REVIEW ARTICLE

Web-based exercise interventions for patients with depressive and anxiety disorders: a systematic review of randomized controlled trials

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Objective: The number of people suffering from depression and/or anxiety has increased steadily due to the coronavirus disease 2019 (COVID-19) pandemic. In this context, web-based exercise interventions have emerged as a potential treatment strategy. The objective of this study was to synthetize evidence from randomized controlled trials regarding the effects of web-based exercise interventions on patients with depressive and/or anxiety disorders.
Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed. Six databases were searched (Cochrane Library, EBSCO, PubMed, SciELO, Scopus, and Web of Science), and eligible articles were identified according to a PICOS inclusion-exclusion approach (participants with depressive or anxiety disorders; web-based exercise interventions; active or passive control group; assessment of changes in depressive or anxiety disorders; randomized design). Primary outcomes were depressive and/or anxiety symptoms. The quality of evidence was assessed with Grading of Recommendations Assessment, Development, and Evaluation.
Results: Of 7,846 search results, three studies met the inclusion criteria (172 participants between 18 and 65 years of age, 95.9% women). The web-based exercise interventions lasted 8-12 weeks and involved endurance training, yoga, or combined endurance and strength training. The comparators involved non-exercise controls or active controls. Compliance rates were low. Web-based exercise interventions were not superior to controls regarding anxiety symptoms, and only one study found benefits for depressive symptoms (p $\leqslant$ 0.05). The quality of the cumulative evidence was low.
Conclusion: The available data regarding the effects of web-based exercise interventions on depression and/or anxiety symptoms is scarce, the risk of bias is high, and the quality of the cumulative results is low. Currently, no clear recommendations can be provided.
Registration number: PROSPERO CRD42021225938.

Keywords: Telemedicine; internet-based interventions; exercise; depression; anxiety; mental health

Introduction

Anxiety (e.g., generalized anxiety disorder) and depressive disorders (e.g., major depressive disorder) are psychiatric conditions that can be severely disabling, leading to negative health and economic outcomes.[1] Worldwide, approximately 264 million people of all ages suffer from depression.[2] The costs linked with lost work days due to anxiety and depression have been estimated at USD 1.15 trillion per year globally, and they are predicted to increase twofold by 2030.[1] However, due to coronavirus disease 2019 (COVID-19), this scenario is worsening: evidence suggests that symptoms of anxiety and depression (16-28%) and self-reported stress (8%) are common psychological reactions to the pandemic.[3]

Despite advances in psychological and pharmacological treatment for many psychiatric disorders, a substantial proportion of individuals diagnosed with these disorders do not achieve full remission following treatment.[4,5] The largest open trial assessing the effects of pharmacological antidepressants, psychotherapy, or a combination of both, in the treatment of depression (the Sequenced Treatment Alternatives to Relieve Depression study) found that the response rate following the first pharmacological attempt was < 50%.[6] Only some people achieve remission,[7] and not everyone responds to medication and/or psychotherapy.[8]

Exercise and physical activity prevent or delay the onset of several mental disorders and have therapeutic effects in several psychiatric disorders.[9,10] One meta-analysis demonstrated that exercise is a potential treatment for depression,[11] while another demonstrated that exercise decreased anxiety symptoms compared to control conditions.[12] A meta-review[13] analyzed data from 16 meta-analyses representing 152 randomized controlled trials, finding that exercise had moderate benefits in adults with depressive disorders. However, four high quality trials that compared exercise to other active control conditions found only trivial benefits. This review[13] found that exercise decreased anxiety symptoms more than control conditions in patients with panic disorder, generalized anxiety disorder, post-traumatic stress disorder, and social phobia.

Experts have proposed biological and psychological mechanisms by which exercise could reduce depression[8] and anxiety.[14] In support of this, current neurobiological hypotheses for depression include chronic and acute responses that influence several systems, such as neuroendocrine, neurogenesis, oxidative stress, auto immune, and cortical structural modifications.[15] Studies in both animals and humans show that exercise can attenuate anxiety behaviors via neurobiological mechanisms, including regulation of brain-derived neurotrophic factor, neuroinflammation, synaptic transmission, and the hypothalamic pituitary adrenal axis.[16] Additionally, exercise decreases the tendency to ruminate,[17] restores psychosocial function,[18] and increases self-esteem.[19]

Web-based interventions include website, mobile app, and email-based interventions[20] and can be used to support people who do not seek help from health services due to social stigma[21] or transportation problems.[22] These interventions prescribe a structured exercise program that is performed at home[23] with varying degrees of supervision, differing from interventions that only focus on motivating people to exercise.[24] These interventions provide inexpensive and time-saving alternatives to in loco exercise programs,[25,26] and the programs can vary from yoga[27] to aerobic-based exercise,[23] although little is known regarding dosage, i.e., recommendations about frequency, intensity and volume do not depart from generic exercise recommendations.[28] To our knowledge, there are no clear guidelines about prescribing web-based exercise interventions to people with depressive or anxiety disorders. A systematic review analyzed the effects of online physical activity interventions for mental disorders,[29] finding positive effects on depressive symptoms, although the authors noted the paucity of available studies. Relevant databases such as Scopus, EBSCO, PubMed, and Web of Science were not included in their review.

