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THEMED REVIEW

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Mental Health Benefits of Strength Training in Adults

Abstract: *This review summarizes evidence from randomized controlled trials to examine whether strength training influences anxiety, chronic pain, cognition, depression, fatigue symptoms, self-esteem, and sleep. The weight of the available evidence supported the conclusion that strength training is associated with reductions in anxiety symptoms among healthy adults (5 trials); reductions in pain intensity among patients with low back pain (5 trials), osteoarthritis (8 trials), and fibromyalgia (4 trials); improvements in cognition among older adults (7 trials); improvements in sleep quality among depressed older adults (2 trials); reductions in symptoms of depression among patients with diagnosed depression (4 trials) and fibromyalgia (2 trials); reductions in fatigue symptoms (10 trials); and improvements in self-esteem (6 trials). The evidence indicates that larger trials with a greater range of patient samples are needed to better estimate the magnitude and the consistency of the relationship between strength training and these mental health outcomes. Plausible social, psychological, and neural mechanisms by which strength training could influence these outcomes rarely have been explored. This review revealed the high-priority research need for animal and human research aimed at better understanding the brain mechanisms underlying mental health changes with strength training.*

Keywords: anxiety; cognition; depression; fatigue; pain; resistance training; self-esteem; sleep; weight training

After providing some background information about muscle strengthening activities, this review summarizes empirical evidence about the effects of strength training on several key aspects of mental health. This is followed by a discussion of plausible mechanisms for the effects and suggested methods for better understanding the potential mechanisms.

> There is a need for effective behavior change interventions targeted at increasing the prevalence of resistance exercise behaviors.

What Are Muscle-Strengthening Activities?

Muscle-strengthening activities are repeated muscle actions against a resistance greater than those typically encountered during activities of daily living.[1] Muscle strengthening activities often are performed as part of a progressive strength training program conducted with free weights, resistance training equipment, or elastic bands. Examples of other physical activities that may require a high resistance, depending on individual differences such as a person's age, body size, strength, and state of training, include gardening (eg, shoveling), carrying loads (eg, weighted stair climbing[2]), water-based exercises,[3] and activities that use body weight for resistance such as pull-ups and push-ups.

How Prevalent Is Muscle-Strengthening Activity?

Results from National Health Interview Surveys indicate that 25% of adults in the United States report

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engagement in "any leisure-time activities designed to strengthen muscles, such as weight lifting or calisthenics."[4] The prevalence of participation in leisure-time muscle-strengthening activity declines with age (see Figure 1). The prevalence is lower among Hispanics/Latinos (16%) compared with other ethnic or racial groups, including Asians (23%), blacks (22%), whites (25%), and those with a mixed ethnic/racial heritage (31%). The prevalence is lower among those near or below the poverty level (16%) compared with those with incomes that are 2 to 3.9 times (24%) or 4 or more times the poverty level (35%). The prevalence is lower among those who did not graduate from high school (12%) compared with high school graduates (19%), those with some college (28%), those with a college degree (35%), and those with an advanced degree (39%). The prevalence of any leisure-time muscle-strengthening activity is lower among women (21%) than men (28%), but an increased rate of participation among women has been reported. The percentage of women meeting the strength levels (2 or more times per week) recommended by the US Department of Health and Human Services[5] increased from 14.4% to 17.5% from 1998 to 2004.[6] Despite the increase, the percentage of men (22%) and women (17.5%) who strength train 2 or more times per week is lower than the 2010 US national target of 30%.[5]

There is a need for effective behavior change interventions targeted at increasing the prevalence of resistance exercise behaviors. These might include mass media campaigns promoting strength training, environments built that encourage resistance exercise, financial incentives for participating in strength training such as reduced health insurance premiums, and education about the benefits of strength training.[7] Health care practitioners are potentially instrumental in assisting people in making the decision to adopt and maintain strength training as part of a healthy lifestyle, but these professionals often lack knowledge about strength training. One national survey found nearly twice as many primary care physicians reported that a lack of knowledge was a barrier in counseling patients about strength training compared with aerobic exercise counseling (27% vs 16%).[8] The consequence of this lack of knowledge appears to be reduced counseling of patients about strength training (see Figure 2).

Figure 1.

Percentage of US adults reporting some type of leisure-time muscle-strengthening activity as a function of sex and age. Adapted from Adams and Schoenborn.[4]

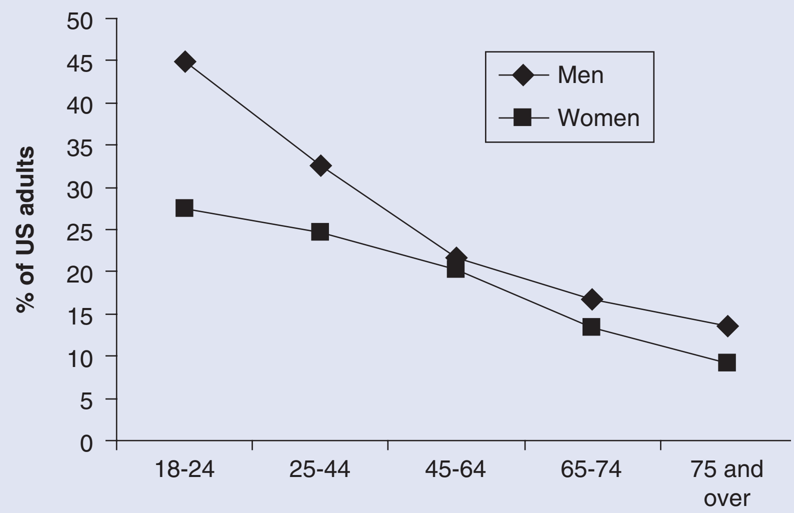
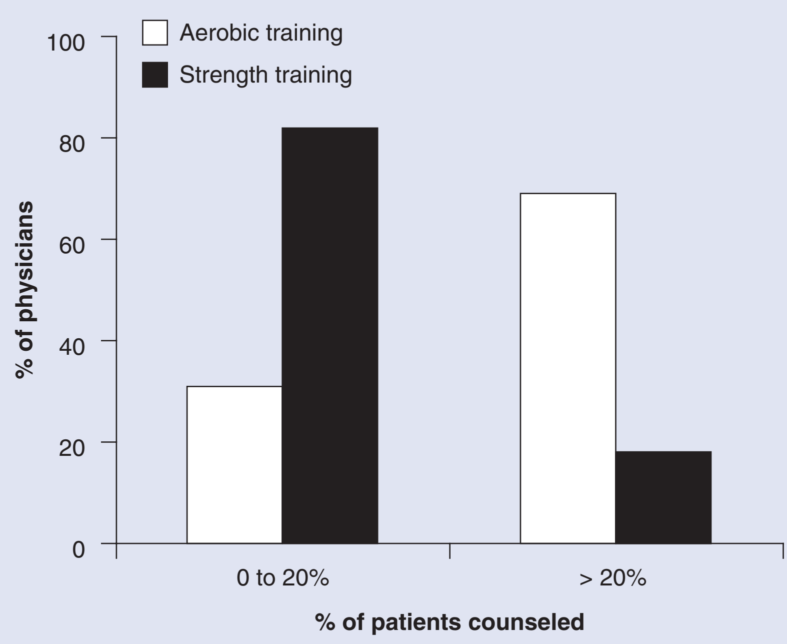


Figure 2.

