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Review

# A review of current advances in the transformative effects of physical exercise on the psychological wellbeing of those suffering from anxiety disorders

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**Abstract: Background:** Anxiety is characterized by excessive worry, fear, or apprehension, often leading to significant impairments in daily functioning, including difficulties maintaining physical health and psychological well-being (PWB). There is a lack of conclusive research regarding the efficacy of physical exercise (PE) as a treatment for anxiety in primary care settings, as well as uncertainty about the specific degree of activity required to produce therapeutic benefits. The goal of this systematic review is to investigate the effects of PE on the PWB of people suffering from anxiety disorders (AD), as well as to compare the benefits of different PE regimens. **Method:** A systematic literature search was carried out utilizing seven databases (PUBMED, PsycINFO, Science Direct Engine, Semantic Scholar, Google Scholar, Online Library, and other sources such as periodicals). Inclusion and exclusion criteria were based on the PICOS framework, and the risk of bias (ROB) was utilized to assess the quality of eligible research. **Result:** Aerobic exercise (AE) is the most effective PE modality in reducing anxiety symptoms, while the benefits of resistance exercise (RE) are also notable. Moreover, research suggests that moderate intensity PE (MI-PE) tends to yield superior results over other PE regimens in managing anxiety symptoms. These findings underscore the importance of PE intensity in achieving therapeutic benefits for anxiety management. PE is acknowledged as an effective intervention for lowering anxiety symptoms, making it an attractive therapeutic choice for those with AD. **Conclusion:** PE is a safe, efficient, and effective therapeutic method for treating anxiety symptoms. However, the majority of published studies contain substantial methodological flaws, necessitating additional research to determine the suitable PE modalities, frequency, duration, and intensity for maximizing the therapeutic effects of PE on AD.

**Keywords:** anxiety disorder; mental health; psychological well-being; physical exercise

## 1. Introduction

Anxiety and its accompanying illnesses are major phenomena in the field of psychiatric problems (Steel et al., 2014). Anxiety disorders (AD) such as panic disorder (PD), specific phobias (SP), and generalized anxiety disorder (GAD) have a lifetime prevalence of 12.9% (Steel et al., 2014). The effect of anxiety and associated disorders on lifespan adjusted for disability varies with age (Vos et al., 2020). This burden is increased by the presence of co-morbid chronic physical health conditions such as obesity (Batelaan et al., 2016), metabolic syndrome (Rosenbaum et al., 2015), diabetes, arthritis, and back pain (El-Gabalawy et al., 2011; Firth et al., 2019). Antidepressants, cognitive-behavioral therapy (CBT), or a combination of the two are

commonly used as primary treatments for AD and associated illnesses (Craske and Stein, 2016). Despite advances in treatment modalities, a large proportion of people do not achieve complete remission using traditional methods (Craske and Stein, 2016). Furthermore, due to the stigma associated with psychotherapy and medication, as well as the high expenses connected with these treatments, a significant majority of individuals with these diseases do not seek treatment (Clement et al., 2015; Gulliver et al., 2010; Harvey and Gumport, 2015; Mojtabai, 201l). Those with higher severity levels face additional difficulties in obtaining therapy (Goetter et al., 2020; Velasco et al., 2020).

Recently, there has been a focus on investigating the potential of lifestyle therapies, notably physical exercise (PE), in treating mental disorders (Firth et al., 2020). Physical activity (PA), sometimes known as exercise, requires energy expenditure and has health benefits (Biddle and Mutrie, 2008). Regular PE has been shown to improve both general health and physical fitness (Acil et al., 2008). PE has been shown in studies to reduce the signs and symptoms of GAD, post-traumatic stress disorder (PTSD), trait anxiety, depressive symptoms, tension, and exhaustion (Ashdown-Franks et al., 2019; Tull et al., 2018).