The variety of exercise modalities and web-based interventions has resulted in a loosely systematized body of literature that could benefit from a focused overview of what is being done in web-based exercise interventions for patients with depressive or anxiety disorders. Our systematic review assessed the available evidence on web-based, randomized exercise interventions for people with depressive or anxiety disorders. We aimed to provide a summary of the characteristics and efficacy of currently available web-based exercise interventions for anxiety and depression disorders, hypothesizing that web-based exercise intervention would be an effective therapy for patients with depression and anxiety disorders, similar to other telehealth interventions for depression[30,31] and anxiety-related disorders.[32,33] Hopefully, this review will provide decision-makers with better-informed parameters for promoting and implementing web-based exercise interventions for patients with depressive or anxiety disorders. As a worst-case scenario, it will highlight current limitations and suggest future avenues of research.

Methods

Protocol and registration

This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[34,35] The quality of evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation approach, better known as GRADE.[36] The methods and protocol were registered prior to beginning the searches in PROSPERO (CRD42021225938).

Eligibility criteria

Studies were included if they were published in peer-reviewed journals and focused on web-based exercise interventions, defined according to Barak et al.[20] as including website, mobile app, and email-based interventions, but excluding telephone-based interventions. There were no limitations concerning publication date or language. Data on inclusion and exclusion criteria are presented in Box 1. To ensure the greatest quality and reduce the risk of bias, only randomized controlled trials were included.[37,38]

Information sources and search

The search was performed on February 18, 2021 in six electronic databases: Cochrane Library, EBSCO, PubMed, SciELO, Scopus, and Web of Science (all databases). Boolean operators were applied to the title, abstract, or keywords in the searches. Search strategy: (depress* OR dysthymia OR anxi*) AND (tele* OR web-based OR remote OR online OR internet) AND (exercise* OR training OR "physical activity" OR sport OR fitness OR workout) AND random*. In EBSCO and SciELO, we

Box 1 Inclusion and exclusion criteria

Rule	Inclusion criteria	Exclusion criteria
Study type	Original research published in peer-reviewed journals. No limitations on language or publication date.	Conference abstracts Non-peer-reviewed publications Peer-reviewed publications that are not original research
Participants	Participants of any age, sex, or training status: (i) diagnosed with depression according to well-established criteria, such as DSM-5® American Psychiatric[39] WHO ICD-11,[40] or previous versions, or presenting with depressive symptoms above clinically established thresholds in validated scales, such as BDI or BDI-II,[41] HAM-D,[42] GDS[43]; and/or (ii) presenting with anxiety symptoms above clinically established thresholds on a validated rating scale such as BAI[44] or a formal DSM-5® American Psychiatric[39] WHO ICD-11,[40] diagnosis of a specific anxiety disorder (e.g., generalized anxiety disorder). Previous versions of the aforementioned scales were acceptable. Participants could have additional conditions (e.g., mental disorders and other comorbidities).	Participants not diagnosed with depression or anxiety or without depressive or anxiety symptoms
Interventions	Web-based (i.e., website-, e-mail- and/or mobile-app-based) exercise interventions, i.e., planned, structured, repetitive, and purposeful physical activity,[45] such as strength training, balance, endurance, etc., as well as any multimodal exercise program.	Absence of web-based exercise interventions (e.g., in person, telephone-based)
Comparators	Non-exercising controls and/or alternative interventions. Usual care had to be described. When a description was not provided, the authors were contacted.	Absence of comparators Comparators following usual care, if no information could be obtained to describe usual care
Outcomes	Primary outcomes were changes in depressive symptoms and/or anxiety symptoms according to validated scales, scored from baseline to post-intervention. If available, remission rates were considered among primary outcomes. Secondary outcomes consisted of any other effects on performance, health and quality of life. Adverse effects and dropout rates, when reported, were also analyzed.	Primary outcomes of interest not assessed
Study design	Randomized controlled trials (parallel or cross-over).	Non-randomized studies Observational studies Case studies and case series