Percentage of patients counseled about aerobic and strength training by primary care physicians. Adapted from Abramson et al.[8]



What Elements Should a Strength Training Program Entail?

The characteristics of a well-designed strength training program are context dependent and take into consideration individual differences in a variety of factors such as age, goals for fitness or health outcomes, fitness level, health status, access to equipment, and experience with weight lifting. Science-based recommendations on how to effectively structure strength training programs are beyond the scope of this article, and details are available elsewhere.[9-13]

The US Department of Health and Human Services recommends that adults perform at least 1 set of 8 to 12 repetitions of muscle-strengthening activities of the major muscle groups (legs, hips, back, chest, shoulders, arms, abdominals) at least 2 days per week for health.[1] It has been suggested that a program of this nature, which can take less than 30 minutes per week, will convey most of the health benefits of strength training.[1,14]

A more rigorous program recommended for improving muscle strength and size among healthy adults has been suggested by the American College of Sports Medicine.[9] The program would involve the use of both free weights and machines to perform multiple-joint (eg, squats, bench press, leg press, shoulder press) and single-joint (eg, leg extension, calf raise, arm curl) exercises of the entire body. The program would involve slow- to moderate-velocity actions (eg, 2 seconds each for both the concentric and eccentric exercise phases) for 2 to 3 sets per exercise at an intensity that starts low (when individuals are learning technique) and increases to 60% to 80% of 1–repetition maximum (1-RM) for 8 to 12 repetitions. The program would include 1 to 3 minutes of rest between sets and occur at a frequency of 2 to 3 days per week. Each session in a program of this nature could be completed in approximately 40 to 80 minutes. This type of strength training program, performed for 8 to 52 weeks, which we term *typical strength training*, is characteristic of many of the research studies included in our review.

What Are Some of the Key Health Benefits of Strength Training?

Muscle-strengthening activities confer several health benefits, perhaps most notably for older adults, who often are characterized by inadequate muscle mass, strength, and physical functional abilities.[13] Evidence supports strength training effects on increased muscular strength[15] and power,[16] bone density,[17] and physical functional abilities such as improved balance and a reduction in the number of injurious falls among older adults.[18,19] Strength training can prevent sarcopenia and increase the ability to maintain muscle mass during a weight loss program.[20] Strength training positively influences risk factors for diabetes and heart disease by improving glycemic control and insulin resistance[21] as well as by lowering blood pressure.[22] Muscular strength also is inversely associated with all-cause mortality in men, even after adjusting for potential confounders such as cardiorespiratory fitness.[23] The mental health consequences of strength training are often touted, but they are less frequently studied and consequently less well understood than the psychological effects of aerobic training.

Purpose, Scope, and Methods

One purpose for the remainder of this article is to summarize what is known about the influence of strength training performed by adults on the following important aspects of mental health: anxiety, chronic pain, cognition, depression, fatigue symptoms, self-esteem, and sleep. This review emphasizes results from randomized controlled trials that investigated the effects of strength training alone. Selected information about these studies is presented in Table 1. We estimate that strength training alone has been used in ~3% to ~11% of randomized controlled trials that have examined the influence of exercise training on mental health outcomes (see Figure 3). We did not include studies of children because there are too few randomized trials of strength training alone performed by children to draw meaningful conclusions about effects on mental health.[1,24-26] Studies with quasi-experimental designs (eg, no control group, no random assignment) were excluded because of the widely recognized limitations to drawing causality with designs of this type. Also, most epidemiological investigations of associations between physical activity and mental health have rarely included adequate questions or analyses regarding muscle-strengthening exercises; consequently, information from population-based studies was not included.

We searched PubMed and Google Scholar databases using the phrases *strength training*, *resistance training*, and *weight training* combined with the mental health outcome key words (anxiety, pain, cognition, depression, fatigue, self-esteem, and sleep). Also searched were the reference lists of identified review and data-based articles. In the sections on anxiety, chronic pain, cognition, depression, fatigue symptoms, self-esteem, and sleep, a synopsis of the research evidence regarding the effect of aerobic training also is provided to put the information from the strength training investigations in the greater context of the relevant scientific literature. When possible, we describe the magnitude of psychological changes with strength training using a standardized effect size. This is useful in part because raw scores from psychometric questionnaires often do not have the intrinsic meaning to readers that an objective physical measure such as body weight does. In some instances, we reported this effect size as it was presented in a paper, and in other cases, we calculated the effect size. A commonly used effect size is Cohen *d*, which is defined as the difference between 2 means divided by the pooled standard deviation (SD). A common convention is that Cohen *d* values of .50 and >.80 SD represent moderate and large effects, respectively.

(text continues on page 384)

Table 1.

Selected Characteristics of Randomized Trials of Effect of Strength Training on Mental Health Outcomes

Reference #	Country of Origin	Mental Health Outcomes	Sample Size EX	Sample Size CONT	Sex	% Female	Age	Program Duration, wk	Session Duration, min	Frequency, Sessions per Week
36	Brazil	Anxiety, depression, self-esteem	19	23	Men	0	68	24	60	3
37	United States	Anxiety, depression, fatigue, sleep	33	29	Women	100	68	8	45	2
38	United States	Anxiety, depression, fatigue	107	108	Men and women	76	75	24	35	3
39	Finland	Anxiety	55	35	Men and women	73	46	15	6	5
40	United States	Anxiety, cognition, fatigue, self-esteem	12	12	Women	100	69	12	NP	3
41	Canada	Anxiety, depression, self-esteem	82	82	Women	100	49	17	NP	3
42	United States	Anxiety, depression, OA pain	108	72	Men and women	66	62	26	10	5
48	Finland	Back pain	30	24	Men and women	37	40	12	90	2
49	Denmark	Back pain	27	32	Men and women	NP	45	12	NP	2-3
50	Australia	Back pain	29	28	Men and women	59	41	4	NP	2