Globally, over 150 million individuals grapple with mental illness (Kenari, 2014). Regular PE has been shown to be effective in reducing symptoms of anxiety and depression (Herring et al., 2016; Wu et al., 2022). Current research shows that PE reduces anxiety, tension, and stress in a variety of settings (Herring et al., 2011; Salmon, 2001), and consistent PE has been found to lower anxiety symptoms and enhance psychological well-being (PWB) by relieving tension and stress (Anderson and Shivakumar, 2013; Firth et al., 2020). Furthermore, low intensity PE (LI-PE) levels are associated with increased anxiety, whereas moderate to high-intensity PE (MHI-PE) significantly lowers anxiety symptoms and improves general well-being (Newman and Motta, 2007). A meta-analysis of prospective cohort studies found that those who engage in high-intensity PE (HI-PE) have a decreased chance of acquiring anxiety symptoms (Schuch et al., 2019).

The impact of PE on AD, especially the differential effects of short- and long-term PE on anxiety symptoms in both healthy and clinical populations, is still a relatively unexplored area of research. While accumulating data suggests that PE might alleviate anxiety symptoms (Anderson and Shivakumar, 2013; Stubbs et al., 2017), knowing the specific mechanisms, optimal forms, intensities, and durations of PE is still limited (Asmundson et al., 2013; Craft and Landers, 1998). Barbour et al. (2007) identified this research gap and encouraged future research efforts to address these issues. Although previous studies have shown that PE can reduce anxiety, they have also highlighted the need for more research into ideal PE parameters (Herring et al., 2011; Jayakody et al., 2014). In addition, meta-analyses have consistently demonstrated the anxiolytic effects of PE, stressing the significance of investigating the underlying biological and psychological mechanisms (Conn, 2010; Mahindru et al., 2023; Wipfli et al., 2008). Further research is needed to better understand these connections and create evidence-based PE interventions for AD.

Prior research has shown the importance of PE intensity in the management and treatment of mental health (MH) issues. Broman-Fulks and colleagues conducted a study in which 54 students (13 male, 41 female) with high anxiety sensitivity

participated in 20-minute treadmill PE sessions that were repeated 2–4 times per week for a total of six PE sessions over two weeks at either HI-PE ($n$ = 29) or LI- PE ($n$ = 25) levels. The results showed that both HI-PE- and LI- PE successfully reduced anxiety sensitivity. Notably, HI-PE resulted in a faster drop in the global measure of anxiety sensitivity (GMAS) and a more dramatic treatment response when compared to LI-PE (Broman-Fulks et al., 2004). Likewise, LI-PE to moderate-intensity PE (MI-PE) has been recognized as a way to reduce anxiety, improve mood, and act as a stress buffer (Tsatsoulis and Fountoulakis, 2006). PE is important in reducing symptoms of anxiety, tension, and stress in a variety of contexts as well as improving mood and quality of life (Mahindru et al., 2023). It increases the production of neurotransmitters such as serotonin and dopamine, which serve to improve mood and reduce anxiety (Pahlavani, 2023; Ren and Xiao, 2023), as well as endorphins, which promote well-being and reduce anxiety perception (Boecker et al., 2008; Morgan, 1985). It also regulates the hypothalamic-pituitary-adrenal (HPA) axis, which reduces cortisol levels, enhances mood, and helps to manage stress (Sharma and Petty, 2006; Tsatsoulis and Fountoulakis, 2006). PE increases self-efficacy by giving people the confidence to effectively control their anxiety symptoms (DeBoer et al., 2012; McAuley et al., 2011). It also serves as a cognitive diversion, moving attention away from anxious thoughts (Anderson and Shivakumar, 2013). This shift helps to mitigate the effects of anxiety by engaging the mind in PE, which reduces the frequency and intensity of anxious feelings (Biddle and Mutrie, 2008; Herring et al., 2010).

The current review aims to evaluate the utility of PE in anxiety management, with the goal of offering insights for broader integration of PE as a treatment modality for patients commonly encountered in primary care settings. Through the implementation of rigorous inclusion criteria, the objectives of this review are: (1) to exclusively focus on randomized controlled trials (RCTs) for a comprehensive examination of PE effects on anxiety symptoms in individuals diagnosed with AD compared to standard treatments; (2) to conduct an analysis of outcomes from studies comparing various PE intensities (low, moderate, severe). This comprehensive review, which used novel selection criteria, has the potential to make significant and novel contributions to existing scientific knowledge about the impact of PE on anxiety symptoms, as well as the physical and MH of patients suffering from AD.