BAI = Beck Anxiety Inventory; BDI = Beck Depression Inventory; DSM-5 = Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; GDS = Geriatric Depression Scale; HAM-D = Hamilton Depression Rating Scale; ICD-11: International Classification of Diseases 11th Revision; WHO: World Health Organization.

expanded the searches and accepted all fields. A search of the reference lists of the included studies was also performed. The updated list and inclusion criteria were submitted to four experts in the field, whose role was to suggest additional relevant papers that met the inclusion criteria. Finally, the databases were searched again for errata regarding the included studies, i.e., to ensure that no study had been retracted or, if corrected, to ensure that we were using the most accurate data.[37]

The following is an example for searches conducted in PubMed on February 18, 2021:

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(((depress*[Title/Abstract] OR dysthymia[Title/Abstract]
OR anxi*[Title/Abstract]) AND (tele*[Title/Abstract] OR
web-based[Title/Abstract] OR remote[Title/Abstract] OR
online[Title/Abstract] OR internet[Title/Abstract])) AND
(exercise*[Title/Abstract] OR training[Title/Abstract] OR
"physical activity"[Title/Abstract] OR sport[Title/Abstract]
OR fitness[Title/Abstract] OR workout[Title/Abstract]))
AND (random*[Title/Abstract])
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Study selection and data extraction

JA, AM, and FMC conducted the search, screening, and exclusion processes independently. LC reviewed the process for error detection. These steps were repeated for the manual reference list search, expert assessment, and errata search.

Data extraction

Study characteristics: (i) sample size and features (e.g., subjects, age, sex, health status, training status, single or multicenter study, geographical location); (ii) length and characteristics of the interventions (e.g., exercise modality, frequency, session duration, intensity, supervision ratio, supervisor qualifications, compliance rates) and comparators (e.g., non-exercise controls, alternative interventions); (iii) major comorbidities; (iv) funding and potential conflicts of interest.

Primary outcomes: trials could use more than one psychometric instrument to assess depression. Our primary outcome of interest was the mean change in depressive and/or anxiety symptoms in the exercise groups from baseline to post-intervention, assessed by any validated scale, in comparison with the mean change of the control groups, calculated as the standardized mean difference, together with 95% confidence intervals. If an author reported the results of two outcome measures meeting our criteria (i.e., mean change/pre and post-test change in depressive and/or anxiety symptoms according to two different measures), only one scale was considered. The preferred instrument was the Hamilton Depression Rating Scale, which was considered to be more robust for psychosomatic disorders.[46] When available, remission rates were compared.

Secondary outcomes: any additional outcomes concerning physical status (e.g., body composition or performance tests) or psychosocial effects (e.g., self-esteem, perceived competence, or perceived quality of life). Dropout rates and adverse effects analyzed when available. Measurement tools and metrics were provided for both the primary and secondary outcomes. JA, AM, and FMC independently extracted the relevant information. LC reviewed the process. Discrepancies were discussed until a consensus was reached.

Risk of bias in individual studies

Risk of bias was assessed in individual studies using the revised Cochrane risk-of-bias tool for randomized trials,[47] which is divided into five dimensions of bias: (i) randomization process; (ii) deviation from intended interventions; (iii) missing outcome data; (iv) outcome measurement; and (v) selection of reported results. JA, AM, and FMC independently assessed risk of bias. LC resolved disagreements.

Quality of cumulative evidence

The GRADE approach was used.[36] Inconsistency (i.e., heterogeneity), risk of bias in individual studies, publication bias, indirectness, and imprecision were evaluated. JA and FMC independently assessed study quality, and LC reviewed the process.

Results

Study selection

The initial search identified 7,846 results (Cochrane Library: 2,626; EBSCO: 2,040; PubMed: 912; SciELO: 9; Scopus: 607; Web of Science: 1,652), which, after removing duplicates, were reduced to 4,572. After screening the titles and abstracts, 4,551 records were excluded. Twenty-one studies were eligible for full text analysis, and 16 were excluded: 14 did not have web-based exercise interventions or the interventions were limited to encouragement,[21,24,48-59] one had mixed web-based and *in loco* exercise intervention,[60] and one examined participants without depressive or anxiety

symptoms.[61] In two studies, the samples were a mixture of participants with and without depression and/or anxiety symptoms, but the data were merged.[62,63] The authors were contacted through e-mail and ResearchGate but they did not respond, and these studies were excluded.

Thus, three studies were eligible for review.[23,27,64] A manual search within these studies' reference lists resulted in no additional studies that fit the inclusion criteria. Four experts were contacted: two declined the invitation and two did not respond. We searched for errata or retractions related to these studies but found none. Due to the small number of studies and considerable heterogeneity in design, interventions, comparators, and populations, no quantitative synthesis was performed. The process is summarized in Figure 1.