(conitnued)

Table 1. (continued)

Reference #	Country of Origin	Mental Health Outcomes	Sample Size EX	Sample Size CONT	Sex	% Female	Age	Program Duration, wk	Session Duration, min	Frequency, Sessions per Week
51	United States	Back pain	31	23	Men and women	38	45	10	NP	1-2
52	Germany	Back pain	30	30	Men and women	50	52	12	10	2
62	United States	OA pain	23	23	Men and women	78	68	16	NP	3
63	United States	OA pain	146	149	Men and women	71	69	72	60	3
64	Australia	OA pain	83	43	Men and women	73	66	8	60	2
65	United States	OA pain	35	35	Men and women	72	63	16	50	3
66	Netherlands	OA pain	93	98	Men and women	78	68	11	~30	1-3
67	Taiwan	OA pain	36	36	Men and women	69	62	8	~30	3
68	United States	Depression, OA pain	146	144	Men and women	70	69	60	60	3
75	Finland	FM pain, depression, fatigue	11	10	Women	100	38	21	NP	2
76	United States	FM pain	15	14	Women	100	46	12	30	2
77	United States	FM pain, depression, fatigue	28	28	Women	100	48	12	60	2

(conitnued)

Table 1. (continued)

Reference #	Country of Origin	Mental Health Outcomes	Sample Size EX	Sample Size CONT	Sex	% Female	Age	Program Duration, wk	Session Duration, min	Frequency, Sessions per Week
78	Finland	FM pain	13	13	Women	100	62	21	NP	2
86	Brazil	Cognition	14	17	Men and women	74	72	36	60	2
87	United States	Cognition	102	108	Men and women	NP	75	24	35	3
88	United States	Cognition	10	10	Men and women	63	69	16	45	5
89	United States	Cognition	20	12	Men and women	53	73	24	30	3
90	Switzerland	Cognition	23	23	Men and women	39	73	8	NP	1
99	United States	Depression	20	20	Women	100	29	48	20	3
100	United States	Depression, fatigue	15	13	Men and women	63	71	10	45	3
101	United States	Depression, self-esteem	15	14	Men and women	63	71	20	NP	2-3
102	Australia	Depression, fatigue, sleep	20 low & 20 high	20	Men and women	55	69	8	60	3
103	United States	Depression	39	40	Women	100	53	26	NP	NP
104	Finland	Depression	24	28	Women	100	83	10	90	2
105	Netherlands	Depression, fatigue	41	35	Men and women	79	81	24	NP	2
106	Australia	Depression	14	18	Men and women	66	74	10	NP	3

(conitnued)

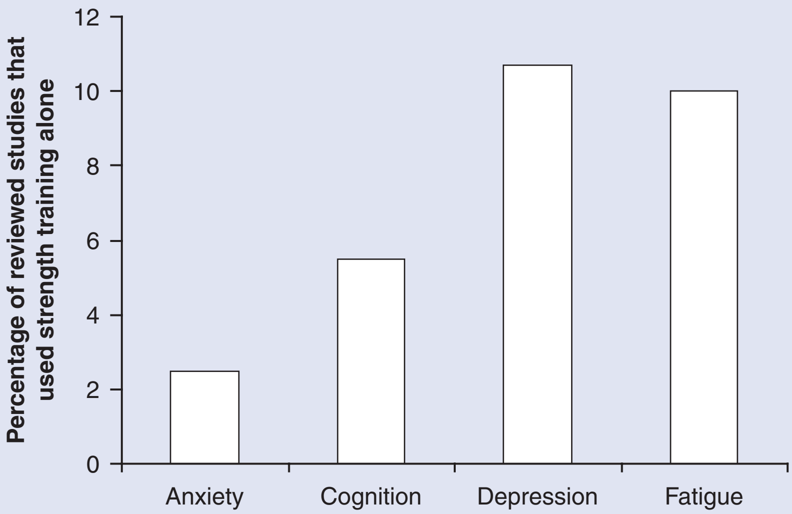
Table 1. (continued)

Reference #	Country of Origin	Mental Health Outcomes	Sample Size EX	Sample Size CONT	Sex	% Female	Age	Program Duration, wk	Session Duration, min	Frequency, Sessions per Week
107	United States	Depression	14	15	Men	0	33	16	20	3
108	Canada	Depression	21	13	Men and women	NP	39	36	105	2
112	Canada	Fatigue	82	73	Men	0	68	12	NP	3
113	Canada	Fatigue	40	41	Men	0	66	24	45	3
120	United States	Self-esteem	43	42	Women	100	22, 44	12	60	3
121	United States	Depression	20	20	Women	100	29	48	20	3
122	United States	Self-esteem	13	10	Women	100	~20	16	NP	NP
136	United States	Depression, sleep	15	13	Men and women	61	71	10	60	3

NP, information not provided; OA, osteoarthritis; FB, fibromyalgia.

Figure 3.

Percentage of studies that investigated the effects of strength training alone on a mental health outcome. Adapted from meta-analyses of exercise training effects on anxiety,[28] cognition,[85] depression,[98] and fatigue.[111]



What Is the Effect of Strength Training on Anxiety Symptoms?

Anxiety is a common mental health problem. Approximately 15% of the US population reports frequently experiencing anxiety (eg, symptoms on more than 15 of 30 days during the prior month), and those with frequent anxiety symptoms are more likely to report poor health, poor sleep, mental distress, pain, and activity limitations.[27]

Reviewers have concluded that aerobic exercise training is associated with moderate reductions in anxiety symptoms among both adults with a chronic medical illness[28] and healthy adults.[29-34] Two studies show large improvements in anxiety symptoms after aerobic exercise training performed by patients with an anxiety disorder,[34,35] although in 1 study, the effect was judged to be less effective than treatment with clomipramine.[34] Reviewers have not previously summarized the influence of strength training on symptoms of anxiety.

At least 7 randomized controlled trials have investigated the effects of strength training and included an outcome measure of anxiety symptoms. Five studies involved healthy adults,[36-40] and 2 involved medical patients.[41,42] In these 7 studies, strength training resulted in a small mean anxiety reduction of 0.19 SD. The effect was larger for the 5 studies of healthy adults (0.54 SD).

Two of these investigations compared the effects of moderate- versus high-intensity strength training on anxiety symptoms among healthy older adults.[36,40] The improvement in anxiety symptoms was best after moderate intensity training (1.00 SD effect when the intensity was 50%-60% of 1-RM) compared with the higher intensity training (0.71 SD when the intensity was 80% 1-RM).

