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The effectiveness of serious games in alleviating anxiety: A systematic review and meta-analysis

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Abstract

Background: Anxiety is one of the mental disorders characterized by apprehension, tension, uneasiness, and other related behavioral disturbances. One of the non-pharmacological treatments used for reducing anxiety is serious games, which are games that have a purpose other than entertainment. The effectiveness of serious games in alleviating anxiety was investigated by several systematic reviews, however, they are limited by design and methodological weaknesses.

Objective: This study aims to assess the effectiveness of serious games in alleviating anxiety through summarizing the results of previous studies and providing an up-to-date review.

Methods: We carried out a systematic review of randomized controlled trials (RCTs). We searched 7 databases: MEDLINE, CINAHL, PsycINFO, ACM Digital Library IEEE Xplore, Scopus, and Google Scholar. We also conducted backward and forward reference list checking of the included studies and relevant reviews. Two reviewers independently carried out the study selection, data extraction, risk of bias assessment, and quality of evidence appraisal. We used a narrative and statistical approach, as appropriate, to synthesize results of the included studies.

Results: Out of 935 citations retrieved, 33 studies were included in this review. Of those, 22 RCTs were eventually included in meta-analyses. Very low quality evidence from 9 RCTs and 5 RCTs showed no statistically significant effect of exergames (games entailing physical exercises) on the anxiety level as compared to conventional exercises (P=0.70) and no intervention (P=0.27), respectively. While 6 RCTs demonstrated a statistically and clinically significant effect of computerized cognitive behavioral therapy (CBT) games on the anxiety level when compared with no intervention (P=0.01), the quality of the evidence reported was low. Likewise, low quality evidence from 3 RCTs showed a statistically and clinically significant effect of biofeedback games on the anxiety level when compared with conventional video games (P=0.03).

Conclusions: This review shows that serious games have the potential in alleviating anxiety levels. However, our findings remain inconclusive mainly due to the high risk of bias in the individual studies included, the low quality of meta-analyzed evidence, few studies included in some meta-analyses, patients without anxiety recruited in most studies, and using purpose-shifted serious games in most studies. Therefore, serious games should be deemed as complementary to existing interventions. To have adequate and robust evidence, researchers should use serious games that are designed specifically to alleviate depression and deliver other therapeutic modalities, recruit a diverse population of patients with anxiety, and minimize the risk of bias by following the recommended guidelines for conducting and reporting RCTs.

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Abstract

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Keywords: Serious games; Exergames; Anxiety; Computerized cognitive behavioral therapy games; Biofeedback games; Systematic reviews; Meta-analysis

Introduction

Background

Mental disorders are conditions that can be episodic and occasional or chronic and long-lasting, thus affecting one’s mood, feelings, thinking, and behaviors [1]. Mental disorders are among the most significant causes of death worldwide [2]. There is a growing burden of disability-related to mental disorders [3]. The American Psychiatric Association estimated that as much as one-third of the population suffers from a mental disorder once in their lifetime [4]. Globally, the prevalence of mental disorders among the general population was estimated to be “28.0% for depression; 26.9% for anxiety; 24.1% for post-traumatic stress symptoms; 36.5% for stress; 50.0% for psychological distress; and 27.6% for sleep problems” [5].

Anxiety is a normal response to situations in human life. However, excessively, it may indicate
anxiety disorders, which are one of the mental disorders characterized by apprehension, tension, uneasiness, and other related behavioral disturbances. They are potentially coupled with other physiological symptoms such as shortness of breath, headaches, nausea, and abdominal pain [6, 7]. Anxiety disorders are among the most prevalent mental disorders globally. Anxiety disorders include separation anxiety disorder, phobia, social anxiety disorder, panic disorder, and substance/medication-induced anxiety disorder [8]. Anxiety disorders affect all age groups, including children and adolescents [9] and can be debilitating in nature causing significant impairment in one’s social and professional functioning [10]. Evidence revealed a strong association between anxiety and mortality rate among healthy individuals [11, 12]. Anxiety contributes to a decrease in the quality of life and other health-related problems [12]. Globally, over 45 million incidents are estimated to be attributed to anxiety disorders, which, in turn, are responsible for approximately 28.68 million disability-adjusted life years [13, 14].

Despite the prevalence of anxiety disorders, they often go undetected and undertreated [15]. Anxiety requires treatment and management because of stimulation of the sympathetic system that would lead to adverse effects. Treatment for anxiety disorders can be divided into pharmacological treatments (e.g., psychotropic medications) and non-pharmacological treatments (e.g., cognitive-behavioral therapy (CBT)) [16, 17]. Although the use of pharmacological treatments can be effective for the treatment of anxiety disorders, they could cause many adverse events and would not be effective for everyone. Therefore, non-pharmacological treatments have been used to reduce anxiety levels [18, 19].

One of the non-pharmacological treatments used for reducing anxiety is serious games, which are games that have a purpose other than entertainment [20-23]. In recent years, the popularity and adoption of serious games have been on the rise due to their ability to educate and influence change in one’s experience or behaviors [24, 25]. Evidence suggests that serious games can enable the player to experience more meaningful, engaging, and challenging learning compared to other traditional interventions or methods used for reliving anxiety [26].

Research Gap and Aim

Various studies assessed the effectiveness of serious games in alleviating anxiety. Examining and summarizing the evidence from these various studies is critical to reach informed conclusions about the effectiveness of serious games in the treatment of anxiety disorders. Two published reviews summarized the evidence about the effectiveness of serious games on anxiety [20, 21]. However, these reviews are undermined by certain shortcomings that limit the generalization of the findings. Specifically, these reviews (i) focused on only one type of serious games (i.e., exergames) [20], (ii) included non-randomized controlled trials (non-RCTs) [20, 21], (iii) focused on a specific age group (e.g., adolescents) [21], (iv) did not search main databases information technology and health fields (e.g., Medline, PsychInfo, IEEE Xplore, ACM Digital Library) [20, 21], or (v) did not conduct meta-analyses [21]. To address the existing gaps in the literature, this review aims to assess the effectiveness of serious games in alleviating anxiety through summarizing the results of previous studies and providing an up-to-date review.

Methods

We conducted a systematic review and meta-analyses in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Multimedia Appendix 1) [27]. The protocol for this review is registered at PROSPERO (ID: CRD42021264126).
Search Strategy

Search Sources

To retrieve the relevant studies, we searched the following bibliographic databases: MEDLINE (via Ovid), PsycInfo (via EBSCO), CINAHL (EBSCO), IEEE Xplore, ACM Digital Library, and Scopus. The first author searched these databases on 29 June 2021 by the first author. We also set up automatic alerts as needed in order to retrieve weekly searches for 12 weeks (ending on 28 August 2021). Furthermore, we also searched “Google Scholar” to identify grey literature. We considered only the first 10 pages (i.e., 100 hits) as Google Scholar retrieves a vast number of studies, and it orders them based on their relevance. Finally, we conducted backward and forward reference list checking (i.e., screening the reference lists of the included studies and relevant reviews and screening the studies that cited the included studies).