## 2. Methods

The systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring methodological rigor and a thorough analysis of the relevant literature (Ziebart et al., 2022). The use of the 27-point PRISMA criteria aided in the complete evaluation of systematic review papers (Page et al., 2021). The major goal of this study is to examine progress in the transforming effects of PE on the PWB of patients suffering from AD. While previous assessments have looked at the overall physical, psychological, and social impacts of PA, there has been little consideration paid to the specific focus on PWB and PE intensity. This particular study sought to assess the impact of PE on PWB, with the reviewer closely adhering to criteria and considering only papers that expressly stated PE intensity. In total, 11 studies with a total of 723 participants were included in the

analysis.

## 2.1. Studies consideration criteria for review

We identified RCTs with single- and double-blind techniques that matched our inclusion criteria. Cross-sectional studies, conference presentations, posters, and non-RCT were all excluded. Our research focused on trials with diagnosed AD patients who utilized PE as an additional treatment, with the major outcome being the measurement of PWB and the characterization of PE intensity.

**Participants**

a) Individuals diagnosed with AD using the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, DSM-IV-TR, and DSM-V).

b) To assess the patient population holistically, we examined all studies encompassing both inpatient (hospitalized) and outpatient (follow-up and OPD) settings.

## 2.2. Types of interventions

1) Aerobic exercise (AE)

AE, also referred to as cardio, is a type of PE distinguished by changing intensity levels ranging from low to high and relying mostly on the aerobic energy-generation process. This PE method has potential therapeutic benefits for those with anxiety problems, as research reveals that regular AE can greatly improve PWB, making it an effective option for dealing with anxiety-related issues.

2) Resistance exercise (RE)

RE, often known as strength training, consists of activities such as weightlifting, leg presses, curls, extensions, planks, sit-ups, push-ups, and elastic band PE. Integrating RE into AD treatments can improve PWB by promoting physical wellbeing and resilience through structured PE routines.

3) Mix exercises (ME)

Studies using combined PE therapies, such as circuit training, cardiorespiratory PE, and RE, are to determine how different PE modalities affect the PWB outcomes of patients with AD.

## 2.3. Search strategy

The data evaluation procedure began in September 2023 with two reviewers and ended in February 2024. A systematic review was carried out using several databases, including PUBMED, PsycINFO, Google Scholar, Science Direct, Semantic Engine, and Online Library. The review followed Stern et al.'s (2014) PICOS (Population, Intervention, Comparison, Outcome, Study Design) approach. The search strategy for this study encompassed four main categories: 1. Targeted population: "Anxiety Disorder" OR "Generalized Anxiety Disorder" OR "Panic Disorder" OR "Social Anxiety Disorder" OR "Phobia" OR "Posttraumatic Stress Disorder" OR "Obsessive Compulsive Disorder". 2. Intervention design: "Physical Exercise" OR "Physical Activity" OR "Aerobic Exercise" OR "Resistance Training" OR "Exercise Intensity" OR "Low level of Physical Exercise" OR "Moderate level of Physical Exercise" OR "Moderate to Vigorous level of Physical Exercise" OR "High level of Physical

Exercise". 3. Study design: "Randomized Controlled Trail" OR "Clinical Trails". 4. Outcomes: "Psychological Wellbeing" OR "Mental Health" OR "Emotional Health" OR "Psychological Health".

**Searching for other resources**

Furthermore, to ensure that the electronic search was thorough, the reference lists of retrieved articles were reviewed to identify any possibly relevant research that may have been missed.

## 2.4. Selection procedure and eligibility criteria

The major eligibility requirement is the screening of research proving the effect of PE on PWB in patients suffering from anxiety; second, the selection criteria was limited to studies that clearly stated the PE intensity. The articles written in English were selected for consideration. Two independent experts carried out an electronic search on the databases. After completing their own searches, they evaluated the results together, looking at the titles, abstracts, methodology, and full texts of the selected papers. During the review process, all disagreements and conflicts among reviewers were resolved systematically through structured discussions. Established conflict resolution strategies, such as active listening, respectful discourse, and applying predetermined evaluation criteria, were implemented. There were no major inconsistencies recorded, as all arguments were effectively resolved.