Study characteristics

The samples ranged from 20[64] to 90[27] participants. Of the 172 total participants, only seven were men.[64] In one study, patients had moderate to severe unipolar depression and were aged between 20 and 65 years.[64] Another study recruited 90 women who had experienced a recent stillbirth (within 2 years) and were diagnosed with post-traumatic stress disorder but without severe depression[27]; the only information provided was that they were $\geqslant$ 18 years of age. Teychenne et al.[23] recruited mothers at risk of postnatal depression. The exercise interventions were also heterogeneous (Table 1), ranging from 12 weeks of endurance training[23] to 12 weeks of yoga[27] to 8 weeks of a combined endurance + strength training.[64] Two studies used non-exercise control groups,[23,64] and one used a "stretch-and-tone" comparator.[27] The two larger studies had low compliance.[23,27]

Risk of bias in individual studies

Detailed assessments of risk of bias were performed using Cochrane's risk of bias tool[47] and the results are shown in Table 2. No study had an overall low risk of bias. No major problem was identified with randomization (D1). Issues were identified for missing outcome data (D3)[23,27] and, in one case, for statistical methods used to deal with missing outcome data (D2).[27] In domain 4 (outcome measurement), all authors used best-practice measures; however, the use of self-report scales inherently raised some concerns.[37] There were no major problems arising from selection of the reported results (D5), although one study reported the protocol retrospectively.[23]

Results of individual studies

The results of individual studies are presented in Table 3. In Haller et al.,[64] web-based exercise interventions produced benefits in several outcomes (e.g., quality of life, aerobic capacity, and self-efficacy) but not for the main outcomes (i.e., depressive or anxiety symptoms) in relation to controls. In Huberty et al.,[27] both exercise groups experienced significant decreases in depression compared to controls, but not in anxiety symptoms. Teychenne et al.[23] found no evidence that web-based
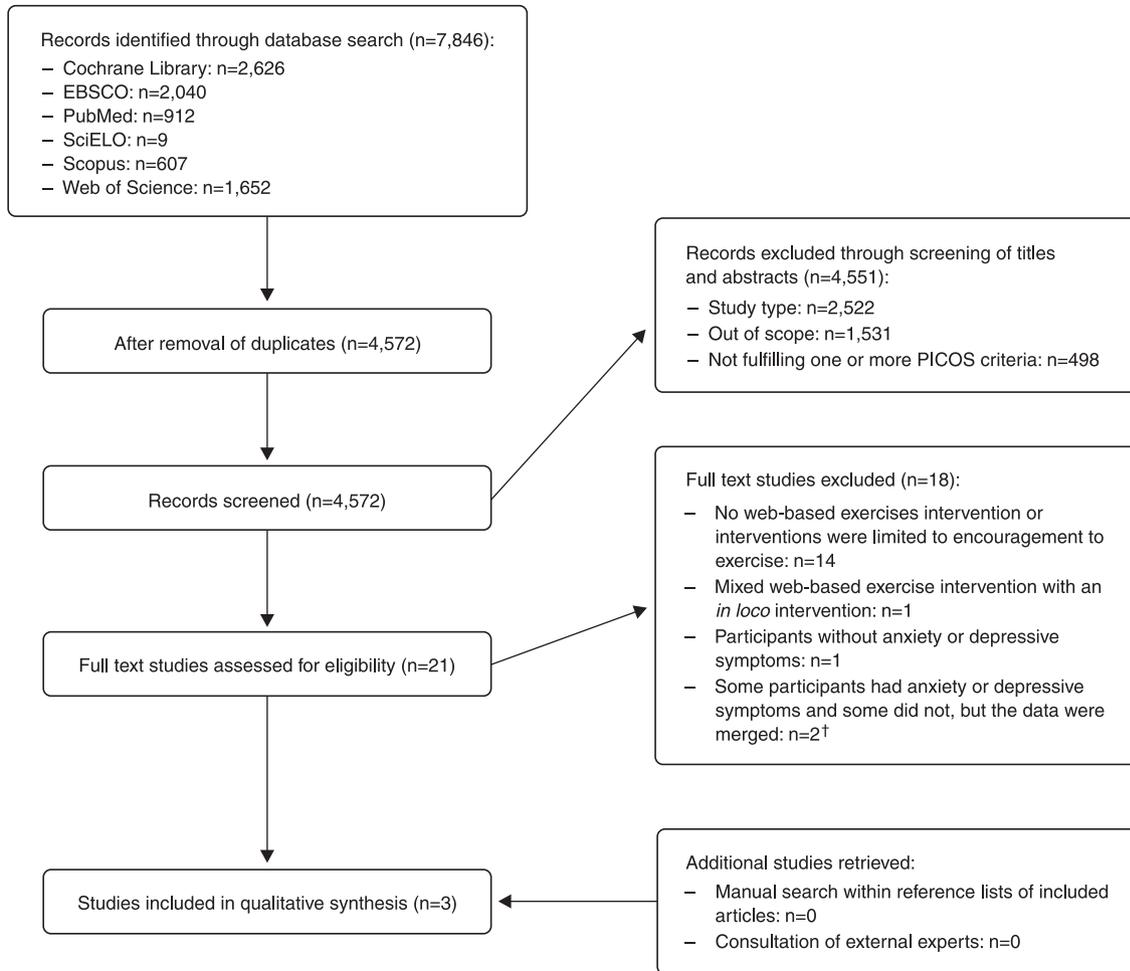
Figure 1 Flowchart describing the study selection process. [†] The authors were contacted for further data, but no response was obtained.