The evidence supports the conclusion that strength training alone consistently reduces anxiety symptoms among healthy adults. Researchers have yet to document either the effects of strength training on anxiety symptoms among people with an anxiety disorder or comparisons between strength training and other treatments for anxiety disorders.

What Is the Effect of Strength Training on Chronic Pain?

Chronic pain is a major public health problem. Common types of chronic pain disorders include headaches, osteoarthritis, low back pain, other musculoskeletal pains such as fibromyalgia, and neuropathic pain that results from medical conditions such as cancer, diabetes, and strokes. The prevalence of chronic pain is high. For example, about one third of adults in community samples report low back pain during the prior month, and as many as two thirds will report an episode of low back pain during the prior year.[43] The economic cost of lost time at work from common pain conditions for the US workforce is estimated at $61 billion annually.[44] Exercise training has been found to be useful in treating several types of chronic pain, including low back, osteoarthritis, and fibromyalgia pain.

Low Back Pain

Large randomized trials and systematic quantitative reviews of more than 3 dozen trials reveal that exercise training of all types is more effective than usual care in reducing pain and improving physical function among people suffering from chronic (>3 months) low back pain.[45-47] The magnitude of the effect on pain is clinically meaningful and moderate, and it ranges from 6 to 10 points on a 100-point pain intensity scale. The efficacy of strength training per se for reduced pain cannot be determined from most of these studies because strength training was included as but one component in multidimensional rehabilitation programs designed to treat back pain.

The efficacy of strength training alone on back pain has been examined in at least 5 randomized controlled trials.[48-52] A quantitative review that included a meta-regression analysis found that strength training alone not only reduced pain to a moderate amount and to a magnitude that was equivalent to aerobic training but also was the best type of exercise for improving physical function among those with chronic back pain.[46] The reviewers emphasized that strength training programs yield the largest effects when delivered in supervised health care settings.[46]

It is noteworthy that strength training is a popular form of therapy for low back pain. A survey of a random sample of 419 therapists found that advice and exercise, respectively, were the treatments most frequently used for chronic low back pain, with strength training being the most frequently used exercise type.[53]

The available evidence supports the conclusion that strength training alone is effective in reducing pain intensity among people suffering from low back pain.[46,47]

Osteoarthritis

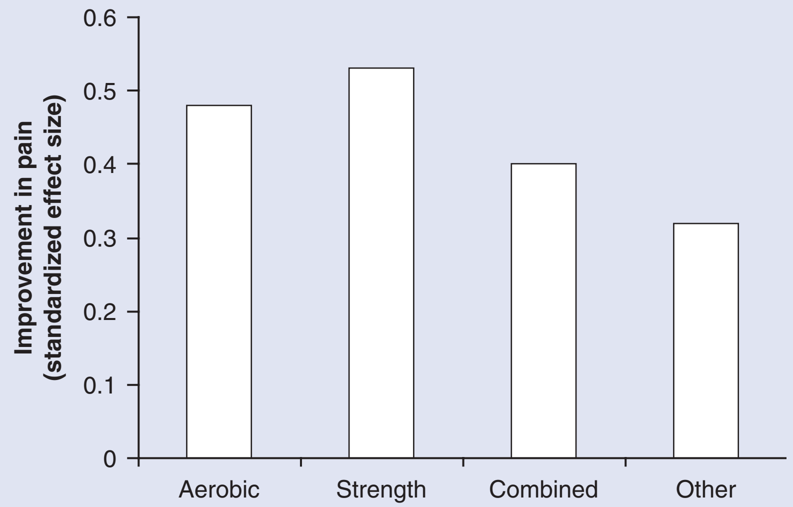
Several quantitative reviews of randomized trials showed that exercise training of all types significantly reduces pain associated with knee and hip osteoarthritis.[54-58] These analyses indicate that the magnitude of the pain reduction following exercise training ranges from 0.33 to 0.50 SD. The evidence is strong enough that exercise is recommended as an osteoarthritis treatment by the American College of Rheumatology,[59] the American Geriatric Society,[60] and the Centers for Disease Control and Prevention.[61]

The efficacy of strength training alone on osteoarthritis has been examined in at least 8 randomized controlled trials.[42,62-68] Some trials show effects as large as 1.39 SD.[67] Other trials show an extra benefit of strength training when it is combined with nonsteroidal anti-inflammatory medication therapy.[69] Quantitative reviews of this literature show a moderate-sized, positive effect of strength training for reducing pain.[70-72] The effect of lower limb muscle strength training alone on improved pain scores exceeded other types of exercise to a small degree, although the effect was not statistically different than aerobic (walking) training (see Figure 4).

The evidence supports the conclusion that strength training alone is effective in reducing pain intensity among people suffering from osteoarthritis.[73]

Figure 4.

Average magnitude of improvement in osteoarthritis pain based on results of randomized trials involving aerobic walking (4 studies, 351 participants), lower limb muscle strengthening (9 studies, 1383 participants), the combination of aerobic plus strength training (9 studies, 998 participants), and other types of exercise training (7 studies, 565 participants). Adapted from Fransen and McConnell.[70]



Fibromyalgia

Physical function is reduced among fibromyalgia patients. More than 60% report difficulty going up 1 flight of stairs, walking one-half mile, or lifting 10 lb, and those with lower function report higher pain intensity.[74] More than a dozen randomized trials show that aerobic training reduces pain among patients with fibromyalgia.[54]

Four randomized trials have examined the effects of strength training alone on pain among fibromyalgia patients. One trial found a large reduction (>2.0 SD) in pain,[75] whereas the other trials showed moderate reductions (<0.80 SD) in pain.[76-78] Two trials compared the effects of strength to aerobic training and found that both types of exercise were similarly effective in improving pain.[79,80] Another investigation compared the effects of strength to flexibility training and found that the magnitude of improvement in total muscle pain scores favored strength training over flexibility training (effect size of 0.75 vs 0.49, respectively).[77]

The evidence supports the conclusion that strength training alone is effective in reducing pain intensity among fibromyalgia patients. Consequently, strength training is viewed favorably by clinicians for the management of fibromyalgia.[81,82]

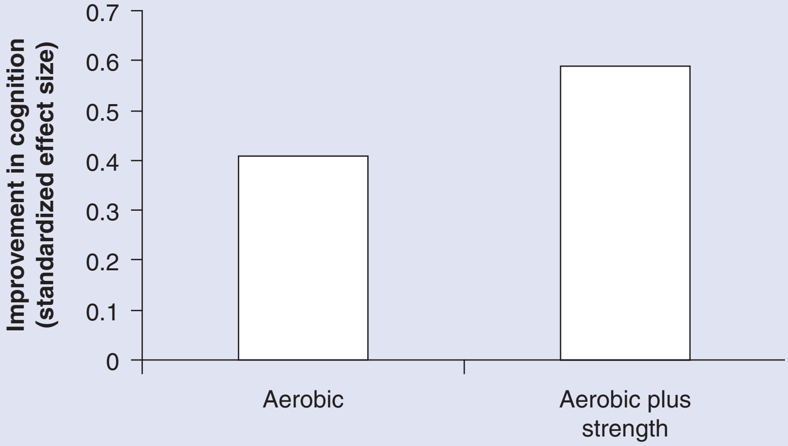
What Is the Effect of Strength Training on Cognition?

