data are generated, compelling evidence may emerge showing that the moderating effect of session duration is in part a function of

Table 3. Summary of Univariate Moderator Analysis (continued)

Effect Moderator[a]	Contrast Weights	Effects, k	Δ	95% CI	*P* Value
Frequency					
1	NA	10	0.19	−0.01 to 0.40	.06
2	NA	6	0.16	−0.04 to 0.37	.12
3	NA	45	0.33	0.25 to 0.42	<.001
4	NA	4	0.13	−0.13 to 0.39	.34
5	NA	7	0.33	0.14 to 0.52	<.001
Physical activity recommendations					
Moderate	1/2	3	0.28	0.01 to 0.56	.04
Vigorous	1/2	34	0.28	0.19 to 0.37	<.001
Not meeting either	−1/2	34	0.29	0.20 to 0.39	<.001
Not reported	−1/2	4	0.42	0.16 to 0.68	.001
Author reported fitness significance					
Not significant	0	7	0.11	−0.09 to 0.31	.29
Yes, significant	1	33	0.32	0.22 to 0.42	<.001
Not reported	−1	35	0.31	0.22 to 0.40	.001
Anxiety measure					
STAI-State	NA	18	0.31	0.18 to 0.44	<.001
POMS	NA	16	0.24	0.09 to 0.38	.001
HADS-A	NA	8	0.19	−0.01 to 0.39	.06
SCL-90	NA	6	0.34	0.11 to 0.58	.005
STAI-Trait	NA	7	0.56	0.33 to 0.79	<.001
Other	NA	21	0.27	0.16 to 0.39	<.001

Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; CV, cardiovascular disease; HADS-A, Hospital Anxiety and Depression Scale; MS, multiple sclerosis; other, other anxiety measure not categorized herein and not commonly used; NA, not applicable; POMS, Profile of Mood States; SCL-90, Symptom Checklist-90; STAI-State, State-Trait Anxiety Inventory (state scale); STAI-Trait, State-Trait Anxiety Inventory (trait scale).

[a]See definitions in Table 2.

its interactions with other relevant variables. We found that mean adherence for session durations of 10 to 30 minutes (74% [14%]; k=24) was worse than for those lasting longer than 30 minutes (81% [13%]; k=27), but the difference was not statistically significant ($t_{(49)}=-1.85$; $P=.07$). There also is a potential interaction between session duration and the anxiety report time frame. While only 1 effect in the shorter session duration category used an anxiety measure with a report time frame of greater than 1 week, a report time frame of greater than 1 week was used in 23% of effects in the longer session duration category. The mean effect Δ for those studies was 0.62 (95% CI, 0.42-0.82).

Time Frame of Anxiety Report

The magnitude of the anxiolytic effects of exercise training was larger for investigations using measures with anxiety report time frames that exceeded the past week compared with investigations using measures with time frames of "past week including today" and "right now." The present analysis may have underestimated the true effect of exercise training on anxiety because of the measurement methods used by most investigators. Although a larger mean effect was found in those studies that asked participants to report anxiety over a time frame that exceeded the prior week, approximately 80% used a shorter report time frame.

Although it is uncertain why most investigators did not use an anxiety report time frame of longer than 1 week, it may have stemmed from a misinterpretation that trait anxiety scores would be insensitive to change in response to an exercise training intervention of a few months. Trait anxiety is conceptualized as a relatively stable measure of individual differences in anxiety proneness,[87] yet there is substantial evidence that trait anxiety scores are sensitive to change. Short-term interventions (up to several months) designed to reduce anxiety, including cognitive and behavioral therapies, long-term massage, and relaxation training, produce moderate-to-large reductions in trait anxiety scores.[88-91] These changes are consistent with data showing that genetic factors explain only 30% to 50% of the variability in trait anxiety.[92] Trait anxiety also discriminates better than state anxiety among patients and samples of people without an illness, particularly among older adults.[93]

State anxiety responses to an intervention theoretically depend in part on individual differences in trait anxiety.[87] Only 5 studies[47,55,56,59,67] reported data from both state and trait subscales of the same psychometric instrument. The mean effect Δ for trait measures was 0.56 (95% CI, 0.30-0.83) compared with 0.31 (95% CI, 0.04-0.58) for state measures in these studies. Thus, a limitation to research on the effect of exercise training on anxiety outcomes conducted with people with a chronic illness is the atheoretical nature of the anxiety measurement.

In addition, a randomized controlled trial assumes a lack of systematic error across the premeasurement to postmeasurement trials. There seems to be a greater potential for systematic error associated with the use of a "right now" time frame in exercise training studies because of the greater number of variables that could change state anxiety scores on only 1 day of testing, including psychosocial stressors, circadian timing,[94,95] and physical fac-

Table 4. Standardized Regression Coefficients for Remaining Primary and Secondary Moderators

Effect Moderator	Standardized Regression Coefficient (β)	*P* Value
Remaining primary		
Comparison type × intervention type	0.27	.13
Design type	0.18	.14
Fitness change	0.16	.22
Comparison type	−0.22	.69
Program length × session duration	−0.01	.91
Secondary		
Adherence	0.28	.08
Relative exercise intensity	0.15	.20
Exercise mode	0.05	.67
Exercise frequency	0.04	.73
Age, y	0.002	.99
Sex	−0.05	.66

tors such as caffeine[96] or light exposure.[97]

Theory, evidence from our analysis, and findings from related investigations support the idea that future exercise training investigations would benefit from including anxiety outcome measures with a time frame of anxiety report greater than 1 week.