**Inclusion and exclusion criteria**

Eligibility criteria for included studies were as follows: (1) Only RCTs were included. (2) Studies were necessary to assess PWB as an outcome. (3) Participants are required to be diagnosed with anxiety using criteria from the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, DSM-IV-TR). (4) PE used as an additional therapy (5) measure the effects of PE intensity in their intervention; (6) findings in PWB had to be quantified. (7) The literature search was limited to studies published before 2011. The following exclusion criteria were applied: (1) case studies, (2) short reports, (3) letters, (4) conference proceedings, (5) studies involving uncontrolled or mixed populations, and (6) animal studies were excluded.

## 2.5. Data extraction

Understanding was achieved using the data extraction technique described in the Cochrane Handbook for systematic reviews of interventions (Higgins et al., 2022). Two evaluators independently assessed the data from the included studies, and any inconsistencies were resolved through discussion. For data extraction, we adhered to the following steps for detailed evaluation and screening: (1) Duplicate records were removed from the overall dataset to ensure accuracy. (2) Reviewed study titles and abstracts to determine the impact of PE on PWB of anxiety sufferers. (3) Thoroughly reviewed the selected studies to ensure that their objectives were closely aligned with the aims of our review article. (4) Studies that focused on various types of PE interventions and explicitly mentioned PE intensity were included. (5) Findings focused on the validated scale results utilized by the selected studies to evaluate the effects of PE interventions on PWB outcomes. By following these steps, the shortlisted papers were selected for synthesis analysis.

### 2.6. Quality assessment

Two independent reviewers assessed the RCTs included in the study for risk of bias (ROB) assessment by using the Cochrane ROB tool (Higgins et al., 2011). This tool measures seven domains: (1) random sequence generation, (2) allocation concealment, (3) blinding of participants and personnel, (4) blinding of outcome assessment, (5) incomplete outcome data, (6) selective reporting, and (7) other bias. Each study was assessed based on predetermined criteria within these domains to determine whether the risk of bias was "low," "unclear," or "high". We categorized the assessment of ROB per study as Low ROB (if low ROB was judged for all seven domains); Unclear ROB (if unclear ROB was scored for one or more of the seven domains); or High ROB (if high ROB was judged for one or more of the seven domains) (Higgins et al., 2011).

### 2.7. Data synthesis

Following a thorough review of the literature, it became clear that important data is extremely rare. While many papers discuss the benefits of PE for AD, there is a noticeable lack of articles that particularly address PE intensity. The major goal of this study was to determine the impact of PE on PWB in AD. The reviewers purposefully chose trials with carefully defined PE intensity to determine which degrees of PE intensity have a greater impact on those with AD. This systematic review includes RCTs looking at the effects of PE, different types of PE, and a comparison of various PE regimens.

## 3. Results

The main goal of this study is to investigate the effect of PE on PWB in AD. AE has been shown to reduce anxiety, obsessive behavior, tiredness, vigor, tension, sadness, stress-related physical symptoms, and boost positive mood and PWB. RE appears to reduce anxiety, pain intensity, tension, and irritability while also improving sleep quality, whereas ME appears to reduce anxiety and depressive symptoms. When PE intensities are compared, MI-PE is found to be the most useful in terms of producing the most impact on curing AD symptoms.

### 3.1. Study selection

A computerized database search across six databases initially found 532 articles. After removing 57 duplicates, 475 publications remained. After screening the titles and abstracts, 397 items were excluded, leaving 78 articles. A further review based on inclusion criteria resulted in the removal of an additional 37 articles following a five-step process.1) Eight studies were unrelated to the current review topic. 2) Nine studies that did not include the target population, 3) Twelve studies that did not conform to the specified study designs; 4) Five studies with non-original data sources; 5) Three studies that did not present original research. Out of the 41 remaining articles, 30 articles were further excluded after full-text screening. This reduction was generally completed by applying the following seven inclusion criteria steps: (1) Four study designs were other than RCT; (2) Two studies published before 2011; (3) Three studies did not report PWB as an outcome; (4) Eight studies that did not involve patients

diagnosed with AD as per DSM-IV or DSM-V criteria. (5) Nine studies that did not define the PE intensity; (6) One study with incomplete data on PWB outcomes; and (7) Three studies without accessible full texts. Finally, 11 studies were chosen for synthesis analysis in this systematic review. These studies meet all of the required criteria, including relevance to the research question, a suitable research design, particular demographic characteristics, relevant interventions or exposures, and predefined outcome measures. This final selection gives a strong and focused dataset for comprehensive analysis. **Figure 1** provides a detailed breakdown of the study selection process.