Search Terms

Two experts in digital mental health were consulted before developing the search query for this review, in addition, systematic reviews of relevance to this review were checked. The search terms were chosen based on the target intervention (e.g., serious games and exergames), target outcome (e.g., anxiety), and target study design (e.g., randomized controlled trial and clinical trial). Multimedia Appendix 2 summarized the search query that was used for searching each of the 8 databases.

Study Eligibility Criteria

Only RCTs that assessed the effectiveness of serious games in alleviating anxiety levels were included in this study. Specifically, the target intervention in this review was serious games that were delivered on any digital platforms such as computers, consoles (Xbox, PlayStation, etc.), mobile phones, tablets, handheld devices, or any other computerized devices. Further, gaming had to be an integral and primary component of the intervention. Serious games must be used for therapeutic or prevention purposes. Non-digital games and those used for other purposes such as monitoring, screening, and diagnosis were excluded. RCTs whether they are parallel RCTs, cluster RCTs, crossover RCTs, or factorial RCTs were all included but we excluded quasi-experiments, observational studies, and reviews.

The outcome of interest in this review is anxiety level regardless of the outcome measures. We included outcome data that was measured immediately after the intervention rather than follow-up data. Trials in the English language were eligible for inclusion in this review, excluding all other languages. We excluded conference abstracts and posters, commentaries, preprints, proposals, and editorials. RCTs published as journal articles, conference proceedings, and dissertations were included. No restrictions related to the population, year of publication, country of publication, comparator, and study settings were applied.

Study Selection

We identified relevant studies in the following steps. Firstly, we exported the retrieved studies into the EndNote software to identify and eliminate duplicate entries. In the second step, two reviewers independently screened the titles and abstracts of all retrieved studies. Finally, full texts of the studies included from the previous step were screened independently by two reviewers. The two reviewers resolved any disagreements by discussion. The inter-rater agreement (Cohen $\kappa$) in steps two and three were 0.81 and 0.93, respectively, indicating a perfect level of inter-rater agreement [28].

[unpublished, non-peer-reviewed preprint]
Data Extraction

Using Microsoft Excel, two independent reviewers extracted data from the included studies. Multimedia Appendix 3 shows the data extraction form that was used by the two reviewers to extract the data precisely and systematically from the included studies. We pilot tested the form using 5 included studies before proceeding. Disagreements between reviewers were resolved via discussion. We observed an inter-rater agreement of 0.86 indicating a perfect level of the agreement [28]. Where outcome data such as mean, standard deviation, and sample size were unavailable, we contacted the corresponding authors in an attempt to retrieve them. In this way, we managed to retrieve such information for an additional 5 studies.

Risk of Bias Appraisal

As recommended by Cochrane Collaboration [29], the risk of bias was assessed by two independent reviewers using the Risk-of-Bias 2 (RoB 2) tool. This tool appraises the risk of bias in 5 domains in RCTs: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result [29]. The risk of bias judgments in these domains is used to determine the overall risk of bias for each included study. Disagreements in judgments between the two reviewers were resolved via discussion. Interrater agreement between the reviewers was perfect (Cohen κ=0.86) [28].

Data Synthesis

We used a narrative and statistical approach to synthesize the extracted data. Specifically, in our narrative synthesis, we describe the characteristics of the included studies, population, intervention, comparator, and outcome measures using texts and tables. The findings of the included studies were summarized and grouped according to the type of serious games (e.g., exergames, computerized cognitive behavioral therapy (CBT) games, biofeedback games). Where at least two studies of the same type of serious games reported enough data (i.e., mean, standard deviation, number of participants in each intervention group), we also conducted a meta-analysis. We used Review Manager (RevMan 5.4) to carry out the meta-analyses. The effect of each study and the overall effect was assessed using the standardized mean difference (SMD) (Cohen’s d) because the type of data for the outcome of interest (anxiety level) was continuous, and instruments used to evaluate the outcome were diverse amongst the included trials. We selected the random-effects model for the analysis due to the high clinical heterogeneity between the meta-analyzed studies in terms of serious game characteristics (e.g., its types, duration, frequency, and period), population characteristics (e.g., sample size, mean age, and health condition), and outcome measures (i.e., tools and follow-up period).

When meta-analysis showed a statistically significant difference between groups, we examined whether this difference was clinically important. We used the concept of “minimal clinically important difference” (MCID), which refers to the smallest change in a measured outcome that a patient would deem as worthwhile and substantial enough to warrant a change in a patient's therapy. MCID boundaries were calculated as ± 0.5 times the standardized mean difference (SMD) of the meta-analyzed studies.

We calculated I² and a chi-square P-value to examine the degree and statistical significance of heterogeneity, respectively, in the meta-analyzed studies. A chi-square P-value of 0.05 or less suggests heterogeneous meta-analyzed studies [30]. When I² ranged from 0% to 40%, 30% to 60%, 50% to 90%, 75% to 100%, the degree of heterogeneity was judged insignificant, moderate, substantial, or considerable, respectively [30].

We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach to assess the overall quality of evidence resulting from meta-analyses [31].
approach appraises the quality of evidence based on 5 domains: risk of bias, inconsistency (i.e. heterogeneity), indirectness, imprecision, and publication bias [31]. The overall quality of meta-analyzed evidence was appraised separately by two reviewers, and any differences in decisions were addressed by discussion. The reviewers' interrater agreement was deemed perfect (Cohen κ=0.96) [28].

Results

Search Results

As shown in Figure 1, we identified 935 records by searching the 7 electronic databases. Of these records, we identified and removed 198 duplicates using the software EndNote. Screening titles and abstracts of the remaining 737 records led to excluding 649 citations because (i) they did not use serious games (n=319), (ii) anxiety level was not a measured outcome (n=98), (iii) they were not RCTs (n=186), (iv) they were not peer-reviewed articles, theses, or conference proceedings (n=29), and (v) they were published in languages other than English (n=17). Reading the full text of the remaining 88 publications led to excluding 59 publications for the following reasons: (i) the intervention did not use serious games (n=25), (ii) anxiety level was not a measured outcome (n=19), (iii) they were not RCTs (n=13), and (iv) they were published in a language other than English (n=2). We identified 4 additional RCTs through backward and forward reference list checking. In total, 33 RCTs were included in the current review [32-64]. Of those, 22 RCTs were included in meta-analyses [32-50, 53-55].
Characteristics of Included Reviews

The included studies were published between 2012 and 2021 (Table 1). The year that witnessed the largest number of included studies was 2017 (n=8) followed by 2020 (n=6) and 2021 (n=6). The included studies were conducted in 16 different countries as shown in Table 1. The country that published the largest number of the included studies was the United States of America (n=6). All included studies were published in peer-reviewed journals except one that was a thesis. The trial type used in the most included studies was parallel RCTs (n=31).

The sample size in the included studies ranged from 30 to 709 with an average of 112.8. The mean age of participants reported in 31 studies ranged between 6.6 and 84.2 years, with an average of 34.7 years. The percentage of males reported in 31 studies ranged from 0% to 100%, with an average of 43.2%. Participants’ health conditions were varied between studies, and anxiety was the most common (n=7). Participants in most studies were recruited from clinical settings (n=22).

