The effectiveness of online exercise on physical activity, motor function and mental health: A systematic review with meta-analysis

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Abstract

Background: Regular engagement in exercise is associated with a multitude of physical and mental health benefits. In view of the technical progress, the ageing society and the recent public life restrictions during the COVID-19 pandemic, the delivery of interventions using digital devices has become highly popular. This systematic review with meta-analysis examined the effects of online exercise programs on physical activity (PA), motor performance, and mental health.

Objective: To examine the effects of online exercise programs on physical activity (PA), motor performance, and mental health.

Methods: A systematic literature search was performed using PubMed, Cochrane and Google Scholar. Randomized, controlled trials assessing the effects of online exercise (OE) vs. no exercise (NEX) or face-to-face exercise (FFE) in healthy adults were included. Effect sizes (standardized mean difference/SMD) were pooled using robust variance estimation and the certainty about the evidence was rated by means of the GRADE criteria.

Results: A total of 18 articles with moderate to high methodological quality (8/11 points on the PEDro scale) were identified. OE was superior to NEX regarding strength (SMD=0.61), balance (SMD=0.52), endurance (SMD=0.85), PA (SMD=0.46), depression (SMD=1.08), mood/emotion (SMD=0.47), mental wellbeing (SMD=0.79), and self-efficacy (SMD=1.1). Compared to FFE, OE was non-inferior for all tested outcomes. The certainty about the evidence was low to moderate.

Conclusions: OE represents an effective strategy to improve PA, physical function and mental health in healthy adults. However, in view of the partly limited certainty about the evidence, additional well-designed studies are warranted to further delineate the value of OE. Clinical Trial: PROSPERO registration number: CRD42022338871

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Conclusion: OE represents an effective strategy to improve PA, physical function and mental health in healthy adults. However, in view of the partly limited certainty about the evidence, additional well-designed studies are warranted to further delineate the value of OE.

PROSPERO registration number: CRD42022338871

Keywords: Online physical activity, motor performance, mental health.

Introduction

Physical Activity (PA) has been demonstrated to represent a significant contributor to health[1]. Irrespective of the type of

PA, its advantages are unanimously agreed upon as regular movement has been shown to decrease morbidity and improve prognoses in relation to a wide variety of pathologies[2,3]. Regular PA is, furthermore, linked to improved psychological wellbeing[4,5] and a lower incidence of mental disorders[6]. In recent years, however, the increasing time demands placed on the average individual have posed a definite threat to the ability to achieve the recommended levels of PA[7]. This is of utmost importance because sedentary lifestyle habits are a risk factor of major non-communicable diseases, such as diabetes, obesity, and hypertension[8-10] as well as of mental health conditions such as, depression and anxiety[11].

In view of the pivotal role of PA, the availability of exercise offers (e.g. gyms, sports clubs, public exercise facilities) is central to maintain public health. Yet, as the hallmark of the demographic change, the number of older people is expected to more than double within the next 25 years[12], meaning that more and more seniors with co-morbidities will require attention, supervision, and treatment. Of note, PA decreases with increasing age, which reflects a pressing need for novel and easily accessible PA platforms[13]. Further to this, there has been a shift towards individualisation in both, the society and healthcare[14,15]. All these issues highlight that exercise interventions be tailored according to the preferences of the indivual[15,16].

The onset of the SARS CoV-2 pandemic has been another accelerator to the development of digital exercise offers. The global population was denied access to exercise establishments in an attempt to curb the spread of the virus[17], which inadvertently forced otherwise physically active people into a state of inactivity[18,19]. This created a large demand for online programs, that were user-friendly, effective and, most importantly, allowed individuals from various fitness backgrounds to remain physically active without increasing the risk for contracting SARS CoV-2[20]. Online exercise programs have included simple pedometer tracking software, PA support forums, home exercise guidelines, PA reporting logs, structured virtual exercise platforms, and live-streamed workouts[21]. Alike programs have remained popular even though pandemic-related restrictions have been lifted. As vaccinations have formed a foundation for infection control, the virus continues to mutate, leaving room for future outbreaks that cannot be controlled without adjustments to the current vaccines, which may still require the need for social distancing in the future[22,23]. Hence the necessity for efficient online exercise programs remains relevant.