Cognition refers to nervous system processes in which sensory information is transformed, reduced, elaborated, stored, recovered, and used.[83] Although there are hundreds of tests of cognitive function, most of which involve multiple aspects of information processing, tests of cognition are often categorized according to the process that appears to dominate the test (eg, sustained attention, short-term memory). Some tasks are complex and thought to more greatly involve the frontal lobe and "executive function." Executive function involves abilities such as mental set shifting and the inhibition of prepotent responses. Executive function is inferred from tests such as the Wisconsin Card Sorting test and dual tasks in which 2 tasks are completed simultaneously.

A high percentage of studies examining the effects of exercise training on cognition have been conducted with older adults. This is logical because exercise training is perceived as having a greater potential effect on the brains of older adults, who more frequently are characterized by physical inactivity, brain neuronal dysfunction or loss, reduced vascular health, and declines in cognitive function. Cognitively impaired older adults often can participate in strength training, and when they do, they obtain increases in muscular strength and endurance that are similar to those who are cognitively intact.[84]

Figure 5.

Average magnitude of improvement in cognitive function across all types of cognitive tasks based on results of randomized trials involving aerobic exercise training alone (average of 52 effect sizes) and exercise training that combined both aerobic and strength training (average of 49 effect sizes). Adapted from Colcombe and Kramer.[85]



Evidence from randomized controlled trials, primarily of aerobic training alone or aerobic combined with strength training, indicates that exercise training improves cognitive function in healthy older adults and reduces symptoms of dementia among people with cognitive impairments.[1,85]

The positive effect of aerobic exercise training on cognition among older adults appears to be largest for complex cognitive tasks categorized as involving executive function. Moreover, and as illustrated in Figure 5, results from 18 randomized trial experiments of exercise training performed by sedentary older adults found significantly larger improvements in cognitive function when aerobic training was combined with strength training compared with aerobic training alone.[85] Left uncertain was whether strength training alone improves cognition.

At least 7 randomized controlled trials have examined the influence of strength training alone on various aspects of cognition among healthy older adults.[36,40,86-90] All 7 studies show positive, small to moderate effects on some aspect of cognition. Although the effects were statistically nonsignificant in 3 studies, these investigations had relatively small samples (8-17 per group) and therefore may have lacked statistical power to detect potentially meaningful small to moderate effects.[40,88,89] Four of the studies found statistically significant improvements in memory after strength training.[36,86,87,90] Other studies that examined the influence of strength training in combination with balance or flexibility training also have reported small to moderate positive effects on cognitive function among older adults.[91-95]

The evidence supports the conclusion that strength training alone is associated with small to moderate improvements in cognition among healthy older adults.[96] To date, the largest effects of strength training alone have been found for memory tasks.

What Is the Effect of Strength Training on Depression and Symptoms of Depression?

Depression is an important mental health problem that causes substantial morbidity and costs the United States more than $50 billion annually.[97] Depression often can be treated effectively with drugs and psychological therapies, but these treatments are costly and often have adverse side effects. Exercise is an attractive alternative because of the low cost, the largely positive side effects, and the evidence for its effectiveness.

Twenty-five randomized trials indicate that exercise training of all types reduces symptoms of depression among people diagnosed as depressed.[98] At least 4 studies with depressed patients have involved strength training alone.[99-102] Uniformly positive results were reported, and the average improvement in depression symptoms is large (see Figure 6).

At least 42 trials show that exercise training of all types improved depression symptoms among healthy adults and medical patients.[1] At least 18 trials have examined the effects of strength training alone on symptoms of depression,* and of these, 10 focused on older adults, and 2 each were conducted with fibromyalgia and breast cancer patients. The results for older adults have been mixed, with some showing a reduction in depression symptoms[36,100,104] and others showing little change.[37,38,68,105,106] Strength training has consistently reduced symptoms of depression among patients with fibromyalgia.[75,77] No significant improvement in depression symptoms has been realized after strength training alone in cancer patients.[41,103] Improvements in depression symptoms after strength training also have been realized in college students,[99] osteoarthritis patients,[42] law enforcement personnel,[107] and patients with spinal cord injuries.[108]

The evidence supports the conclusion that strength training alone is associated with both large reductions in symptoms of depression among depressed patients and moderate reductions in depression symptoms among patients with fibromyalgia.

What Is the Effect of Strength Training on Symptoms of Fatigue?

Approximately 1% of the population suffers from chronic fatigue syndrome, and ~25% report persistent fatigue

*References 36-38, 41, 42, 68, 75, 77, 99-108.

Figure 6.

Average magnitude of improvement in symptoms of depression among depressed samples after aerobic, strength, and aerobic and strength combined (mixed) types of exercise. Based on 25 randomized trials involving exercise training of depressed patients. Adapted from Mead et al.[98]