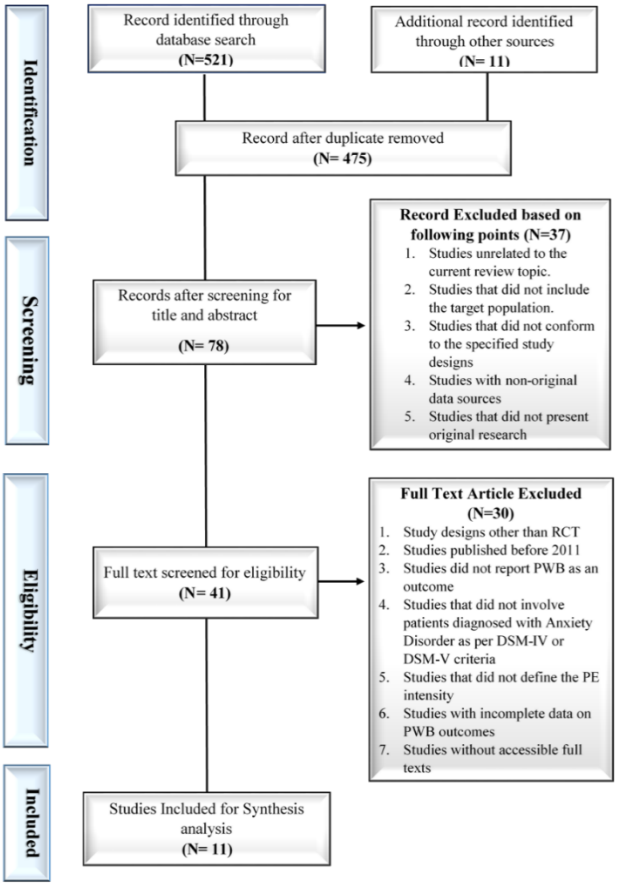


**Figure 1.** PRISMA flowchart depicting the literature search and screening procedure.

## 3.2. Characteristics of included studies

**Table 1** presents an overview of the author, year, participant characteristics, study design, PWB outcome, PE modalities, and regimens. The sample sizes employed in the 11 included studies ranged from 30 to 223, with two studies having more than 100 participants. Participants' ages ranged from 16 to 65. The studies included in the review range from 2011 to 2022, with eight studies conducted between 2011 and 2018 (Abrantes et al., 2018; Bischoff et al., 2018; Gaudlitz et al., 2015; Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016; LeBouthillier and Asmundson, 2017) and three studies conducted between 2020 and 2022 (Henriksson et al., 2022; Ji et al., 2022; Plag et al., 2020). Among the 11 RCTs included, eight were simple RCTs (Abrantes et al., 2018; Bischoff et al., 2018; Herring et al., 2011; Herring

et al., 2012; Herring et al., 2015; Herring et al., 2016; Ji et al., 2022), one was a blinded RCT (Plag et al., 2020), one was a parallel RCT (Henriksson et al., 2022), and one was a double-blind RCT (Gaudlitz et al., 2015). The duration of PE interventions in the selected studies ranged from 12 days to 12 weeks. Specifically, one study had a 12-day intervention (Plag et al., 2020), one study had a 4-week intervention (LeBouthillier and Asmundson, 2017), five studies had a 6-week intervention (Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016; Ji et al., 2022), one study had a 7-week intervention (Bischoff et al., 2018), one study had an 8-week intervention (Gaudlitz et al., 2015), and two studies had a 12-week intervention (Abrantes et al., 2018; Henriksson et al., 2022). In this review, five studies focused specifically on GAD (Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016; Plag et al., 2015), three studies measure AD as a whole (Henriksson et al., 2022; LeBouthillier and Asmundson, 2017; Ji et al., 2022), two studies examine PD/AG (Bischoff et al., 2018; Gaudlitz et al., 2015; Plag et al., 2020), and one study investigated the OCD (Abrantes et al., 2018).