Table 1: Characteristics of studies and population

| Study [Ref] | Year | Country | Publication type | RCT type | Sample size | Mean age (male) | Target group/condition | Setting |
|-------------|------|---------|-----------------|----------|-------------|------------------|------------------------|---------|
| Adomaviciene [32] | 2019 | Lithuania | Journal article | Parallel | 60 | 64.6 66.7% | Stroke | Clinical |
| Carvalho [33] | 2020 | Brazil | Journal article | Parallel | 35 | 51.3 0.0% | Fibromyalgia | Educational |
| Meldrum [34] | 2015 | Ireland | Journal article | Parallel | 71 | 54.1 38.0% | Unilateral peripheral vestibular loss | Clinical |
| Schumacher [35] | 2018 | Germany | Journal article | Parallel | 42 | 56.3 59.5% | Hematopoietic stem cell transplantation recipients | Clinical |
| Ruivo [36] | 2017 | Ireland | Journal article | Parallel | 32 | 59.9 81.3% | Cardiovascular diseases | Clinical, community, educational |
| Mazzoleni [37] | 2014 | Italy | Journal article | Parallel | 40 | 71.2 N/R | Chronic respiratory diseases | Clinical |
| Polat [38] | 2021 | Turkey | Journal article | Parallel | 40 | 44.8 0.0% | Fibromyalgia | Clinical |
| Lin [39] | 2020 | Taiwan | Journal article | Parallel | 80 | 57.0 48.8% | Knee osteoarthritis | Clinical |
| Vieira [40] | 2017 | Portugal | Journal article | Parallel | 46 | 57.7 N/R | Cardiovascular diseases | Clinical |
| Thomas [41] | 2017 | UK | Journal article | Parallel | 30 | 49.3 10.0% | Multiple sclerosis | Clinical |
| Wagener [42] | 2012 | USA | Journal article | Parallel | 41 | 14.0 33.3% | Obese adolescents | Clinical |
| Jahouh [43] | 2021 | Spain | Journal article | Parallel | 80 | 84.2 44.0% | Elderly | Clinical |
| Collado - Mateo [44] | 2017 | Spain | Journal article | Parallel | 83 | 52.5 0.0% | Fibromyalgia | Clinical |
| Cooney [45] | 2017 | Ireland | Journal article | Parallel | 52 | 40.6 38.8% | Anxiety, depression, and/or intellectual disability | Clinical |
| Donker [46] | 2019 | Netherlands | Journal article | Parallel | 193 | 41.3 33.2% | Acrophobia | Community |
| Fish [47] | 2014 | USA | Journal article | Parallel | 59 | 30.0 49.2% | Depression | Clinical, educational |
| Fleming [48] | 2012 | New Zealand | Journal article | Parallel | 130 | 32 44.0% | Depression | Educational |
| Merry [49] | 2012 | New Zealand | Journal article | Parallel | 187 | 15.6 34.2% | Depression | Clinical, educational |
| Perry [50] | 2017 | Australia | Journal Cluster | Cluster | 540 | 16.7 36.9% | Secondary students | Educational |

Figure 1: Flow chart of the study selection process.
Serious games alone were used as interventions in 28 of the included studies, whereas the remainder used serious games combined with other interventions (Table 2). The most common game used in the included studies was Nintendo’s Wii Fit (n=5) followed by MindLight (n=4). We identified 8 types of serious games based on the therapeutic modality that they deliver: exergames (n=13), computerized cognitive behavioral therapy (CBT) games (n=6), biofeedback games (n=5), attention distraction games (n=3), brain-training games (n=2), social skills training games (n=2), exposure therapy games (n=1), and psychoeducation games (n=1). In 20 studies, games were designed with a “serious” purpose from the beginning (designed serious games), however, in the remaining 13 studies, they were not designed as serious games from the start but rather were used for a serious purpose (purpose-shifted games). The most common platforms used for playing the games were computers (n=17) and video game consoles (n=8). The duration of the games in the included studies ranged between 5 and 150 minutes, but it was 60 minutes or less in most studies (n=28). The frequency of playing the games varied between only one time throughout the study and once a day, but it ranged between once a week and 3 times a week in 24 studies. The period of interventions ranged from one week to 24 weeks, but it ranged from 1 to 10 weeks in 25 studies.
### Table 2: Characteristics of interventions