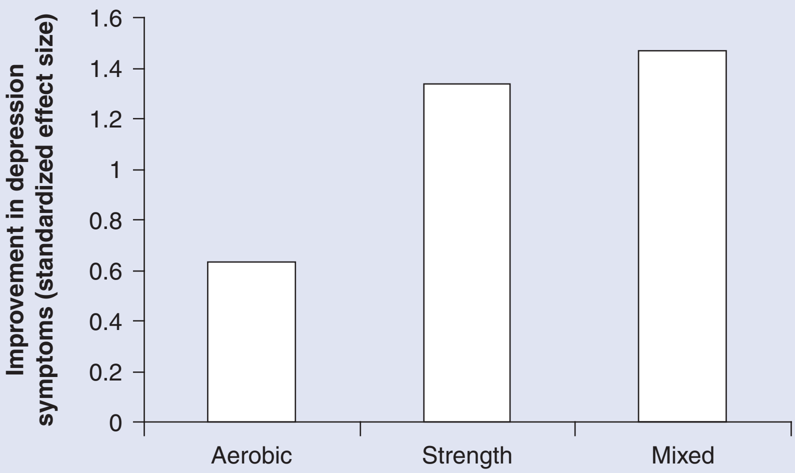
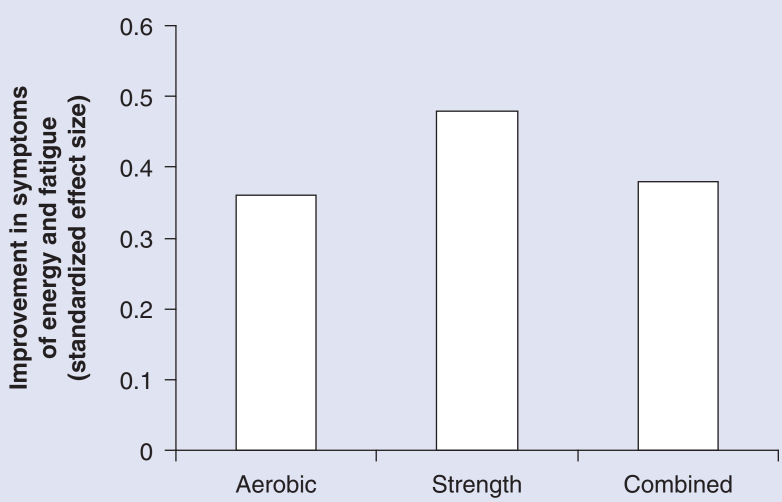


Figure 7.

Average magnitude of improvement in symptoms of energy and fatigue based on randomized trials involving aerobic exercise training alone (average of 44 effect sizes), strength training alone (average of 7 effects), and exercise training that combined both aerobic and strength training (average of 21 effect sizes). Adapted from Puetz et al.[111]



symptoms.[109] The prevalence of fatigue symptoms is even higher among people with a variety of chronic medical illnesses, especially those with psychiatric disorders.[110] Fatigue is a common reason for medical visits, and it is so common that the symptom typically does not aid in differential diagnosis.

The results of a quantitative review showed that exercise training of all types improved symptoms of fatigue in 94% of 70 randomized trials. The overall average effect of 0.37 standard deviations was judged to be clinically meaningful and was larger than effects on fatigue found in trials of cognitive-behavioral or drug treatments.[111] Most of the studies (77%) involved sedentary medical patients and used aerobic exercise alone or a combination of exercise modes.

Strength training alone resulted in the largest improvements in fatigue (see Figure 7). Positive effects of strength training alone were found for several patient groups, including those with cancer[112] and fibromyalgia.[75] More recent trials also consistently show improvements in fatigue symptoms after strength training alone.[36,102,105]

The evidence from at least 10 trials supports the conclusion that strength training alone is associated with improvements in symptoms of fatigue.†

What Is the Effect of Strength Training on Self-Esteem?

Self-esteem refers to how an individual feels about himself or herself. High self-esteem is widely accepted as advantageous, and it is positively associated with better physical and mental health, including greater happiness and overall well-being.[114,115]

Exercise training investigations that measured self-esteem have focused on overall (global) self-esteem. Self-esteem is thought to be hierarchical such that overall self-esteem is linked to, and can potentially be influenced by, several more narrow aspects of the self, including how one feels about his or her relationships with significant others.[116] Narrow aspects of the self are more easily changed than global self-esteem, and exercise training plausibly has the best chance to influence aspects of physical self-esteem such as feelings about physical appearance or muscular strength.[117,118] Potent changes in physical self-esteem ultimately could plausibly cause changes in overall self-esteem. Overall self-esteem, however, is relatively stable and theoretically

†*References 37, 38, 40, 75, 77, 100, 102, 104, 112, 113.*

less subject to large change, especially from minor or nontraumatic events of daily living, including typical exercise training.

A meta-analysis of 113 published and unpublished studies involving 7724 adult participants found that exercise training of all types resulted in small improvements in global self-esteem.[119] The small mean effect for strength training studies (0.26 SD) was similar to that found for aerobic training studies (0.25 SD) and those studies in which aerobic exercise was combined with a second form of training (0.22 SD).

Among randomized trials, a positive effect of strength training alone on overall self-esteem has been observed in younger and older healthy adults as well as patient groups, including those with cancer and depression.[40,41,101,120-122] Improvements in overall self-esteem also have accrued when strength training was added to outpatient rehabilitation performed by cardiac patients.[123]

The evidence from at least 6 randomized trials supports the conclusion that strength training alone is associated with improvements in overall self-esteem. Theory as well as cross-sectional and related longitudinal exercise studies that were not focused on strength training alone suggests that changes in overall self-esteem and other aspects of quality of life and mental health, including depression symptoms, may be mediated by changes in more narrow aspects of the self such as physical self-efficacy or physical self-worth.[124,125]

What Is the Effect of Strength Training on Sleep?

Although we spend ~30% of our lives sleeping, the purpose of sleep remains unclear. Inadequate sleep is problematic, and interventions that enhance sleep could have a major impact on improving public health. The most prevalent sleep disorders are insomnia and obstructive sleep apnea.[126] Chronic insomnia (eg, sleep <6 hours) is associated with daytime sleepiness, motor vehicle accidents, and an increased risk of cognitive impairment,[127] hypertension,[128] obesity,[129] and mental illness.[130] Obstructive sleep apnea also is associated with hypertension, obesity, cardiovascular disease, stroke, daytime sleepiness, motor vehicle accidents, and a diminished quality of life.[131]

The idea that daytime exercise improves sleep is widespread.[132] More than a dozen population-based studies show that physically active people consistently report better sleep than inactive people,[133] and 1 analysis calculated a 27% reduced odds of poor sleep among physically active compared with sedentary adults.[1] Two epidemiological studies found that physically active adults have a lower risk of sleep apnea.[134,135]

Three randomized trials have examined the influence of strength training alone on self-reported sleep among older adults. No effect was found for the trial that studied mentally healthy older adults who were normal sleepers,[37] but 2 studies of depressed patients have shown positive strength training effects on sleep. Older adults (n = 32) with a diagnosis of major or minor depression or dysthymia were randomly assigned to a 3 times per week strength training or an attention control condition for 10 weeks. Prior month sleep quality was measured before and after training with a well-validated questionnaire. After strength training, symptoms of poor sleep were improved by 30%, and the number of poor sleepers was reduced from 66% to 26%; these effects were not observed in the control group.[136] A subsequent study compared the effects of 8 weeks of low-intensity (20% 1-RM without progression in the resistance used) versus high-intensity (80% 1-RM with progression) strength training on sleep quality among community-dwelling, depressed older adults (n = 60). Improvements in sleep quality were significantly larger for the high-intensity group compared with both the low-intensity and control groups.[102] Improved sleep also has been reported after exercise training programs that measured sleep polysomnographically, including those in which strength training was combined with other types of exercise.[137,138]

The weight of evidence supports the conclusion that strength training alone performed by depressed older adults improves sleep quality.