exercise interventions had beneficial effects on depressive and anxiety symptoms compared to controls. Relevant dropout rates were observed in the studies.

Quality of evidence

Table 4 presents the GRADE assessments. The small number of studies and their heterogeneity resulted in low quality of evidence and, thus, no recommendations are advanced.

Discussion

There has been a growing interest in exercise as a complementary therapy for people with mental illnesses, such as depression and anxiety.[13] Web-based exercise interventions may improve access to physical activity. We reviewed the evidence about web-based, randomized exercise interventions in people with depressive or anxiety disorders, and it was unclear whether such interventions could improve depressive or anxiety symptoms. It was also unclear whether the problem was due to

the intervention types or their application. Only three studies (total participants = 172) fulfilled the inclusion criteria.[23,27,64] A previous systematic review of online physical activity interventions for mental disorders found only two trials,[29] but this was 6 years ago, before the widespread dissemination of online interventions, which has been accelerated by the COVID-19 pandemic. A PubMed title search for "telehealth" + "covid" found 355 results in 2020-2021, compared to zero results in 2014-2015.

Definitive findings were precluded due to heterogeneity in the sample size, recruitment criteria, study length, and characteristics of the interventions and comparators, in addition to low compliance and high dropout rates. This heterogeneity is in line with similar reviews.[29,65,66] Less than 5% of the participants were men, meaning that even less is known about how men with depressive or anxiety symptoms respond to web-based exercise interventions. Anxiety and depression are more prevalent in women than in men,[67-69] but not in a 20 to 1 proportion, and the prevalence is sometimes actually greater in men than women.[70]

Providing online physical activity interventions for people with mental illnesses may be a useful strategy

Table 1 Characteristics of individual studies

Study	Sample	Location, funding, and conflicts of interest	Characteristics of the intervention	Characteristics of the comparator(s)
Haller[64]	20 patients (seven male, 13 female) with moderate to severe unipolar depression (45±14 years-old, range 20-65 years-old), but otherwise in good health	Single-center, Germany No mention of funding No conflicts of interest declared	n=14 (four male, 10 female) Individualized web-based exercise program. Participants received a HR monitor and four different types of resistance bands, as well as exercise schedules 1x/week with instructions for 8 weeks of endurance (maximum three exercises) and strength training (maximum two exercises). After each week, the patients had to upload their weekly protocol to the platform, and motivational feedback was provided to improve adherence. Once every 2 weeks, a group training session was offered by a sports therapist (only one patient accepted this session). Training goals were individually adapted in the duration and intensity for the following week. Progression in endurance exercise was achieved through increased intensity and/or duration. Progression in strength training was achieved by increasing the number of sets and repetitions or by changing the type of resistance band. Participants had a median of 75 min (IQR: 63 to 98) of endurance and nine (IQR: 4 to 12) of 10 recommended units of strength training per week. In addition, they had four (IQR: 2 to 28) optional, alternative training units, such as relaxing, hiking or yoga.	n=6 (three males, three females) Treatment-as-usual group
Huberty[27]	90 underactive women (≤ 120 min/week of moderate intensity PA) who experienced a stillbirth within 6 weeks to 24 months and PTSD (IES score ≥ 33), but without severe depression and otherwise healthy Unreported ages (≥ 18 years-old)	Multicenter United States Funded by a grant from the U.S. NIH No conflicts of interest declared	Home-based, online yoga intervention of varying doses for 12 weeks (with follow-up at 20 weeks). The low-dose group (n=30) performed 60 min of exercise per week, while the moderate-dose group (n=30) performed 150 min per week. Participants received study information and directions, a yoga mat, two blocks and one yoga strap. The intervention was provided via email, including 12 videos developed for women who had experienced stillbirth, and 48 videos with yoga exercises. Participants were asked to accompany the yoga videos in a pre-defined order. Both the low-dose and moderate-dose groups had identical poses and sequences in each prescription. Compliance: of the participants that completed the study, only nine of 34 performed > 90% of the prescribed minutes for a minimum of 9 weeks. The low-dose group performed an average of 44 min per week, and the moderate-dose group 77.3 min per week.	"Stretch and tone" control group (n=30), 60 min per week for 12 weeks (follow-up at 20 weeks) Participants received study information and directions, a stretching mat and one resistance band. They also received 12 30-min videos including warm-up, cool-down, stretching, and toning exercises.
Teychenne[23]	62 mothers (33.0±3.7 years in CG, 33.6±3.7 in IG) at risk of postnatal depression and insufficiently active	Multicenter Australia Funded by IPAN, Deakin University No conflicts of interest declared	Home-based, multi-component PA for 12 weeks (n=32). Participants received a multi-component program, exercise equipment (treadmill or stationary bicycle), logbook for goal setting and self-monitoring, access to a smartphone web app and an online forum (facilitated by a research assistant with a Ph.D. in behavioral epidemiology). The web app helped design individualized PA programs. Compliance: only 20 subjects (63%) used the web app, most ≤ 2 times per month (57%). Logbook data was only available for 20 participants. Overall, compliance was low.	Control group (usual routine) (n=30)