| Study [Ref] | Intervention | Serious game name | Serious game type | Serious game genre | Platform | Duration (minute) | Frequency (time/week) | Period (week) |
|-------------|--------------|-------------------|-------------------|-------------------|----------|------------------|----------------------|--------------|
| Adomaviciene [32] | Serious game | N/R | Exergame | Designed | Computer, Kinect | 45 | Once a day | 2 |
| Carvalho [33] | Serious game | Wii Fit Plus | Exergame | Purpose-shifted | Wii console, balance board, Wii remote plus | 60 | 3 | 7 |
| Meldrum [34] | Serious game | Wii Fit Plus | Exergame | Purpose-shifted | Wii console, balance board, Frii Board | 15 | 5 | 6 |
| Schumacher [35] | Serious game | Wii Fit, Wii Sports | Exergame | Purpose-shifted | Wii console, balance board | 30 | 5 | 2 |
| Ruivo [36] | Serious game | Wii Sports | Exergame | Purpose-shifted | Wii console, Kinect | 60 | 2 | 6 |
| Mazzoleni [37] | Serious game + pulmonary rehabilitation program | Wii Fit Plus | Exergame | Purpose-shifted | Wii console, balance board, Wii remote plus | 60 | 7 | 3 |
| Polat [38] | Serious game + cycling activity | Kinect Sports (Beach Volleyball) | Exergame | Purpose-shifted | Computer, Kinect | 35 | 3 | 4 |
| Lin [39] | Serious game + hot packs + transcutaneous electrical nerve stimulation | Hot Plus | Exergame | Designed | Computer, sensing pad | 20 | 3 | 4 |
| Vieira [40] | Serious game | Kinect-RehabPlay | Exergame | Designed | Computer, Kinect | 70-85 | 3 | 24 |
| Thomas [41] | Serious game | Wii Fit Plus, Wii Sports, Wii Sports Resort | Exergame | Purpose-shifted | Wii console, balance board, Wii remote controls | 27 | 2 | 24 |
| Wagener [42] | Serious game | Dance Dance Revolution | Exergame | Purpose-shifted | Computer, sensing pad | 40-75 | 3 | 10 |
| Jahouh [43] | Serious game | Step, Nodding | Exergame | Purpose-shifted | Wii console | 40-45 | 2-3 | 8 |
| Designer | Serious game | Game title | Game type | Platform | Duration (min) | Frequency | Notes |
|----------|--------------|------------|-----------|----------|---------------|-----------|-------|
| Collado-Mateo [44] | Serious game | VirtualEx-FM | Exergame | Designed | Computer, Kinect | 60 | 2 | 8 |
| Cooney [45] | Serious game | Pesky Gnats: The Feel Good Island | CBT game | Designed | Computer | 60 | 1 | 7 |
| Donker [46] | Serious game | ZeroPhobia | CBT game | Designed | Smartphone, wearables (VR goggles) | 5-40 | 2 | 3 |
| Fish [47] | Serious game | Bejeweled II, Peggle, Bookworm Adventures | CBT game | Purpose-shifted | Computer | 30 | 3 | 4 |
| Fleming [48] | Serious game | SPARX | CBT game | Designed | Computer | 30 | 1-2 | 5 |
| Merry [49] | Serious game | SPARX | CBT game | Designed | Computer | 20-40 | 1-2 | 4-7 |
| Perry [50] | Serious game | SPARX-R | CBT game | Designed | Computer | 20-30 | 1-2 | 5-7 |
| Schoneveld [51] | Serious game | MindLight | Biofeedback game | Designed | Computer, wearables (EEG headset) | 60 | 1 | 6 |
| Tsui [52] | Serious game | MindLight | Biofeedback game | Designed | Computer | 60 | 2 | 3 |
| Schoneveld [53] | Serious game | MindLight | Biofeedback game | Designed | Computer, wearables (EEG headset) | 60 | 2 | 3 |
| Wijnhoven [54] | Serious game | MindLight | Biofeedback game | Designed | Computer, wearable (headset) | 60 | 1 | 6 |
| Scholten [55] | Serious game | Dojo | Biofeedback game | Designed | Computer | 60 | 2 | 3 |
| Marechal [56] | Serious game | N/R | Attention distraction game | Purpose-shifted | Tablet | 20 | One time throughout the study | N/A |
| Sakızci Uyar [57] | Serious game | Angry Birds, Subway Surfers, Snail Bob | Attention distraction game | Purpose-shifted | Tablet | 20 | One time throughout the study | N/A |
| Liu [58] | Serious game | SpaceBurgers | Attention distraction game | Designed | Wearables (VR goggles), hand-held | N/R | One time throughout | N/A |
| Study            | Game Type                  | Game Name     | Purpose Shifted | Controller                  | Times of Use (Tetris, EMDR) | Time per Session (min) |
|------------------|---------------------------|---------------|-----------------|-----------------------------|-----------------------------|------------------------|
| Butler [59]      | Serious game + eye movement desensitization and reprocessing (EMDR) therapy | Tetris        | Brain-training game | Purpose-shifted Nintendo DS XL console | 120-150                  | 6                      |
| Bove [60]        | Serious game              | Band Togather | Brain-training game | Designed                  | Tablet                      | 25                     |
| Sanchez [61]     | Serious game              | Adventures    | Social skills training game | Designed | Computer | 25 | 1 | 9 |
| Beidel [62]      | Serious game              | Pegasys-VR    | Social skills training game (Social effectiveness therapy game) | Designed | Tablet | 60-120 | 2 | 12 |
| Haberkamp [63]   | Serious game              | Spider App    | Exposure therapy game | Designed | Smartphone | 12 | 2 | 1 |
| Litvin [64]      | Serious game              | eQuoo         | Psychoeducation game | Designed | Smartphone, tablet 10-15 | 1 | 5 |

EEG: Electroencephalography; N/R: not reported; VR: Virtual reality
As shown in Table 3, the comparison groups received inactive interventions in 14 studies while they received active interventions in 21 studies (e.g., conventional exercises, CBT programs, video games, medication, and psychotherapy). Note that the numbers do not add up because 2 studies delivered both active and inactive interventions as comparators. The duration of the active comparators ranged between 10 and 180 minutes. The frequency of the active comparators varied between only one time throughout the study and once a day, but it ranged between once a week and 3 times a week in about half of the studies. The period of the active comparators varied between one week and 24 weeks. The outcome of interest (e.g., anxiety level) was measured using 15 different tools, but the most common tools used by the included studies were the Spence Children’s Anxiety Scale (SCAS) (n=8) and the Hospital Anxiety and Depression Scale (HADS) (n=7). The outcome of interest was measured immediately after the intervention in all included studies, and the most common follow-up period was 3 months (n=10). Participant attrition was reported in 32 studies and ranged from 0 to 335.

Table 3: Characteristics of comparators and outcomes

| Study [Ref] | Comparator | Duration (minute) | Frequency (time/week) | Period (week) | Outcome measures | Follow up | Attrition |
|-------------|------------|-------------------|-----------------------|---------------|------------------|-----------|-----------|
| Adomaviciene [32] | Robot-assisted trainings | 45 | Once a day | 2 | HADS | Post-intervention | 18 |
| Carvalho [33] | Conventional exercises | 60 | 3 | 7 | FIQ | Post-intervention | 14 |
| Meldrum [34] | Conventional exercises | 15 | 5 | 6 | HADS | Post-intervention | 9 |
| Schumacher [35] | Conventional exercises (Physiotherapy) | 30 | 5 | 2 | HADS | Post-intervention, 30 & 100-day follow-up | 11 |
| Ruivo [36] | Conventional exercises | 60 | 2 | 6 | HADS | Post-intervention, 2-month follow-up | 4 |
| Mazzoleni [37] | Conventional exercises (pulmonary rehabilitation programme) | 60 | 7 | 3 | STAI | Post-intervention | 1 |
| Polat [38] | Conventional exercises + cycling activity | 35 | 3 | 4 | HADS | Post-intervention, 1-month follow-up | 6 |
| Lin [39] | Conventional exercises + hot packs + transcutaneous electrical nerve stimulation | 20 | 3 | 4 | HADS | Mid of intervention, Post-intervention, 1 & 3-month follow-up | 1 |
| Vieira [40] | Conventional exercises, control | 70-85 | 3 | 24 | DASS-21 | Mid of intervention, Post-intervention | 13 |
| Thomas [41] | Control | N/A | N/A | N/A | HADS | Post-intervention | 2 |
| Wagener [42] | Control | N/A | N/A | N/A | BASC 2 | Post-intervention | 1 |
| Jahouh [43] | Control | N/A | N/A | N/A | GADS | Post-intervention | N/A |
| Collado - Mateo [44] | Control | N/A | N/A | N/A | FIQ | Post-intervention | 7 |
| Study | Intervention Type | Control | Length | Focus | Follow-up | Outcome | Authors |
|-------|-------------------|---------|--------|-------|-----------|---------|---------|
| Cooney [45] | Control | N/A | N/A | N/A | GAS-ID | Post-intervention, 3-month follow-up | 3 |
| Donker [46] | Control | N/A | N/A | N/A | BAI, AQ | Post-intervention, 3-month follow-up | 59 |
| Fish [47] | Educational website | 30 | 3 | 4 | STAI | Post-intervention | 0 |
| Fleming [48] | Control | N/A | N/A | N/A | SCAS | Post-intervention | 5 |
| Merry [49] | Control | N/A | N/A | N/A | SCAS | Post-intervention, 3-month follow-up | 17 |
| Perry [50] | Control (Interactive online program) | 20-30 | 1-2 | 5-7 | SCAS | Post-intervention, 6 & 18-month follow-up | 134 |
| Schoneveld [51] | Conventional CBT | 60-90 | 1 | 8 | SCAS | Post-intervention, 3 & 6-month follow-up | 36 |
| Tsui [52] | Conventional CBT (Online CBT) | 60 | 2 | 3 | SCAS, STAI | Post-intervention, 3-month follow-up | 19 |
| Schoneveld [53] | Video game | 60 | 2 | 3 | SCAS | Post-intervention, 3-month follow-up | 21 |
| Wijnhoven [54] | Video game | 60 | 1 | 6 | SCAS | Post-intervention, 3-month follow-up | 33 |
| Scholten [55] | Video game | 60 | 2 | 3 | SCAS | Post-intervention, 3-month follow-up | 9 |
| Marechal [56] | Midazolam | N/A | N/A | N/A | m-YPAS | Post-intervention, 2-hour follow-up | 3 |
| Sakızçı Uyar [57] | Midazolam, watching an informative cartoon | N/A | One time throughout the study | N/A | m-YPAS | Post-intervention | 4 |
| Liu [58] | Control (topical analgesia) | N/A | N/A | N/A | SUDS | Post-intervention | 0 |
| Butler [59] | EMDR therapy | 60-90 | 2 | 6 | STAI | Post-intervention, 6-month follow-up | 0 |
| Bove [60] | Video game | 25 | 5 | 6 | STAI | Post-intervention, 2-month follow-up | 4 |
| Sanchez [61] | Control | N/A | N/A | N/A | SASC-R | Post-intervention | 24 |
| Beidel [62] | Social effectiveness therapy | 60-180 | 2 | 12 | SCAI-C | Post-intervention | 4 |
| Haberkamp [63] | Video game | 12 | 2 | 1 | Survey developed by the authors | Mid of intervention, Post-intervention | 6 |
| Litvin [64] | Conventional CBT, control | 10 | 1 | 5 | Survey developed by the authors | Mid of intervention, Post-intervention | 355 |