Two previous systematic reviews[21,24] found beneficial effects of online PA programs on a variety of outcomes. However, more than 10 years have passed since their publication. Furthermore, these articles either did not include a meta-analysis[21], combined healthy and diseased individuals[21,24], or did not report on possible changes in mental health[21,24]. This systematic review aimed to provide an up-to-date insight into the collective effectiveness of structured online exercise programs on PA, motor function and mental health.

Methods

We performed a systematic review with meta-analysis summarizing the effects of digital online exercise (OE) vs. no exercise (NEX) or conventional face-to-face exercise (FFE). Outcomes included markers of PA, physical function and mental health. The review protocol was prospectively registered in the PROSPERO database (CRD42022338871).

Date Sources and Source Strategy

Two independent investigators performed a systematic literature search using PubMed, Cochrane library, and Google Scholar. The search term was: "(exercise OR "PA") AND (internet* OR online* OR web* OR e-health OR digital OR tele* OR virtual) AND home*". Searches were limited to articles published from 1 January 2000. This range was chosen due the lack of suitable online technologies prior to 2000. In addition to database searches, the reference lists of all included studies were checked to identify further potentially eligible articles[25].

Eligibility Criteria

Studies were considered eligible for inclusion based on the following criteria; (1) randomized, controlled trial (RCT) design; (2) OE intervention with a duration of at least 4 weeks, (3) recruitment of healthy adults, (4) measurement of PA, motor performance and/or mental health surrogates; (5) publication in English language.

Study Quality, Risk of Bias and Certainty about the Evidence

Study quality was evaluated by means of the PEDro scale[26,27]. Two examiners independently rated each study and in case of disagreement, meetings were held to achieve consensus[28]. For the identification of a potential reporting bias, we used visual inspection of funnel plots. To classify the certainty about the evidence as very low, low, moderate, or high, the criteria of the GRADE working group were applied[29]. Briefly, the evaluation starts with the assumption of a high certainty about the evidence due to the RCT design. The GRADE framework then suggests adjusting the certainty as follows: in case of risk of bias, imprecision, inconsistency of results, indirectness of the evidence, or publication bias, one point is subtracted for each weakness. In contrast, a large-magnitude of the effect or a dose-response gradient lead to an upgrade of the certainty rating[29].

Data Extraction

We extracted the following data: sample size, participant characteristics, interventions, measurements, and results (pre–

post changes plus standard deviations of each intervention arm). The primary outcomes of the meta-analysis were PA, motor function (strength, endurance, balance, flexibility, gait, body composition) and mental health (depression, anxiety, mood/emotion, psychological well-being, sleep, self-efficacy). If a study performed more than one test assessing the same outcome, all effect sizes (ES) were obtained.

Data Processing and Statistical Analysis

For each trial arm, we extracted the mean baseline and postintervention values, pre-post changes, and the related standard deviations (SD). In case of incomplete reporting (i.e., missing SDs of the changes from baseline), the corresponding authors of the trials were contacted. If no values could be obtained, missing data were determined from figures or imputed according to Cochrane recommendations: $SD_{change} = \sqrt{(SD^2_{baseline} + SD^2_{postintervention})}–(2 \times Corr \times SD_{baseline} \times SD_{postintervention})$,where Corr = 0.7. The value chosen for Corr represents a conservative estimate of the correlation between the baseline and post-treatment SDs[30].

Robust variance estimation random[31] was used to pool the standardized mean differences (SMD) and 95% confidence intervals for OE vs. NEX as well as OE vs. FFE. Dependency of ES was considered by nesting the term ‘study’ as a random factor in the model. The between-study variance component was determined by means of Tau^2, using the method-of-moments estimate; for within-study variance (more than one dependent effect size), ω^2 was calculated[32]. We interpreted resulting ES as follows: small (SMD = 0.2), medium (SMD = 0.5) or large (SMD = 0.8) [40]. The employed software was R (R Foundation for Statistical Computing, Vienna, Austria), packages meta (G Schwarzer) and robumeta (version 2.0)[33].

Results

The initial database searches yielded a total of n=6335 articles (Figure 1). After removal of duplicates and application of inclusion criteria, n=18 studies were included.