CG = control group; HR = heart rate; IES = impact of events scale; IG = intervention group; IPAN = Institute for Physical Activity and Nutrition; IQR = interquartile range; NIH = National Institute of Health; PA = physical activity; PTSD = post-traumatic stress disorder.

Table 2 Risk of bias in individual studies

Study	D1	D2	D3	D4	D5	Global
Haller[64]	Some concerns	Low	Low	Some concerns	Low	Some concerns
Huberty[27]	Low	High	High	Some concerns	Low	High
Teychenne[23]	Low	Low	High	Some concerns	Some concerns	High

D1 = randomization process; D2 = deviations from the intended intervention – effect of assignment to intervention; D3 = missing outcome data; D4 = outcome measurement; D5 = selection of the reported results.

for reaching a large number of people in the community,[29] but low dropout rates and high compliance are paramount for successful interventions, regardless of whether they are web-based[71] or not,[72] or exercise-based[73] or not.[74] The drop-out rates ranged from ~ 10[23] to $\sim 47\%$ in the studies included in our review,[27] and the compliance of patients who completed the intervention was very low in two studies. Web-based exercise interventions should consider strategies to decrease dropouts and increase the compliance of participants who continue in the interventions.[75] Individuals with mental disorders face many of the same barriers to physical activity as the general population, including low income, pre-existing health conditions, overweight or obesity, and the perception that a huge effort is needed to exercise.[76] In people with depressive or anxiety disorders, autonomous motivational strategies and supervision by an expert in exercise prescription have been shown to reduce dropouts.[77,78]

In Haller et al.,[64] a sports therapist supervised the intervention group, and the dropout rate was 21% (3/14), while all controls completed the study. The participants in Teychenne et al.[23] received logbooks for goal setting and self-monitoring, access to an online forum for social support (facilitated by a research assistant with a Ph.D. in behavioral epidemiology) and web app access (purposely designed by the research team to provide motivational and informational material). The sessions were not supervised by an exercise professional. Only 20 participants (63%) used the web app, most $\leqslant 2$ times per month (57%). Logbook data was only available for 20 participants. Overall, compliance was low. Huberty et al.[27] provided no information about supervision. In this study, 13 participants (14%) formally dropped out of the trial (low dose, n=4; moderate dose, n=3; and stretch-and-tone control group, n=5), 11 of whom filled out a survey about the reasons for withdrawal. A total of 29 subjects did not complete the study (i.e., did not formally drop out, but did not continue to participate in yoga and did not complete the postintervention surveys). The reasons for dropping out included mood, pregnancy, time, and stress. Interestingly, those who dropped out reported that they enjoyed the streaming videos (n=7; 63.6%) and thought that an online support group would have helped them continue participating in the study (n=7; 55%).

Strategies to increase adherence to face-to-face exercise interventions are far more well-established than those for web-based exercise interventions. The three studies in our review used several strategies to promote engagement in web-based exercise interventions. The higher therapeutic adherence in Haller et al.[64] might be attributed to the preferential recruitment of participants highly interested in sports. Teychenne et al.[23] highlighted

several strategies: feedback and monitoring (self-monitoring of behavior; feedback on behavior); setting goals and planning (goal setting; problem solving; action planning); social support (practical and emotional); and a participant-driven online forum (e.g., weekly prompting from the research team to encourage blog use; sharing experience and progress among the participants). Huberty et al.[27] included reminders to participate in yoga or the stretch-and-tone control group but did not include behavioral strategies or tips on how to overcome barriers.