AQ: Acrophobia Questionnaire; BAI: Beck Anxiety Inventory; BASC 2: Behaviour Assessment System for Children-2; CBT: Cognitive behavioral therapy; DASS-21: Depression, Anxiety and Stress Scale 21; EMDR: Eye movement desensitization and reprocessing; FIQ: Fibromyalgia Impact Questionnaire; GADS: Goldberg Anxiety and Depression Scale; GAS-ID: Glasgow Anxiety Scale for people with an Intellectual disability; HADS: Hospital Anxiety and Depression Scale; m-YPAS: Modified Yale Preoperative Anxiety Scale; N/A: Not applicable; N/R: Not reported; SASC-R: Social Anxiety Scale for Children-Revised; SCAS: Spence Children’s Anxiety Scale.
Results of Risk of Bias Appraisal

About 70% (n=23) of the included studies generated an appropriate random allocation sequence for the randomization process. The allocation sequence in 14 studies was concealed until participants were assigned to interventions. Groups were comparable at baseline in 29 studies. Based on these judgments, the risk of bias due to the randomization process was rated as low in 12 studies (Figure 2).

Participants and carers/people delivering the interventions were blinded to the assigned interventions during the trial in 4 and 5 studies, respectively. In 2 studies, there was a deviation from the intended intervention, which occurred due to the experimental contexts. An appropriate analysis (e.g., intention-to-treat or modified intention-to-treat analyses) was used in 26 studies to estimate the effect of the intervention. According to these judgments, the risk of bias due to the deviations from the intended interventions was low in 20 studies (Figure 2).

Only in 12 studies, missing outcome data was sufficiently small to make a significant difference to the estimated effect of the intervention. There was evidence that the findings were not biased by missing outcome data in only 7 studies. In 8 studies, the missing outcome data resulted from reasons that are documented and not related to the outcome. Accordingly, 27 studies were judged as having a low risk of bias in the “missing outcome data” domain.

Four studies assessed the outcome of interest (i.e., anxiety level) using inappropriate measures. Measurement methods were comparable across intervention groups in all included studies. The assessor of the outcome was aware of the assigned interventions in 20 studies. Given the outcome measure was subjective in all studies, assessment of the outcome could have been affected by knowledge of intervention received. Accordingly, only 9 studies were rated as low risk of bias in the “measuring the outcome” domain (Figure 2).

There was a pre-specified analysis plan (i.e., protocol) for 15 studies. Only three studies reported outcome measurements different from those specified in the analysis plan. In all studies, there is no evidence that they selected their results from many results produced from multiple eligible analyses of the data. Accordingly, the risk of bias due to the selection of the reported results was considered low in 15 studies (Figure 2).

In the last domain “overall bias”, the risk of bias was considered high in 21 studies as they were judged as having a high risk of bias in at least one domain. Ten studies were judged to raise some concerns in the domain of overall bias as they had some concerns in at least one of the domains and were not at high risk for any domain. The 2 remaining studies were judged to be at low risk of bias for the domain of overall bias given that it was rated to be at low risk of bias for all domains. Reviewers’ judgments about each ‘risk of bias’ domain for each included study are presented in Multimedia Appendix 4.

Figure 2: Review authors’ judgements about each ‘Risk of bias’ domain
Results of Studies

In this review, serious games were classified into 8 types based on the therapeutic modality that they deliver: exergames, computerized CBT games, biofeedback games, attention distraction games, brain-training games, social skills training games, exposure therapy games, and psychoeducation games. Results of the included studies were shown in the next subsections based on the types of serious games.

Exergames

Exergames are video games that entail physical exercises (e.g., fitness and balance exercises) as part of the intended game play. The intervention used exergames in 13 studies [32-44]. These studies compared exergames with conventional exercises and/or no intervention. The results of these comparisons were summarized in the next subsections.

Exergames versus conventional exercises

Nine studies compared the effect of exergames with conventional exercises on the level of anxiety [32-40]. While 7 studies did not find a statistically significant difference in anxiety level between the groups [34-40], the 2 remaining studies showed a statistically significant difference in the anxiety level between the groups (one of them favoring exergames over conventional exercises [33] while the other favoring conventional exercises over exergames [32]). Results of the 9 studies were meta-analyzed as shown in Figure 3. No statistically significant difference ($P=0.70$) in the anxiety level was found between the exergame group and conventional exercise group (SMD -0.07, 95% CI -0.45 to 0.30). The degree of heterogeneity of the evidence was substantial ($P=0.002; I^2 = 67\%$). The quality of the evidence was very low as it was downgraded by 6 levels due to a high risk of bias, heterogeneity, and imprecision (Multimedia Appendix 5).

Exergames versus no intervention

Five studies compared the effect of exergames to no intervention/inactive intervention on the anxiety level [40-44]. Whereas 4 studies did not find a statistically significant difference in anxiety level between the groups [40-43], the remaining study showed a statistically significant difference in the anxiety level between the groups, favoring exergames over no intervention [44]. A meta-analysis of the results of the 5 studies showed no statistically significant difference ($P=0.27$) in the anxiety level between the exergame group and no intervention group (SMD -
Computerized CBT games are video games that provide CBT for the users. Six studies compared the effect of computerized CBT games to no intervention on the anxiety level [45-50]. While 3 studies did not find a statistically significant difference in anxiety level between the groups [48-50], the 3 remaining studies showed a statistically significant difference in the anxiety level between the groups, favoring computerized CBT games over no intervention [45-47].