The interventions in the included studies mainly involved AE. Out of the 11 studies, four used AE exclusively (Abrantes et al., 2018; Bischoff et al., 2018; Gaudlitz et al., 2015; Plag et al., 2020), one used RE exclusively (Henriksson et al., 2022), and one used ME (Ji et al., 2022). Moreover, five studies combined both AE and RE interventions (Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016; Ji et al., 2022; LeBouthillier and Asmundson, 2017). In terms of PE intensity, 5 studies adopted MI-PE (Abrantes et al., 2018; Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016); one study used MHI-PE (LeBouthillier and Asmundson, 2017); while the remaining 5 studies come under the category of mixed intensity PE, in which 3 studies applied LI-PE vs. MI-PE (Bischoff et al., 2018; Gaudlitz et al., 2015; Henriksson et al., 2022); one study utilized HI-PE vs. LI-PE (Plag et al., 2020); and only one study measured LI vs. HI PE with frequency (Ji et al., 2022). All the included studies for this systematic review employed structured PE. This technique consists of a thorough plan including the type, duration, frequency, and intensity of workouts, as well as a constant timetable to ensure regular adherence and long-term commitment. This systematic paradigm could be useful for carefully evaluating and quantifying the effects of PE on patients with AD. To evaluate PWB, the most frequently utilized scales were: Yale-Brown Obsessive-Compulsive Scale (Y-BOCS), NIMH self-rating scale, Beck Anxiety Inventory (BAI), Penn State Worry Questionnaire (PSWQ), Hamilton Anxiety Scale (Ham-A), Social Interaction Phobia Scale (SIPS), Scale-Self Report (PDSS-SR), Distress Tolerance Scale (DTS), State-Trait Anxiety Inventory (STAI-Trait), Panic and Agoraphobia Scale (PAS), and Agoraphobic Cognitions Questionnaire.

### 3.3. Risk of bias assessment (study quality)

Two independent review authors (SS and RN) evaluated the ROB for the included RCTs by using the Cochrane ROB Instrument. Among the studies, only one was evaluated as having a low risk of bias (Bischoff et al., 2018). Eight studies were considered to have an unclear risk of bias due to minor methodological issues. For instance, four studies did not mention whether subjects were blinded (Herring et al.,

2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016), and one study did not clearly describe the allocation concealment process (Gaudlitz et al., 2015). Furthermore, three studies lacked clear information on key assessment domains such as random sequence generation, allocation concealment, and blinding of participants and assessors, leading to their classification as having an unclear risk of bias (Abrantes et al., 2018; Ji et al., 2022; LeBouthillier and Asmundson, 2017). Out of the eleven studies, two were thought to have a high risk of bias due to a high dropout rate and lack of participant blinding (Henriksson et al., 2022; Plag et al., 2020). Details of the ROB assessment can be found in the supplementary information. This section gives a detailed analysis of how each study was reviewed, including the particular risk assessment criteria, the rationale for each evaluation, and any methodological flaws detected. **Figure 2** shows the ROB assessment for each study, which summarizes the evaluation of methodological quality and potential biases.