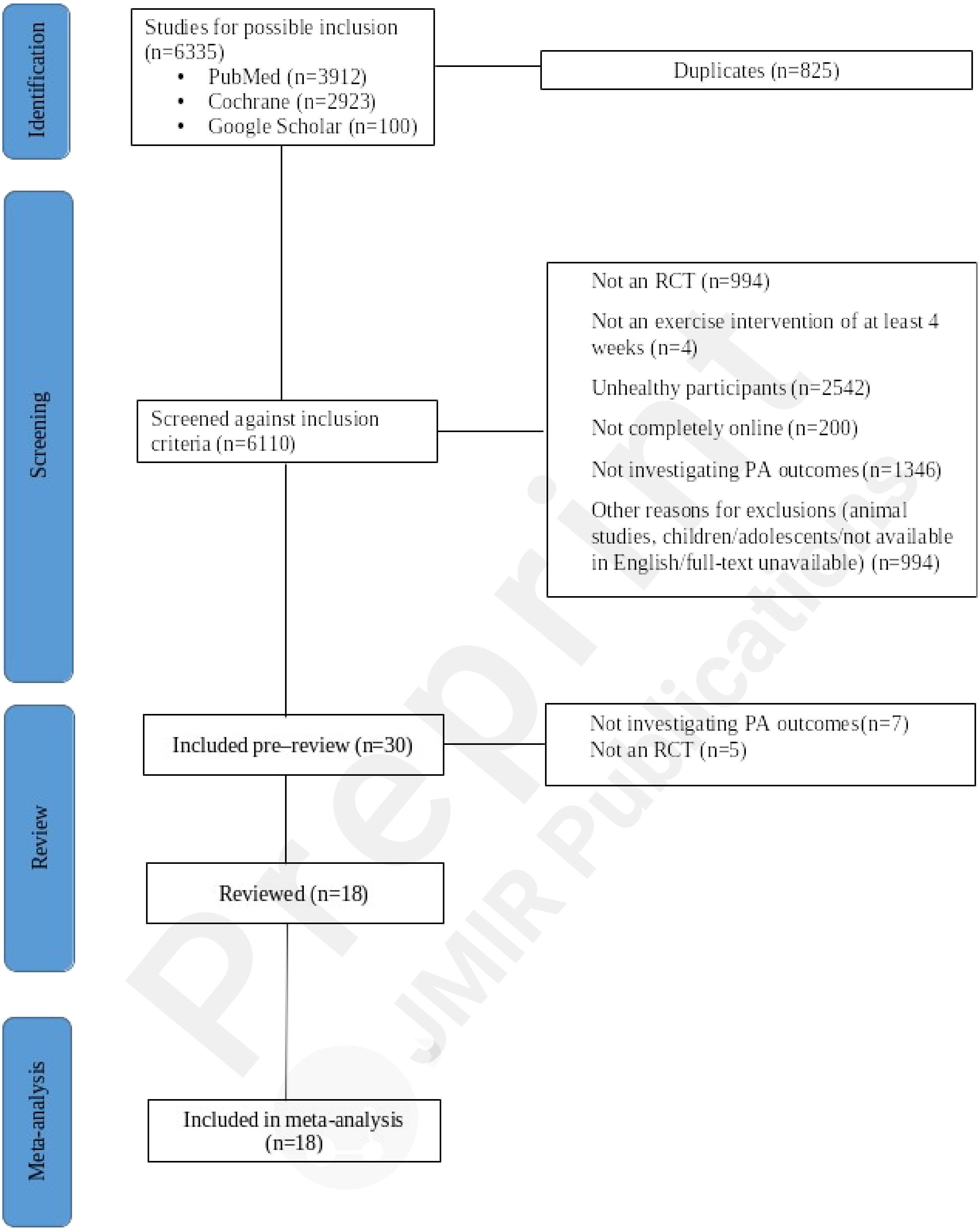

Figure 1: Flow of the literature search

Study Characteristics

The characteristics of the 18 included studies, which included a total of n=3531 cumulative participants, are displayed in Table 1. Half (n=9) of the studies had participants that were older than 65 years, the remaining half (n=9) examined young or middle-aged adults. Five studies compared OE to FFE, while 12 investigated OE vs. NEX, and one compared OE to both FFE and NEX. Motor performance outcomes were assessed in 11 studies, PA was measured in 5 studies, and mental health was examined in 8 studies. The mean (SD) duration of the OE interventions was 12.5 (10.34) weeks and the mean (SD) training frequency was 2.7 (1.94) sessions per week.