By What Mechanisms Could Strength Training Plausibly Influence Mental Health?

The neural mechanisms that underlie and regulate several of the mental health outcomes reviewed here, such as those for anxiety[139] and sleep,[140] are largely discrete. Nevertheless, many of the outcomes, such as anxiety and depression, also are recognized as co-occurring and having shared biological influences. Although it is unlikely that exercise training influences all the mental health outcomes reviewed here through a single biological, psychological, or social mechanism, the possibility cannot yet be ruled out. Indeed, a common mechanism is suggested by some of the proposed social and psychological explanations for mental health improvements after exercise training. The mental health benefits of exercise training may stem from social interactions that typically occur during exercise of all types or from psychological processes such as expectations for improved mental states (placebo effect) that can be present with both strength and aerobic training.[141-143] As more has been learned about "psychosocial" phenomena such as the placebo effect, there is increased evidence that the effects are rooted in brain neurobiology.[144]

Our understanding of the neural mechanisms that underlie physical inactivity and aerobic exercise training effects on the brain has increased substantially in recent years.[145-148] Neural mechanisms for strength training effects on the brain, however, rarely have been investigated with humans or other animals. Ultimately, it will be useful to learn whether the neurophysiological adaptations to strength training that underlie mental health outcomes differ from those that accrue from aerobic training.

Humans

Because aerobic and resistance exercise modes do not stimulate the neuromuscular system in identical ways, it is possible that neurophysiological adaptations will differ between these 2 exercise modes. Some of the ways in which resistance and aerobic exercise often differ include (1) the specific nerves and muscles activated (eg, upper body muscle groups are activated to a greater extent with typical strength training), (2) the load on muscles relative to capacity is often higher with resistance exercise (and many physiological responses and adaptations to exercise are determined by the relative intensity), (3) the total time under tension is often less during typical strength training compared with aerobic training of an equal workout time, (4) the velocity of muscle actions is often slower during typical strength training (resulting in different afferent and efferent activation patterns), (5) the rest periods are greater during typical strength training, (6) the range of motion often is greater with typical strength training, and (7) the achievement of volitional fatigue is reached more often during typical strength training.

Exercise training might improve the central nervous system through indirect mechanisms that help to maintain good brain function such as by enhancing vascular health. Aerobic training is associated with reduced risk for chronic health problems that can adversely influence the brain, including coronary heart disease, hypertension, dyslipidemia, metabolic syndrome, type 2 diabetes, and obesity. The scientific evidence that strength training reduces these risks among humans is less compelling than for aerobic training.[1] However, if strength training does reduce these risks, and there is evidence that it does,[22,149-152] then brain neural function and mental health, especially among middle-aged and older adults, could indirectly benefit. For example, it is plausible that strength training performed by older type 2 diabetic individuals results in improved glycemic control, which could improve cognitive function (or attenuate expected age-related cognitive declines) by reversing molecular and cellular impairments induced by poor glucose regulation.[152]

Strength training also could improve mental health because it directly causes neurophysiological adaptations in circuitry that controls or influences mental health. Several lines of indirect evidence from human studies indicate that portions of the nervous system do adapt to strength training, and the best evidence from human studies concerns neurology underlying motor control of muscle strength.[153] Key observations include the following: (1) large increases in strength are realized shortly after adopting a strength training regimen in the absence of large increases in muscle mass,[154] (2) strength is reduced with detraining or disuse prior to loss of muscle mass,[155] (3) increased strength on one task does not always result in increased strength on a different task that involves the same muscle,[156,157] and (4) strength can increase in an untrained limb contralateral to a limb that undergoes strength training.[158] Also, motor imagery training, which has no effect on skeletal muscle but does activate many of the same brain regions as actual movement, though to a smaller degree,[159,160] can increase maximal voluntary strength.[161]

Much of what is known about human neural adaptations to strength training is based on the training of small muscles of the hand or distal upper limb during the performance of a task that is dissimilar from tasks performed in typical strength training programs, which involve large, proximal muscles (isometric finger task vs dynamic shoulder press). Research using twitch interpolation, transcranial magnetic, and transcranial electrical stimulation, as well as data from Hoffmann reflex and motor unit synchronization studies, suggests that strength training alters the ability to voluntarily activate muscles by more efficiently activating corticospinal cells or by altering the functional properties of spinal cord neural circuits rather than by increasing motor cortex output.[162-166] The degree to which these motor-related adaptations influence specific neural circuitry involved in affective (anxiety, depression, fatigue), behavioral (sleep), or cognitive processes currently is unknown; however, such effects are not implausible.[167,168] It is expected that the effect of strength training on adaptations in the human brain and whether the adaptations account for variations in mental health will be more vigorously investigated in the future. Research with animal models also could provide useful insight into this type of inquiry.

Animals

Studies comparing physically inactive rodents to those that are more active, typically by providing or preventing access to a running wheel for 3 to 12 weeks, suggest that activity-induced increases in neurotransmitters (eg, norepinephrine, serotonin), neuromodulators (eg, galanin), and growth factors, including nerve growth factor, vascular endothelial-derived growth factor (VEGF), insulin-like growth factor (IGF-1), VGF, and brain-derived neurotrophic factor (BDNF), can result in angiogenesis and neurogenesis as well as contribute to cellular and molecular adaptations that enhance learning and attenuate signs of anxiety and depression.[146,169-177] It is unknown whether these effects occur with strength training. Important contributions to our understanding of the mechanisms by which exercise training improves mental health could be made by conducting research that directly examines the brains of animals after strength training.

Several rat models of strength training have been developed,[178] and the approaches include direct electrical stimulation of the muscle while the rodent is anesthetized,[179] climbing with weights added to the back of a rodent,[180] and leg squats performed in a rodent squat exercise apparatus.[181-184] These and other rodent models use operant conditioning to motivate the animals to perform the resistance exercise and typically involve either tail shock avoidance or food reward in hungry animals.[185-188] For example, food deprived Long-Evans rats were trained to reach for a single strand of pasta and then progressively larger bundles of pasta across 30 days of training.[189] The potential for stress effects of hunger or shock to confound effects of strength training per se is a crucial research design concern in studies where brain neurochemistry or mental health inferred from behavior is the primary outcome.