Results of these 6 studies were included in the meta-analysis. Three of these studies assessed the anxiety level using 2 different measures (AQ & BAI [46], STAI-State & STAI-Trait [47], and GAD & SA [50]). Therefore, we included the results of all these measures in the meta-analysis to form 9 comparisons (Figure 5). The meta-analysis showed a statistically significant difference in the anxiety level ($P=0.01$) between computerized CBT games and control groups, favoring computerized CBT games over no intervention (SMD -0.36, 95% CI -0.63 to -0.08). This difference was also clinically important as the overall effect was outside MCID boundaries (-0.18 to 0.18) and its CI neither crossed the ‘no effect’ line (Zero effect) nor any of the two MCID boundaries. For this outcome, MCID boundaries were calculated as ± 0.5 times the SMD value (-0.36). The statistical heterogeneity of the evidence was considerable ($P<0.001$, $I^2=84\%$). The quality of the evidence was very low as it was downgraded by 5 levels due to a high risk of bias, heterogeneity, and imprecision (Multimedia Appendix 5).

Biofeedback games

Biofeedback games are video games that utilize electrical sensors attached to the participant to receive information about the participant’s body state (e.g., electrocardiogram sensors) and seek to influence some of the player body’s functions (e.g., heart rate). Biofeedback games were used in interventions in 5 studies [54-58]. Two studies examined the effect of a biofeedback game (MindLight) and conventional CBT on anxiety level (measured by SCAS) among children with anxiety [51, 52]. Both studies found no statistically significant difference in the anxiety level between the biofeedback game group and the conventional CBT group [51, 52]. The 3 remaining studies examined the effect of biofeedback games and conventional video
Games on anxiety level (measured by SCAS) among children with anxiety [53-55]. While 2 studies did not find a statistically significant difference in anxiety level between the groups [54, 55], the remaining study showed a statistically significant difference in the anxiety level between the groups, favoring biofeedback games over conventional video games [53]. A meta-analysis of the results of these 3 studies demonstrated a statistically significant difference in the anxiety level ($P=0.03$) between the biofeedback game group and conventional CBT group, favoring biofeedback games over conventional video games (SMD -0.23, 95% CI -0.43 to -0.03). This difference was also clinically important as the overall effect was outside MCID boundaries (-0.115 to 0.115) and its CI neither crossed the ‘no effect’ line (Zero effect) nor any of the two MCID boundaries. For this outcome, MCID boundaries were calculated as ± 0.5 times the SMD value (-0.23). The heterogeneity of the evidence was judged as insignificant ($P=0.38$; $I^2=0\%$). The quality of the evidence was low as it was downgraded by 2 levels due to a high risk of bias and imprecision.

**Attention distraction games**

Attention distraction games are video games that are used to direct a user’s attention away from another focus or a given event. Distraction games were used as interventions in 3 studies. Attention distraction games were interventions in 3 studies [56-58]. While 2 studies found a statistically significant effect of the attention distraction games [57, 58], the remaining study did not [56]. Specifically, Marechal et al. [56] compared the effect of attention distraction games with medication (i.e., midazolam) on the anxiety level (measured by m-YPAS) among children undergoing general anesthesia for minor surgical procedures. No statistically significant difference ($P=0.99$) in the anxiety level was detected between the two groups [56]. The second study examined the effect of attention distraction games (Angry Birds, Subway Surfers, Snail Bob), medication (midazolam), and watching an informative cartoon on the anxiety level (measured by m-YPAS) among children undergoing adenoidectomy, adenotonsillectomy, and/or myringotomy [57]. The study showed a statistically significant difference ($P<0.001$) in the anxiety level between the groups, favoring the attention distraction games over medication (midazolam) and watching an informative cartoon. In the third study [58], the effect of an attention distraction game (SpaceBurgers) on the anxiety level (measured by SUDS) among children with otolaryngologic issues was compared to topical analgesia. The study found a statistically significant difference ($P<0.001$) in the anxiety level between the groups; favoring the attention distraction games over topical analgesia [58].

**Brain-training games**

Brain-training games are video games that aim to maintain or improve user's cognitive abilities such as working memory, executive function, processing speed, and attention. Brain-training games were interventions in 2 studies [59, 60]. The first study compared the effect of a brain-training game (Tetris) to eye movement desensitization and reprocessing (EMDR) therapy on the level of trait anxiety (measured by STAI) among patients with posttraumatic stress disorder [59]. The study did not detect any statistically significant difference ($P=0.81$) in the level of trait anxiety post-intervention [59]. The second study compared the effects of a brain-training game (Band Together) and traditional video games on the level of anxiety (measured by STAI) among patients with multiple sclerosis [60]. No statistically significant difference in the level of state anxiety ($P=0.95$) and trait anxiety ($P=0.75$) between the two groups was detected.

**Social skills training games**

Social skills training games were an intervention in 2 studies [61, 62]. The first study
investigated the effect of a social skills training game (Adventures) on the anxiety level (measured by SASC-R) among patients with social skills deficits in comparison with no intervention. The study showed no statistically significant difference ($P=0.104$) in the anxiety level between the groups. In the second study, the effect of a social skills training game (Pegasys-VR) and social effectiveness therapy on the anxiety level (measured by SPAI-C) among children with social anxiety was examined. The study demonstrated no statistically significant difference ($P=0.23$) in the anxiety level between the groups.

**Other types of serious games**

One study compared the effect of an exposure therapy game (Spider App) to an entertainment video game (Bubble Shooter) on the anxiety level among patients with arachnophobia [63]. No statistically significant difference in the anxiety level was detected between the groups post-intervention [63]. Litvin et al. [64] examined the effect of a psychoeducation game (eQuoo), conventional CBT, and no intervention on the anxiety level among healthy employees. The study did not find any statistically significant difference ($P=0.95$) in the anxiety level between the three groups [64].

**Discussion**

**Principal Findings**

This review examined the effectiveness of serious games on the anxiety level as reported by RCTs. Of the 33 RCTs included in the current review, 20 studies were included in 4 meta-analyses. While the review found no statistically significant effect of exergames on the anxiety level, it showed a statistically significant effect of computerized CBT games and biofeedback games on the anxiety levels. Due to the evidence paucity, no statistical analysis was carried out for other types of serious games included in this review.

Very low quality evidence from 9 RCTs showed no statistically significant effect of exergames on the anxiety level as compared to conventional exercises. This insignificant effect can be attributed to the fact that exergames are comparable to conventional exercises, thereby, it should not be surprising that comparing the effect of 2 very similar interventions did not produce a significant difference. This indicates that conventional exercises are at least as effective as conventional exercises. Our finding is similar to those of previous reviews [20, 65]. Specifically, a meta-analysis of 5 RCTs showed no statistically significant difference ($P=0.805$) in anxiety levels between the exergames group and the usual care group (i.e., conventional exercises) [20]. Likewise, no statistically significant difference ($P=0.12$) in depression levels between the exergames group and conventional exercises was found in another meta-analysis of 7 RCTs [65]. Comparing the effects of exergames on the anxiety level as opposed to no intervention, very low quality evidence from 5 RCTs showed no statistically significant effect. This finding is consistent with a previous review [20]. Specifically, a meta-analysis of 5 studies (3 RCTs and 2 quasi-experiments) showed no statistically significant difference ($P=0.939$) in anxiety level between the exergames group and the control group. In contrast, exergames do have a statistically and clinically significant effect on depression levels when compared to no intervention according to a meta-analysis of 8 studies [65]. The insignificant effect of exergames in the current review can be attributed to 2 reasons: (i) the exergames used in 3 of the 5 meta-analyzed studies were not designed specifically to alleviate anxiety, and (ii) participants in the 5 RCTs did not suffer from anxiety at baseline, thereby, the effect of serious games could not have been substantial.