Table 1. Study Characteristics

Study	*Sample*	*Intervention*	*Outcomes*
Baez *et al* [2017]	n= 37 (27 W, 9 M) 71±6 years	Group 1: online personalised program with social environment for group exercising, messaging and persuasion features, 2x30-40min/week, 8 weeks. Group 2: home-based program, no social or individual persuasion features, 2x30-40min/week, 8 weeks.	Strength, Gait Speed, Mood/Emotion
Beauchamp *et al* [2021]	n=241 (187 W, 54 M) 73± 5 years	Group 1: live-streaming, group sessions with a trainer, social breakout groups, 50-60min/session for at least 3xweekly, 12 weeks Group 2: live-streaming, individual sessions with a trainer, 50-60min/session for at least 3xweekly, 12 weeks Group 3: no exercise for 12 weeks, access to program at the end of 12 weeks	Depression, Mental Wellness
Chang *et al* [2022]	n=73 (56 W, 17 M) 70 ± 5 years	Group 1: live-streaming exercise, 70-90min/session, 8 weeks Group 2: no exercise for 8 weeks	Strength, Endurance, Balance, Flexibility
Dekker-van Weering *et al* [2017]	n= 36 (INT=12 W, 9 M) 71±4 years (CON=10 W, 5 M) 69±4 years	Group 1: live-streaming exercise, 3x30min/week, 12 weeks Group 2: no exercise for 12 weeks	Mental Wellness
Hartman *et al* [2017]	n=205 (INT=104 W) 39±11 years (CON=101 W) 40±10 years	Group 1: accelerometer tracks PA, combined with goal setting, motivational messaging, 6 months Group 2: received general health tips such diet etc, no PA advice, 6 months	Physical Activity
Jennings *et al* [2020]	n=1048 (INT=247M, 31 W) 75±7 years (CON=700 M, 70 W) 74±7 years	Group 1: live-streaming therapist led exercise, 1-9 sessions/week, 5 weeks Group 2: no exercise for 5 weeks	Strength, Gait Speed
Kikuchi *et al* [2021]	n=34 (INT=12 M, 11 W) 45±16 years (CON=3M, 8 W) 39±10 years	Group 1: live-streaming, 2x60min/week, 8 weeks Group 2: face-to-face, 2x60min/week, 8 weeks	Strength, Blood Pressure
Langeard *et al* [2022]	n=41 (OE=10 W, 3 M) 73±4 years (FFE=9 W, 6M) 72±4 years (CON= 8 W, 5 M) 74±4 years	Group 1: live-streaming with trainer, 2x60min/week, 16 weeks Group 2: face-to-face with same trainer, 2x60min/week, 16 weeks Group 3: no exercise for 16 weeks	Strength, Endurance, Body Fat
Marcus *et al* [2007]	n=249 (OES=68 W, 14 M) 46±9 years (OET=66 W, 15 M) 45±9 years (FFE=72 W, 14 M) 45±10 years	Group 1: online PA material with PA logs only Group 2: online PA material with PA logs, goal setting, motivational messaging and personalised feedback Group 3: face-to-face PA material with PA logs, goal setting, motivational messaging and personalised feedback	Endurance
Marcus *et al* [2016]	n=205 (INT=104 W) 39±11 years (CON=101 W) 40±10 years	Group 1: online PA material, combined with goal setting, motivational messaging, 6 months Group 2: received general health tips such diet etc, no PA material, 6 months	Physical Activity, Depression, Mood/Emotion, Self-Efficacy
Napolitano *et al* [2003]	n=65 (9 M, 56 W) 43±10 years	Group1: online PA material including weekly health and PA related tip sheets, 12 weeks Group 2: no exercise for 12 weeks	Physical Activity
Pressler *et al* [2010]	n=105 (12 W, 93 M) median age 48 (range 25-60) years	Group 1: online structured exercise, 3x30-70min/week, 12 weeks Group 2: online unstructured exercise, no schedule, no specified sessions/week, 12 weeks	Endurance, Blood Pressure, Body Fat
Tekin & Cetisli-Korkmaz [2022]	n=255 (INT=72 M, 60 W) 68±4 years (CON=66 M, 57 W) 70±5 years	Group 1: online recorded videos, 5days/week, participants recorded themselves doing exercise and forwarded to researchers, 4 weeks Group 2: no exercise for 4 weeks	Strength, Balance, Gait Speed, Depression, Self-Efficacy
Waden & Cartwright [2022]	n=34 (INT=17 W) 43±11 years (CON=14 W, 3 M) 42±10 years	Group 1: live-streaming yoga program, 2-3x50min/week, 6 weeks Group 2: no exercise for 6 weeks, access to exercises post intervention	Depression, Anxiety, Mood/Emotion, Mental Wellness, Self-Efficacy
Wilke *et al* [2022]	n=763 (237 M, 523 W, 2 D, 1 U) 33±13 years	Group 1: live-streaming synchronous exercise program, with trainer, according to schedule, 30-60 min/session, 5 days/week, 4 weeks, recorded sessions 4 weeks post intervention Group 2: no exercise for 4 weeks, access to recorded sessions 4 weeks post intervention	Physical Activity, Anxiety, Mood/ Emotion, Mental Wellness, Sleep
Wu *et al* [2022]	n=80 (34 W, 46 M) 23±3 years	Group 1: live-streaming exercise, 3x30min/week, 4 weeks Group 2: no exercise for 4 weeks	Endurance, Mood/Emotion, Sleep
Yi & Yim [2021]	n=70 (INT=8 M, 27 W) 76±6 years (CON=4 M, 31 W) 77±6 years	Group 1: live-streaming exercise, 2x40min/week, 8 weeks Group 2: no exercise for 8 weeks	Strength, Endurance, Balance, Gait Speed
Zengin Alpozgen *et al* [2022]	n=30 (INT=10 W, 5 M) 67±4 years (CON=7 W, 8 M) 69±6 years	Group 1: live-streaming sessions with trainer, 3x40-45min/week, 6 weeks Group 2: no exercise for 6 weeks, access to program at the end of 6 weeks	Strength, Endurance, Balance, Flexibility, Physical Activity