There should be a minimal effective dose of exercise to improve depressive and/or anxiety symptoms. Rethorst & Trivedi[79] reported that aerobic or resistance training might be effective for people with depression if they underwent three to five weekly sessions (45 to 60 minutes at 50 to 85% of maximum heart rate [aerobic] or 80% of one repetition maximum [resistance]) for $\geqslant 10$ weeks. Our review showed that no intervention is effective without guaranteeing a minimum of dropouts and high compliance. We point out that our findings are specific to patients with mental illness and should not be applied to healthy persons as a form of prevention.

In terms of limitations, our review included only three trials. Since we searched six major and highly relevant databases, we believe this reflects the scarcity of randomized research on this topic. Moreover, consulting with experts added no further studies. This indicates that research on randomized web-based exercise interventions for people with depressive or anxiety disorders is still in its infancy. Due to the low number of studies and their heterogeneous designs and interventions, we decided not to perform meta-analytic comparisons. The validity of a systematic review depends strongly on the quality and size of the included studies, in which case the results of our review are clearly preliminary and are perhaps more relevant for demonstrating knowledge gaps and what needs to be done than for providing solid guidelines on how interventions should be performed.

Considering what we learned during this review, we provide suggestions for future research, although we are fully aware that individual studies will likely have to focus on only a subset of these suggestions due to the difficulties in implementation:

- If possible, conduct randomized trials, which tend to reduce bias and confounding variables.
- Assess follow-up after the intervention: did the participants keep engaged with exercise training? If not, why?
- Promote studies involving men with depressive and anxiety disorders, since they are very poorly represented in the literature.

Table 3 Results of individual studies

Study	Primary outcomes† (pre-post values)		Secondary outcomes‡	Main conclusions
	Intervention	Comparator(s)	Intervention vs. comparator(s)	
Haller[64]	Mean ± SD QIDS-SR: pre = 16±3. Median change 5 (IQR: 2 to 10)§ QIDS-C: pre = 14±3. Median change 5 (IQR: 2 to 7)	Mean ± SD QIDS-SR: 17±4 QIDS-C: 15±1	= Lactate threshold ↑ Spiroergometry during treadmill walking test in IG ↑ Quality of life (SF-36) in IG ↑ GSE in IG ↑ HPA (Baecke Questionnaire) in IG Dropouts: 3 of 14 (21%) in IG; no dropouts in CG. Side effects: minor orthopedic problems in four cases in the IG	Depressive symptoms did not differ between IG and CG (ANCOVA). However, IG improved in several physiological and psychological parameters.
Huberty[27]	Means (95%CI) Low-dose IG PTSD through IES-R: pre = 43.16 (35.77-50.55); post = 24.53 (16.72-32.34); follow-up = 23.03 (13.86-32.20). Anxiety through STAI: pre = 91.38 (82.78-99.98); post = 87.80 (80.72-94.89); follow-up = 88.17 (81.60-94.75). Depression through PHQ-9: pre = 12.67 (9.23-16.11); post = 6.46 (3.50-9.42); follow-up = 6.38 (3.57-9.19). Moderate-dose IGIES-R: pre = 45.99 (39.30-52.68); post = 20.38 (13.31-27.45); follow-up = 23.39 (15.08-31.69), STAI: pre = 86.68 (79.36-94.01); post = 86.06 (80.03-92.09); follow-up = 82.36 (76.76-87.95). PHQ-9: pre = 9.27 (6.28-12.26); post = 6.31 (3.74-8.89); follow-up = 7.11 (4.66-9.56).	Means (95%CI) IES-R: pre = 45.75 (36.81-54.69); post = 36.57 (26.22-45.12); follow-up = 29.67 (18.57-40.77). STAI: pre = 90.67 (80.80-100.55); post = 88.77 (80.63-96.00); follow-up = 85.19 (77.65-92.74) PHQ-9: pre = 13.15 (9.14-17.17); post = 12.56 (9.10-16.02); follow-up = 11.21 (7.92-14.49).	PGS in IG Self-Compassion Scale ERQ MAAS PSQI ↑ Subjective health (SF-12) in moderate-dose IG. Dropouts: 42 of 90 (46.7%). Low-dose IG: 12 of 30 (40%). Moderate-dose IG: 14 of 30 (46.7%). CG: 16 of 30 (53.3%). Side effects: no adverse effects were reported, although eight participants reported discomfort (muscle soreness, wrist/knee discomfort).	Significant decreases in depression levels in both IGs compared to CG. IES-R decreased over the trial, although equally in all groups. For most outcomes, the changes were not statistically significant.
Teychenne[23]	Mean ± SD Depressive symptoms through EPDS: pre = 12.1±3.8; post = 6.0±4.3. Anxiety symptoms through GAD-7: pre = 8.2±4.6; post = 4.3±4.2.	Mean ± SD EPDS: pre = 12.6±3.9; post = 7.4±3.6. GAD-7: pre = 6.8±2.4; post = 4.2±2.9.	↑ Self-reported PA in IG Self-reported sedentary behavior ↓ Accelerometer-assessed PA in IG Accelerometer-assessed sedentary behavior Pittsburgh Sleep Quality Index Dietary intake PA self-efficacy scale Side effects: the authors reported no side/adverse effects. Dropouts: 1 of 32 in IG, 5 of 30 in CG.	Despite some improvements in secondary outcomes, there was no evidence of any beneficial effects in depressive or anxiety symptoms in IG compared to CG.