Very low quality evidence from 6 RCTs demonstrated a statistically and clinically significant effect of computerized CBT games on the anxiety level when compared with no intervention.
However, this finding may not be generalizable to elderly people as participants in the 6 studies were younger than 41.3 years. To the best of our knowledge, no previous reviews examined the effect of computerized CBT games on anxiety although many reviews assessed the effect of computerized CBT in general (i.e., games are not part of the intervention) [66-69]. However, our findings are in line with a previous review focusing on depression, which found a statistically and clinically significant effect of computerized CBT games on the depression level according to a meta-analysis of 6 RCTs.

Low quality evidence from 3 RCTs showed a statistically and clinically significant effect of biofeedback games on the anxiety level when compared with conventional video games. It is worth mentioning that the studies used biofeedback games specifically for alleviating anxiety and recruited participants with anxiety. The generalizability of this finding may be limited due to the following reasons: (i) participants in the 3 studies were adolescents (10-13.3 years), (ii) all studies were conducted in the Netherlands, and (iii) there is a low number of studies included in the meta-analysis.

Meta-analyses were not conducted to assess the effect of other types of serious games due to the low number of studies. Individual studies found no statistically significant effect of brain-training games, social skills training games, exposure therapy games, and psychoeducation games on the anxiety level. However, other studies showed contradicting results regarding the effect of attention distraction games on the anxiety level.

**Strengths and Limitations**

**Strengths**

The current review can be considered more comprehensive than the two previous reviews [20, 21] because it was not restricted to a certain type of serious games, age group, or comparator, and it searched the main databases in health and information technology fields. This review was conducted according to highly recommended guidelines (i.e., PRISMA) and included only RCTs. Therefore, it can be considered a robust and high-quality review.

The risk of publication bias is not a concern in this review because we sought to retrieve as many relevant studies as possible through searching the most popular databases in information technology and health fields and grey literature databases, conducting backward and forward reference list checking, using a comprehensive search query, and not restricting our search to a certain country, year, setting, population, and comparator.

There is no concern about the risk of selection bias in this review given that two reviewers independently performed the study selection, data extraction, risk of bias assessment, and quality of evidence evaluation with a perfect interrater agreement for all processes. The quality of the evidence was appraised using the GRADE approach to enable the reader to draw more accurate conclusions. When possible, we synthesized data statistically, and this improved the power of studies and increased the estimates of the likely size of the effect of serious games on anxiety.

**Limitations**

This review excluded studies that used serious games delivered on non-digital platforms and those used for other purposes (e.g., screening or diagnosis). Therefore, this review cannot comment on the effectiveness of these types of serious games. This review focused on the effectiveness of serious games on anxiety only, thus, we cannot comment on the effectiveness of serious games on other diseases.

Numerous studies were excluded as they were quasi-experiments and/or written in non-English languages. Therefore, it is likely that we missed some relevant studies. We excluded these studies...
as quasi-experiments have lower internal validity than RCTs [70] and, owing to practical constraints, it was not possible to translate all non-English studies. Participants in most studies did not have anxiety before the intervention, thereby, the effect of serious games could not be significant.

This review meta-analyzed post-intervention data rather than follow-up data, thus, this review cannot comment on the long-term effect of serious games on anxiety. Postintervention outcome data was selected given that about half of the included studies did not follow up participants to measure the outcome data, and the follow-up period in the other half of the studies was not consistent between studies.

We used postintervention data for each group to assess the effect size for each meta-analyzed study rather than the pre-post intervention change for each group, thereby, it is likely that the effect size is overestimated or underestimated. We used postintervention outcome data because the majority of studies did not report the standard deviation for pre-postintervention change for each group, and preintervention outcome data was significantly different between groups in only two studies [40, 41].

Research and Practical Implications

Research Implications

While anxiety was one of the measured outcomes in all the included studies, only 6 studies targeted the recruitment of people suffering from anxiety. This may lead to a severe underestimation of the effect of serious games on anxiety levels. This finding is shared with a similar study investigating the effects of depression [65]. Likewise, we second the recommendation to purposefully recruit participants who suffer from anxiety and establish a baseline to objectively assess how effective are serious games in reducing anxiety levels.

We would like to point out that several studies recruited very small samples, with a minimum of only 30 patients. Gaining statistically reliable insights from such small samples can be difficult and may be an additional reason that our meta-analyses provide no conclusive answer to the question if serious games can improve or augment traditionally anxiety treatment. Thus, we encourage researchers to recruit a sample size that is enough to achieve a power of at least 80%. The majority of the included studies were conducted in clinical settings. While this could offer a controlled environment to run the studies, it could also introduce stress to the participants due to the nature of clinical settings. Conducting more studies in the community and educational settings could present different findings as people usually play games outside of the traditional clinical setting.

The current literature focused mainly on exergames and computerized CBT games while the effect of other types of serious games was investigated by no or a few studies. There are opportunities to enrich the body of evidence about the effectiveness of serious games delivered through other therapeutic modalities such as psychoeducation games, biofeedback games, exposure therapy games, and brain-training games.

Although serious games can be used for several purposes and for many diseases, we focused on serious games that were used for therapeutic or prevention purposes and for anxiety only. Researchers should conduct systematic reviews to assess the effectiveness of serious games used for other purposes (e.g., monitoring, screening, and diagnosing) and for other diseases.

In only 2 studies, the overall risk of bias was low given that most studies had issues in the randomization process, measurement of the outcome, and selection of the reported result. Outcome data was missing in several studies, thereby, they were not included in the meta-analyses. Accordingly, researchers should avoid the above-mentioned biases by conducting and
reporting RCTs according to recommended guidelines or tools (e.g., RoB 2 [29]).
Lastly, the majority of the include studies were conducted in developed countries, which, in turn, can limit the generalizability of our findings to developing nations. There is a need to conduct more studies in developing countries, especially given the varying nature of their cultures, socioeconomic conditions, and sources of stress and anxiety (e.g., war zones). Further, more studies are needed to determine any variance in the effectiveness of serious games that are designed specifically to reduce and alleviate anxiety levels intergenerationally.