INT=intervention, CON=control, M=men, W=women, D=diverse, U=unspecified, OE=online exercise, FFE=face-to-face exercise, OES=online exercise standard, OET=online exercise tailored

Study Quality and Risk of Reporting Bias

Ratings on the PEDro scale ranged from 3 to 11 with a mean of 8.1±2.3 out of 11 points (Table 2).

All studies reported between group statistical analyses for at least one key outcome measure. Almost all (94%, n=17) articles provided clear eligibility criteria; had intervention and control groups that were similar at baseline with regards to key prognostic indicators; and reported point and variability measures for at least one key outcome measure. A clear majority (83%, n=15) used randomised groups allocation whilst, 78% (n=14) ensured concealed group allocations. A slightly smaller share (72%, n=13) reported all participants receiving the intended intervention and the use of intention to treat in cases where participants did not receive the intended interventions; and reported outcome measures for at least 85% of the initial group allocations. In terms of blinding, 61% (n=11) of the studies reported participant blinding, 44% (n=8) indicated assessor blinding, and only 17% (n=3) stipulated therapist blinding.

Visual inspection of funnel plots yielded indications for a reporting bias regarding strength measures in OE vs. FFE and for mood/emotion in OE vs. NEX.

Table 2. PEDro scores of the included studies

	Baez *et al* [2017]	Beauchamp *et al* [2021]	Chang *et al* [2022]	Dekker-van Weering *et al* [2017]	Hartman *et al* [2017]	Jennings *et al* [2020]	Kikuchi *et al* [2021]	Langeard *et al* [2022]	Marcus *et al* [2007]	Marcus *et al* [2016]	Napolitano *et al* [2003]	Pressler *et al* [2010]	Tekin & Cetisli-Korkmaz [2022]	Waden & Cartwright [2022]	Wilke *et al* [2022]	Wu *et al* [2022]	Yi & Yim [2021]	Zengin Alpozgen *et al* [2022]
Eligibility criteria specified	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Random group allocation	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1
Allocation concealed	1	1	0	1	1	0	0	1	1	1	1	1	1	0	1	1	1	1
Groups similar at baseline regarding most important prognostic indicators	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Participant blinding	1	1	1	0	1	0	0	1	1	1	1	1	1	0	1	0	0	0
Therapist blinding	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Assessor blinding	1	1	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	1
Measures of at least one outcome obtained from >85% of participants	1	1	0	1	1	0	0	1	1	0	1	1	0	1	1	1	1	1
All participants received treatment or control as allocated or data for >1 outcome analysed intention to treat	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	1	0	1
Results of between-group comparisons reported for >1 outcome	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Point measures and measures of variability for >1 outcome	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL PEDro Score	10	11	6	8	10	3	3	11	9	10	8	8	9	6	10	8	7	9