SECONDARY MODERATORS

Secondary moderators were included to provide descriptive data about variables that plausibly could moderate the influence of exercise training on anxiety. There was little difference in the effect size across categories for age or sex. The effect sizes also were similar whether the exercise training did or did not meet contemporary recommendations for moderate or vigorous physical activity.[98] Secondary moderator variables of special interest, type of illness and adherence, are discussed in more detail in the following 2 subsections.

Types of Illness

Exercise training reliably reduced anxiety among subsets of patients with an illness categorized as cardiovascular, cancer, chronic pain, fibromyalgia, psychological, and pulmonary. These results are generally consistent with meta-analytic reviews of the effect of exercise training on anxiety symptoms among patients with fibromyalgia,[27] coronary heart disease,[28] and cardiac rehabilitation.[29] It is important to note that the present analysis and conclusions assume that effects attributed to exercise training among patients were not biased by confounding from unmeasured or unreported factors such as acute exercise bouts performed within a few hours of the preintervention or postintervention testing sessions.

Exercise training results in large symptom reductions among patients with panic[99] and depressive disorders (ie, mean effects of 0.85 to 1.1 for patients with depression[82,100]). Seven of the 9 effects in the psychological category were from studies of patients with depressive disorders.[31-33,44] Because 5 of these 7 effects were derived from investigations using a short time frame of anxiety report, the aggregated mean for these 7 effects ($\Delta = 0.35$) may have underestimated the true effect.

The present analysis showed that exercise training reduces anxiety among patients with cancer. This observation differs from that of others who concluded that there was weak evidence for a consistent positive effect of increased physical activity on anxiety among cancer survivors.[101] Our analysis differed in that it included both patients with cancer, who exercised during treatment, and survivors who exercised following treatment.

Although anxiety is a common problem among patients with MS, it is often overlooked and poorly treated.[7,102] Multiple sclerosis was the only illness for which the mean effect of exercise training was not statistically significant. Although the mean effect size of 0.19 for studies of patients with MS was comparable with the mean effect of studies of patients with cancer, the associated 95% CI for patients with MS encompassed zero. Of the 10 available effects for patients with MS, 1 study[55] accounted for 6 effects. The mean for those 6 effects was small ($\Delta = 0.07$) compared with the mean for the remaining 4 effects ($\Delta = 0.38$).

Adherence

Exercise adherence is integral to the efficacy of exercise training. The ability to meaningfully assess the effects of the intervention decreases as dropout increases. Adherence to an exercise training program may be particularly difficult for patients during treatment.[103] Exercise may be unacceptable to some patients (eg, patients with cancer) as indicated by poor adherence.[104] The present findings indicated that adherence was also not a significant moderator ($z = 1.75$; $P = .08$) of the anxiolytic effect of exercise training. This finding may be due in part to a larger number of effects for which no corresponding adherence data were provided ($k = 24$).

FUTURE RESEARCH

Several research needs are suggested by the present findings. Needed are well-designed investigations into the effects of exercise training on anxiety that focus on individuals with an understudied illness, including those with an anxiety disorder, COPD, cancer, chronic pain, epilepsy, lupus, and MS. Also needed is better reporting of study features, especially clear and complete information about medication use and the exercise stimulus. Exercise training dose is a complex stimulus involving actual minutes of exercise in each session accumulated over all exercise sessions. Most investigators reported planned session duration as a proxy for actual time spent exercising, and only 1 study[38] reported the degree to which patients complied with the prescribed exercise training during exercise sessions. Consequently, the true effect of exercise training on anxiety may be underestimated because of underexposure to the active feature of the intervention.

A better understanding of the role of exercise stimulus variables in maximizing positive mental health outcomes could be realized through investigations that (1) examine useful types of exercise that have been understudied, including resistance exercises; (2) compare different exercise training intensities and durations while controlling total energy expenditure to better understand the minimal and optimal dose necessary to elicit mental health benefits; and (3) select characteristics of the exercise stimulus to optimize program adherence and compliance with intensity and duration prescription. Findings also underscore the importance of including a valid measure of persistent anxiety to better quantify and understand the chronic effects of exercise training on anxiety symptoms.

CONCLUSIONS

Increasingly, efforts are being made to provide mental health treatments consistent with the available scientific evidence in primary care settings.[105] The present results provide clinicians with solid evidence to recommend exercise training to patients as a means for reducing anxiety symptoms with minimal risk of adverse events. Exercise training may be especially useful for patients who prefer nonpharmacologic treatments[106] because such preferences may influence the magnitude of the treatment outcomes.[107] Perhaps most importantly, the results show that anxiety reduction is a favorable, adventitious outcome of exercise interventions that were designed as a primary treatment or adjuvant for medical conditions other than anxiety.

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