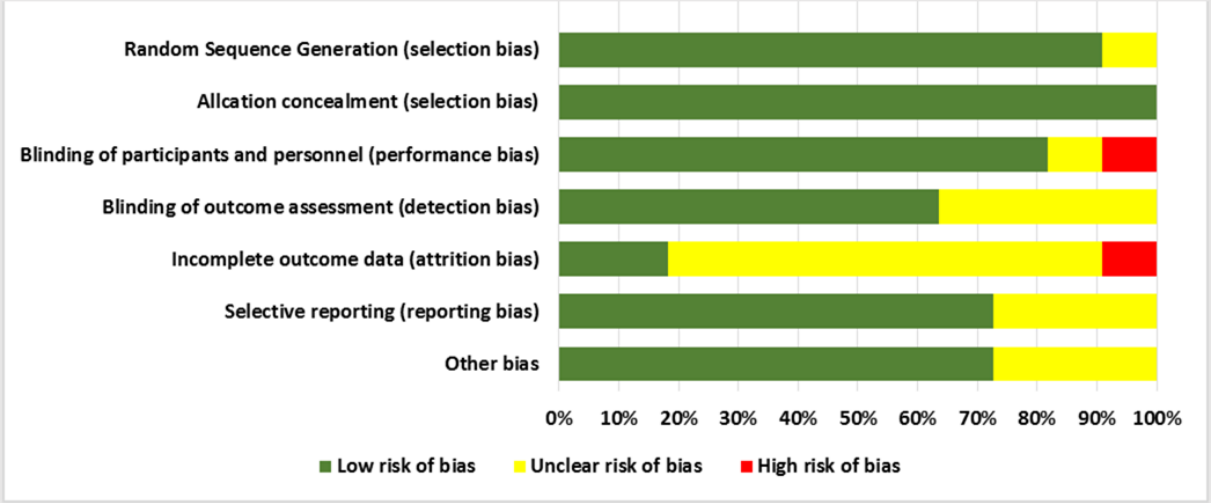


**Figure 2.** Depicts the distribution of ROB across studies, with percentages representing the review author's ratings for each methodological quality component.

### 3.4. Summary of findings

Out of a total of 723 participants in 11 studies (**Table 1**) investigating the effects of PE on AD, four studies focused especially on the advantages of AE. These four studies involved 223 participants, 36 of whom dropped out. AE has been found to improve the efficacy of CBT for treating PD and AG (Bischoff et al., 2018), as well as to reduce anxiety sensitivity and AG avoidance (Gaudlitz et al., 2015). Participants in AE reported a significant reduction in anxiety symptoms, compulsive behaviors, comorbid depression, stress-related physical symptoms, worry, and perceived control, as well as an increase in positive mood (Abrantes et al., 2018; Plag et al., 2020).

One study used RE as an alone intervention with a total number of 223 participants and found that patients in both LI and MI RE groups experienced higher decreases in anxiety and depression symptoms than the control group (Henriksson et al., 2022). Only one study employed ME intervention with 109 participants and compared PE intensity and frequency, concluding that intensity was more effective than frequency. The study also discovered that increasing the intensity of PE improves sleep quality and reduces sadness (Ji et al., 2022).

Five of the included studies, totaling 168 individuals, used combined AE and RE interventions. These interventions have been identified as feasible, low-risk treatments capable of alleviating anxiety symptoms (Herring et al., 2012) and improving sleep patterns (Herring et al., 2015). RE was observed to significantly increase both physical and PWB, whereas AE enhanced physical function and energy levels in individuals with GAD (Herring et al., 2016). Furthermore, both RE and AE significantly reduced anxiety-tension, irritability, depression, fatigue, and pain severity while boosting concentration and PWB (Herring et al., 2011; LeBouthillier and Asmundson, 2017). **Table 1** defines some of the specific studies that assessed the effectiveness of PE programs in treating AD symptoms.

According to the findings, AE is the most effective treatment method for lowering anxiety symptoms and improving PWB in AD patients; however, RE provides notable benefits as well. AE was connected to improvements in anxiety, focus, irritation, fatigue, emotional stability, and psychological distress, while RE significantly improved anxiety sensitivity, role-emotional functioning, and MH in individuals with AD. Regarding participant adherence, AE had a lower dropout rate of 10.9%, whereas RE had a somewhat higher dropout rate of 22.44%. The systematic review also looked at the dropout rate for ME, which was higher (22.9%). It is critical to evaluate anxiety-reduction PE programs in terms of participant adherence, effectiveness, and individual preferences. AE might be recommended due to its multiple benefits and higher adherence rates. The decision between AE and RE depends on individual goals and personal preferences. **Figure 3** highlights how different forms and dosages of PE affect AD findings, including the impacts of various PE modalities and regimens.