1=Yes, 0=No

Meta-analysis

Compared to NEX (Table 3), OE had a beneficial effect on measures of strength (SMD=0.61, 95% CI=0.06 to 1.15, *p*=0.04, moderate certainty about the evidence), balance (SMD=0.52, 95% CI=0.06 to 0.99, *p*=0.04, moderate certainty), endurance (SMD=0.85, 95% CI=-0.01 to 1.70, *p*=0.05, low certainty) and physical activity (SMD=0.46, 95% CI=0.05 to 0.87, *p*=0.04, moderate certainty). No difference was found for gait speed (moderate certainty) and flexibility (low certainty).

Table 3. Effects of online exercise vs. inactive control on markers of motor performance and physical activity

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau^2/Omega^2*
Strength	5 (12)	0.61 (0.06 to 1.15)	0.04	0.14/0
Endurance	5 (6)	0.85 (-0.01 to 1.70)	0.05	0.32/0
Balance	4 (9)	0.52 (0.06 to 0.99)	0.04	0.13/0
Gait	2 (3)	0.26 (-2.23 to 2.75)	0.41	0.03/0
Flexibility	2 (4)	0.74 (-6.32 to 7.80)	0.41	0.53/0
Physical Activity	5 (7)	0.46 (0.05 to 0.87)	0.04	0.07/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

With regard to mental health outcomes (Table 4), OE was superior to NEX for depression (SMD=1.08, 95% CI -0.01 to 2.16, *p*=0.05, moderate certainty), mood/emotion (SMD=0.47, 95% CI=0.05 to 0.90, *p*=0.04, low certainty), mental wellbeing (SMD=0.79, 95% CI=0.06 to 1.52, *p*=0.05, moderate certainty), and self-efficacy (SMD=1.1, 95% CI=1.03 to 1.17, *p*=0.06, moderate certainty). No effect was found for anxiety and sleep (p>0.05, moderate certainty).

Table 4. Effects of online exercise vs. inactive control on markers of mental health

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau^2/Omega^2*
Depression	4 (5)	1.08 (-0.01 to 2.16)	0.05	0.07/0.4
Anxiety	2 (2)	0.20 (-3.19 to 3.59)	0.59	0.10/0
Mood/Emotion	5 (10)	0.47 (0.05 to 0.90)	0.04	0.08/0
Mental Wellbeing	4 (5)	0.79 (0.06 to 1.52)	0.04	0/1.4
Sleep	2 (3)	-0.26 (-2.57 to 2.06)	0.40	0.05/0
Self-Efficacy	3 (3)	1.1 (1.03 to 1.17)	0.06	0/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

Regarding OE vs. FFE (Table 5), no difference was found for most measures (strength: very low certainty, endurance: moderate certainty, body fat: low certainty). However, gait speed improved more in OE (SMD=0.25, 95% CI=0.24 to 0.26, *p*=0.002, moderate certainty).

Table 5. Effects of online exercise vs. face-to-face exercise on markers of motor performance and body composition

Outcome	*Studies (ES)*	*SMD (95% CI)*	*p value*	*Tau^2/Omega^2*
Strength	4 (14)	-0.20 (-0.84 to 0.45)	0.41	0.13/0
Endurance	3 (4)	-0.04 (-0.34 to 0.27)	0.66	0/0
Gait Speed	2 (2)	0.25 (0.24 to 0.26)	0.002	0/0
Body Fat	2 (2)	-0.07 (-4.87 to 4.73)	0.88	0.18/0

ES=effect sizes, SMD=standardised mean difference, CI=confidence interval

Discussion

The manifold benefits of exercise have been repeatedly presented in the literature[1,2]. Recently, there has been a shift towards the use of online platforms aiming to provide easily accessible exercise opportunities to the general population[21,24]. To the best of our knowledge, this article is the most comprehensive and up-to-date quantitative summary of the available evidence. We show that OE is non-inferior to FFE and superior to NEX in a variety of measures of physical function, mental health, and PA.