95%CI = 95% confidence interval; ANCOVA = analysis of covariance; CG = control group; EPDS = Edinburgh Postnatal Depression Scale; ERQ = Emotion Regulation Questionnaire; GAD = Generalized Anxiety Disorder Scale; GSE = General Self-Efficacy Scale; HPA = habitual physical activity; IES-R = Impact of Event Scale; IG = intervention group; IQR = interquartile range; MAAS = Mindful Attention Awareness Scale; PA = physical activity; PGS = Perinatal Grief Scale; PHQ-9 = Patient Health Questionnaire-9; PSQI = Pittsburgh Sleep Quality Index; PTSD = post-traumatic stress disorder; QIDS = Quick Inventory of Depressive Symptomatology; QIDS-C = QIDS blinded clinician rating; QIDS-SR = QIDS self-report; SD = standard deviation; SF = Short Form Questionnaire; STAI = State-Trait Anxiety Inventory.
† Primary outcomes: changes in depressive and/or anxiety symptoms and/or remission rates.
‡ Secondary outcomes: any other effects on performance, health, or quality of life.
§ The graphs presented by the authors consisted of median and IQR, which were not converted into means and SDs since the graphs suggested a highly skewed distribution.
= No changes.
↑ Improvements.
↓ Decrements.

Table 4 GRADE assessment of evidence quality

Outcomes[†]	Study design	Risk of bias in individual studies	Publication bias	Inconsistency	Indirectness	Imprecision	Quality of evidence	Recommendation
Anxiety and depression symptoms	3 RCTs and 172 participants	Moderate to high[‡]	No information, due to reduced number of studies	High[§]	High[||]	High[¶]	Low	No recommendation can be provided on the basis of existing data.

GRADE = Grading of Recommendations Assessment, Development, and Evaluation; RCTs = randomized controlled trials.
[†] Outcomes were grouped as their assessments were not different.
[‡] Detailed assessments in Table 2.
[§] Because the outcomes were continuous variables, high heterogeneity was expected. Heterogeneity also emerged from very distinct study designs, interventions, and comparators.
[||] Due to heterogeneity of the populations and symptom severity.
[¶] Small sample sizes and overlapping results suggest current knowledge is very imprecise.

– Try implementing strategies to reduce dropout and increase compliance, such as regular supervision by a trained exercise specialist, access to online forums for social support, access to user-friendly web apps, and regular conversations with the patients to assess progress and set further goals.

– Consider providing choices within each intervention. For example, individuals allocated to resistance training groups should follow the same basic principles and dosage, but not necessarily engage in the same exercises. Provide two or three exercise options for each goal.

– To understand the different effects of each exercise modality (if any), use contrasting groups, i.e., groups that perform very different exercise modalities (e.g., unimodal vs. multimodal, endurance-based vs. strength-based).

– Complementary research could proceed differently: all of the groups should perform the same exercise modality and general program, but with distinct dosages (e.g., weekly frequency, intensity) to establish dose-response relationships.

– Explore whether different programs and/or strategies for delivering programs should be based on symptom severity.

– Finally, perhaps the most challenging part: explore how to effectively deliver interventions to low-income patients, who perhaps need them the most, but will struggle with access.

In conclusion, we hypothesized that web-based exercise interventions would be an effective therapy for patients with depression and anxiety disorders, similar to other telehealth interventions for depression. However, the available data is scarce, the risk of bias is high, and the quality of the cumulative evidence is low. Currently, no clear recommendations can be provided.

Disclosure

The authors report no conflicts of interest.

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