**Practical Implications**

This review showed that exergames are as effective as conventional exercises in alleviating anxiety, and computerized CBT games and biofeedback games are more effective than no intervention and conventional video games, respectively. However, health professionals and decision makers should be careful when interpreting these findings for the following reasons: the quality of meta-analyzed evidence ranged from very low to low, the overall risk of bias was high in most included studies, the heterogeneity of the evidence was high in the 3 meta-analyses, participants in most studies did not have anxiety, and many studies did not use serious games that designed to specifically alleviate anxiety. Accordingly, psychologists and psychiatrists should consider offering serious games as complementary and not a substitute to existing interventions until further, more robust, evidence is available.

Although anxiety can be alleviated by many non-pharmaceutical interventions, there are no or few serious games that deliver non-pharmaceutical interventions other than exercises and CBT in this review. This may be attributed to the lack of such serious games in real life. Therefore, developers should consider developing serious games that deliver non-pharmaceutical interventions such as breathing techniques, mindfulness training, problem-solving, attention distraction, biofeedback, psychoeducation, relaxation-based exercises, rational emotive behavioral therapy.

Only a handful (n=7) of studies used mobile devices (smartphones and tablets) as the platform for their intervention. Mobile devices are particularly appealing since they are cheaper than computers and more pervasive than gaming consoles. As a direct implication of their mobility, people generally tend to carry these devices with them, irrespective of their anxiety levels. Moreover, mobile devices are more accessible than computers and gaming consoles; it is estimated that there are about 15 billion mobile devices and more than 7.1 mobile users worldwide in 2021 [71]. This could present a lucrative opportunity for app and game developers to develop serious games that target anxiety and can be played via mobile devices.

Few studies were conducted out in developing countries, and this may be attributed to the lack of serious games in these countries. Given that there is a greater shortage of mental health professionals in developing countries than in developed countries (0.1 per 1,000,000 people [72] vs. 90 per 1,000,000 people [73]), it is likely that individuals in developing countries are more in need of serious games than those in developed countries. Therefore, more serious games should be developed to alleviate anxiety among people in developing countries.

We would like to point out that a significant portion of the studies (n=12) investigated intervention methods using now-discontinued platforms: Wii (n=8, end of life in 2017), Kinect (n=5, end of life in 2017), Nintendo DS (n=1, end of life in 2014). Only in one case using Tetris [52], other platforms will readily fill the gap. For interventions using Microsoft’s Kinect sensor, computer-vision based pose estimation on mobile phones or desktop PCs could fill the gap but will result in a different setup. Finally, some of the included studies using WiiMotes (Wii Remote) and none of the more specialized Wii input devices could be recreated using newer Nintendo controllers. These considerations raise a few questions of practical importance: (1)
How well can studies relying on legacy, specialized hardware be reproduced? (2) How useful are interventions relying on platforms designed to undergo comparatively short life cycles? (3) Are off-the-shelf video games (purpose-shifted games) adequate intervention tools?
We believe that some of the included studies relying on legacy hardware could probably be salvaged, following the comments outlined above, but caution should be taken to fall victim to the novelty effect of emerging game controllers and proprietary input devices. The video game industry evolves quickly and is known to experiment with novel technology to attract games away from competitors. Consequently, purpose-shifted games are not only very prone to deprecate quickly, but the very same is true for the platforms they were designed for. Of particular concern in this context are studies that rely on platforms or devices that are already past their life cycle (n=7) since such findings run the risk of being purely academic in nature.
In addition, while we cannot rule out that off-the-shelf games that have undergone, first, a purpose-shift to become a serious game and yet another one to become part of a therapy (e.g., Tetris) have a measurable effect, we also have little reason to assume that they do. It seems tempting to explain the effects of serious games on anxiety by their distractive nature, but studies do not agree on this question either.
There is also an utter need for an inclusive approach when developing these apps and games to include professionals from the gaming industry as well as mental health experts. Technologists and developers are usually very aware of the afore-raised concerns but need medical professionals to avoid falling prey to the temptation of purpose-shifting existing games or designing games for goals different than anxiety relief.

Conclusion
Evidence from this study suggests that serious games have the potential in reducing anxiety levels. However, definitive conclusions regarding the effectiveness of serious games on reducing anxiety remain inconclusive mainly due to the high risk of bias in the individual studies included, the low quality of meta-analyzed evidence, low number of studies included in some meta-analyses, participants without anxiety in most studies, and using purpose-shifted serious games in most studies. Until further, more robust, evidence is available, serious games should be deemed as complementary to existing interventions and not and a substitute to them. To have adequate and robust evidence, researchers should use serious games that are designed specifically to alleviate depression and deliver other therapeutic modalities, recruit patients with anxiety, and minimize the risk of bias by recommended guidelines for conducting and reporting RCTs (e.g., RoB 2).

Conflicts of Interest
None declared

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Abbreviations
AA: Alaa Abd-Alrazaq
AQ: Acrophobia Questionnaire

https://preprints.jmir.org/preprint/29137 [unpublished, non-peer-reviewed preprint]
BAI: Beck Anxiety Inventory
CBT: Cognitive behavioral therapy
DASS-21: Depression, Anxiety and Stress Scale 21
EEG: Electroencephalography
EMDR: Eye movement desensitization and reprocessing
FIQ: Fibromyalgia Impact Questionnaire
GADS: Goldberg Anxiety and Depression Scale
GAS-ID: Glasgow Anxiety Scale for people with an Intellectual disability
GRADE: Grading of Recommendations Assessment, Development and Evaluation
HADS: Hospital Anxiety and Depression Scale
m-YPAS: Modified Yale Preoperative Anxiety Scale
MA: Mohannad Alajlani
MCID: Minimal clinically important difference
N/A: Not applicable
N/R: Not reported
\( P \): P-value
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: Randomized Controlled Trial
RoB 2: Risk-of-Bias 2
SASC-R: Social Anxiety Scale for Children-Revised
SCAS: Spence Children's Anxiety Scale
SMD: Standardized Mean Difference
STAI: State-Trait Anxiety Inventory
SUDS: Subjective Units of Distress
UK: United Kingdom
USA: United States of America

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Supplementary Files
Figures
Flow chart of the study selection process.
Review authors’ judgments about each ‘Risk of bias’ domain.
Forest plot of 9 studies comparing the effect of exergames to conventional exercises on the anxiety level.
Forest plot of 5 studies comparing the effect of exergames to no intervention on the anxiety level.
Forest plot of 6 studies (9 comparisons) comparing the effect of CBT games to no intervention on the severity of depressive symptoms.
Forest plot of 3 studies comparing the effect of biofeedback games to conventional video games on the anxiety level.
Multimedia Appendixes
PRISMA checklist.
URL: http://asset.jmir.pub/assets/04cbca3179ec2a21513d984589582f26.docx

Search strategy.
URL: http://asset.jmir.pub/assets/9a4feba19e2c54e8b884cb90ec157162.docx

Data extraction form.
URL: http://asset.jmir.pub/assets/a56098f1c52e9a27067cf62117d4092b.docx

Reviewers’ judgments about each “risk of bias” domain for each included study.
URL: http://asset.jmir.pub/assets/ccdf21297ab8c8104ebf6b70f2b5eca6.docx

GRADE Profile for comparison of Serious games to control or conventional exercises for Anxiety.
URL: http://asset.jmir.pub/assets/ed988bc81df8f9b23236adb80ad573dc.docx