Regarding motor performance, OE induced moderate-to-large improvements in strength, endurance, and balance, which accords with data from older reviews[21,24] In contrast, gait speed and flexibility did not change. This may be related to a lack of power as both outcomes were investigated in only two studies. For mental health outcomes, the very large positive effects on depression (SMD: 1.08) and self-efficacy (SMD: 1.1) were striking. A beneficial impact, although of smaller magnitude, was also observed for mood/emotion and mental wellbeing. While the sizable effects of OE on most psychological outcomes are in line with studies examining face-to-face exercise[34,35], the lack of a change in anxiety is a bit surprising because anxiety had been reported to improve in response to conventional exercise[36]. Again, the non-significant effect size may be due to the small number of studies (n=2).

Our results have implications for clinical practice. It would be reasonable to assume that exercise performed face-to-face would be the most effective way to improve health and performance. Yet, as we demonstrated non-inferiority of OE, the selection of the exercise mode may be left to the individual preference. Half of the studies reviewed (n=9) utilised older participants (>65 years). This is noteworthy because the projected change in demographics leaves older individuals at a higher risk for decreased PA[13]. Online PA interventions have the potential to provide these elderly persons with a safe, effective and accessible PA opportunity. As much as there is the limitation of digital literacy[37], research suggests that this limitation is improving.[37], hence, as the years unfold, the use of online PA interventions may become more beneficial and used in the older population[39]. Online exercise may also be of particular interest in rural areas where public PA infrastructure (e.g., availability of sports clubs, or gyms) is limited[40]. As the share of users with internet access is increasing steadily around the globe[41], OE may be of help in the fight against the pandemic of inactivity. Finally, OE can also help to reduce the direct costs of exercise as streamed contents would theoretically be available to an unlimited number of individuals rather than being limited to those who can afford memberships in face-to-face PA facilities[42].

However, some caveats also require consideration. A large benefit of FFE is that coaches have a 3D view on exercising individuals which allows for an easier correction and monitoring of movement execution. While this is less a concern for healthy individuals, it may become relevant for elderly or diseased persons[43,44]. Another issue relates to inter-personal factors as sports and exercise cannot be reduced to their direct physical effects. When exercising in a group, social interaction can increase motivation or build friendships that could be of value in other aspects of life[45,46].

A particular strength of our review is that we only included RCTs, as this study type is viewed to be the most valid in the assessment of intervention effectiveness[47]. In addition, the mean PEDro score of 8.1 indicates a good overall quality, which adds to the validity of the findings. Notwithstanding, in about one third of the outcomes, the certainty about the evidence was low which was probably due to the small number of studies resulting in large confidence intervals, reporting bias and heterogeneity. We therefore reinforce the need for additional studies to fully gauge the long-term effects of OE[48-50]. This particularly applies because some of the studies included in our review were conducted during the SARS-CoV-2 pandemic and it is unknown how the specific conditions affected the overall result of the meta-analysis. It is imperative that more studies are conducted in a less volatile period to observe unbiased effects in relation to the everyday lives of individuals[51]. Finally, to reduce heterogeneity, we limited inclusions to studies with healthy participants. Further investigations are required to report specifically on the effectiveness and safety of OE in unhealthy participants.

Conclusion

There is mostly moderate certainty-evidence that OE improves PA, motor performance, and mental health when compared to NEX. In addition, OE seems non-inferior to FFE. However, additional studies including larger sample sizes, longer study durations and long-term follow-up measurements are warranted in order to better delineate the benefits of OE interventions.

Declarations

Competing Interests
None

Contributors
JW was responsible for study design. AKB and JW were responsible for data collection and data analysis. AKB created the initial manuscript, which was read, revised and approved for submission by JW and JDP.

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Supplementary Files

CONSORT (or other) checklists

PRISMA_2020_checklist.
URL: http://asset.jmir.pub/assets/5fa423aa9f047b475d063ec0f35ddbad.pdf