One rodent strength training model has been proposed as a method for minimizing some of the potential confounding effects of hunger or tail shock.[190] Rats were motivated to perform 10 weeks of strength training using electrical stimulation of the brain as a reward. After recovery from a brain surgical procedure, animals received electrical stimulation in the midbrain tegmental area when they lifted their arms to press a bar. Weight was attached to their backs, and the amount of weight attached increased from 30 to 190 g over a 10-week training period.[190] The authors concluded that this intracranial self-stimulation model was relatively easy to implement and did not produce any apparent physical or mental trauma in the animals. Nevertheless, whether the effects of strength training alone could be separated from potentially confounding effects of direct tegmental brain stimulation on other brain regions remains uncertain.

Nonhuman primate models would be potentially advantageous because the brains and weight-lifting behaviors of monkeys are more similar to humans than other animals, including cats[191] and rats.[192] Observational studies have been conducted with capuchin monkeys who daily lift stones weighing from 33% to 77% of body weight and throw them to break open nuts for food.[193] The weight of the stones could be manipulated experimentally to achieve progressive increases in muscle strength. The biomechanics of the capuchins' style of weight lifting resembles human deadlifts and power pulls.[193] Researchers also have used acute weight-lifting exercise performed by rhesus monkeys to better understand central nervous system control over cardiovascular responses to weight lifting.[194-197] For example, in 1 experiment, 4 monkeys learned to use 1 arm to raise and lower a weight of 12 kg a distance of 4.5 cm at least once every 6 seconds for ~1.5 to ~2.5 minutes to avoid a tail shock.[194] Simultaneous electrical stimulation of various brain regions was performed during the exercise to better understand brain mechanisms that underlie cardiovascular responses to exercise.

Although animal models of weight lifting have been developed, few investigators have used them to explore central nervous system adaptations to strength training.[198] Several currently available animal models of strength training could be usefully combined with animal models of psychological processes, such as canine[199] and rodent[200] models of executive function, or mental health problems, such as anxiety[201-204] and depression,[176,205,206] to enhance our understanding of the brain benefits of strength training. High-resistance physical activities, although not strength training per se, could be incorporated in other model animal systems, such as the zebra fish and the fruit fly, to better understand genetic and molecular mechanisms underlying brain neural adaptations of high-resistance muscular activities.[207-210]

Summary

There are relatively few studies, especially randomized controlled trials, of the effects of strength training on mental health outcomes, and many of the studies are small or were not designed specifically to answer a question about mental health. Thus, the scientific evidence regarding the effect of strength training on mental health outcomes is generally characterized by a number of limitations. Nevertheless, the small body of evidence is largely positive, and the weight of the available evidence supported the conclusions that strength training is associated with (1) reductions in anxiety symptoms among healthy adults; (2) reductions in pain intensity among patients with low back pain, osteoarthritis, and fibromyalgia; (3) improvements in cognition among older adults; (4) reductions in symptoms of depression among patients with diagnosed depression or fibromyalgia; (5) reductions in fatigue symptoms; (6) improvements in self-esteem; and (7) improvements in sleep quality among depressed older adults.

It is not uncommon for the effects of strength training to be compared with aerobic training, often to learn whether the benefit of one mode of exercise equals or exceeds that of the other.‡ For example, 1 trial focused on prostate cancer patients who were randomly assigned to 24 weeks of resistance or aerobic exercise or usual care. The authors found that fatigue scores were reduced to a similar extent in the short term for both training modes, but strength training produced longer lasting improvements in fatigue.[113] Because the 2 exercise modes were not matched on all the characteristics of the exercise stimulus, it is not possible to conclude that one mode is better than the other for mental health. Typically, only the total exercise duration is matched when aerobic and strength training programs are compared. Because there are more rest periods in the typical strength training program, significantly more work is performed in a typical aerobic training program of the same duration. Thus, it seems likely that the effects of strength training on mental health outcomes are underestimated when comparisons are made to the effects of aerobic training.

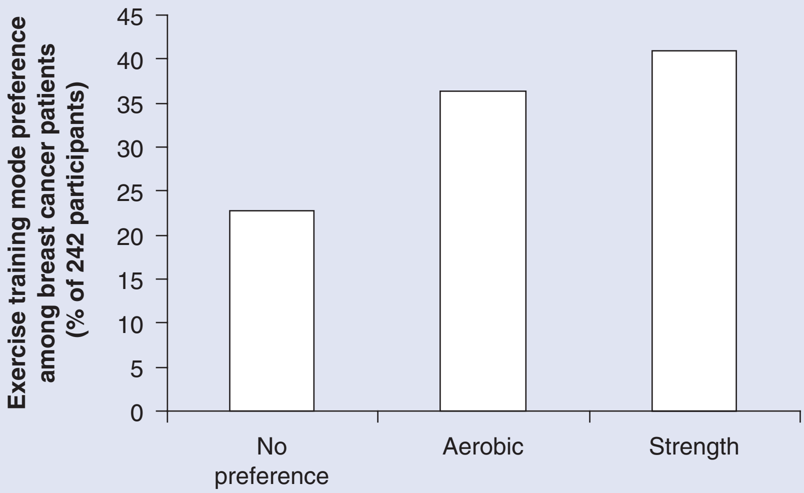
It is also important to consider that some patients prefer strength training to aerobic training and that preference can influence mental health outcomes. A somewhat greater preference for strength than aerobic training was found in a study of 242 breast cancer patients in which participants were randomly assigned to either strength or aerobic training (see Figure 8). Patients with a preference for strength training improved their quality of life only if they were assigned to strength training,[211] and the effect was explained by expected benefits, enjoyment, and difficulty and the support for performing each type of exercise during chemotherapy.[212]

This review indicates that a small body of randomized controlled trials shows that strength training has positive effects on a host of important mental health outcomes. Needed now are studies that determine the variables that mediate and moderate the influence of strength training on mental health. Studies with larger samples, a greater range of strength training exercise dose, and a greater range of patient samples, especially the poor, the less well educated, Hispanics, and women and older adults, also are needed to better estimate the relationship between strength training and mental health outcomes. Plausible social, psychological, and neural mechanisms by which strength training potentially influences these outcomes have not yet been explored. Thus, there is also a pressing need for animal and human

‡*References 68, 77, 79, 80, 104, 113.*

Figure 8.

Preference for exercise training mode among 242 breast cancer patients participating in a study of the effects of exercise training. Adapted from Courneya et al.[211]



research aimed at better understanding brain mechanisms underlying mental health changes with strength training.

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