**Table 1.** Summary of specific studies to assess the effects of PE on AD.

| Studies | Study Characteristics | Diagnosis | Exercise Intensity | Condition | Primary results |
|---|---|---|---|---|---|
| Bischoff et al., 2018 | SD: Single RCT<br>TP: 77<br>PIA: 56<br>FUP: 51<br>Age: 16–65<br>ID: 7 weeks | Patients diagnosed with PD/AG according to DSM-IV criteria. | MI-PE and LI-PE | **Intervention:** 30 min treadmill task with MI or LI AE (70% or 30% of the maximal oxygen uptake [VO2max]) prior to five exposure sessions within a standardized seven-week CBT.<br>**Control:** N/A | All patients experienced significant symptom improvement from baseline to post-treatment ($p$ <0.001). The MI-AE group had higher Ham-A scores due to a significant time-group interaction (F [1, 74] = 4.15, $p$ =.045, $\alpha$ = 0.025). However, this pattern changed at follow-up as the L1-AE group continued to improve. These data indicate that MI-AE may improve the efficacy of exposure-based CBT for AG/PD in lowering anxiety symptoms. |
| Abrantes et al., 2018 | SD: RCT<br>TP: 55<br>PIA: N/A<br>FUP: N/A<br>Age: 18–65<br>ID: 12 weeks | Patients diagnosed with OCD according to DSM-IV criteria | MI-PE | **Intervention:** MI-AE utilized standard modalities, including treadmills and elliptical. The duration started at 20 minutes and progressively increased to 35–40 minutes by week 12<br>HEC: Received 12 weekly 45–60 minutes long psycho education sessions.<br>**Control:** N/A | AE resulted in significantly higher improvements in positive mood as well as significant reductions in anxiety and obsessive behaviors when compared to the health education control (HEC) group. |

**Table 1.** (*Continued*).

| Studies | Study Characteristics | Diagnosis | Exercise Intensity | Condition | Primary results |
|---|---|---|---|---|---|
| Herring et al., 2011 | SD: RCT<br>TP: 30<br>PIA: N/A<br>FUP: N/A<br>Age: 18–37<br>ID: 6 weeks | Patients diagnosed with GAD according to DSM-IV criteria | MI-PE | **Intervention:** RE involved two weekly sessions of six weeks of lower-body weightlifting. AE involved two weekly sessions of six weeks of leg cycling matched with RE on body region, positive work, exercise time, and load progression<br>**Control:** Patients randomized to the control condition delayed entry into any intervention for six weeks, but were tested on all outcomes. | Both RE and AE considerably reduced feelings of anxiety-tension, irritability, depression, exhaustion, vigor, and pain intensity while improving attention. RE had non-significantly bigger effects on 9 of 12 outcomes than AE. |
| Herring et al., 2012 | SD: RCT<br>TP: 30<br>PIA: 30<br>FUP: N/A<br>Age: 18–39<br>ID: 6 weeks | Patients diagnosed with GAD according to DSM-IV criteria | MI-PE | **Intervention:** RE involved two weekly sessions of six weeks of lower-body weightlifting. AE involved two weekly sessions of six weeks of leg cycling matched with RE on body region, positive work, exercise time, and load progression<br>**Control:** Patients randomized to the control condition delayed entry into any intervention for six weeks, but were tested on all outcomes. | PE is a credible, low-risk treatment that has the ability to mitigate worry symptoms in GAD patients and may act as an effective short-term adjuvant therapy for GAD. No significant differences in symptom reduction were found between AE and RE. |
| Herring et al., 2015 | SD: RCT<br>TP: 30<br>PIA: 26<br>FUP:<br>Age: 18–37<br>ID: 6 weeks | Patients diagnosed with GAD according to DSM-IV criteria | MI-PE | **Intervention:** RE condition involved seven sets of 10 repetitions each of leg press, leg curl and leg extension exercises for 6 weeks of twice weekly. AE involved 6 weeks of twice weekly of 16 min of continuous, dynamic leg cycling exercise, matched with RE on body region, positive work, exercise time, and load progression<br>**Control:** Patients randomized to the control condition delayed entry into any intervention for six weeks, but were tested on all outcomes. | Short-term RE and AE training improves sleep patterns among GAD patients. The findings indicate that improved sleep may be associated with reduced clinical severity among GAD patients. |
| Herring et al., 2016 | SD: RCT<br>TP: 30<br>PIA: N/A<br>FUP: N/A<br>Age: 18–37<br>ID: 6 weeks | Patients diagnosed with GAD according to DSM-IV criteria | MI-PE | **Intervention:** RE condition involved seven sets of 10 repetitions each of leg press, leg curl and leg extension exercises for 6 weeks of twice weekly. AE involved 6 weeks of twice weekly of 16 min of continuous, dynamic leg cycling exercise, matched with RE on body region, positive work, exercise time, and load progression<br>**Control:** Patients randomized to the control condition delayed entry into any intervention for six weeks, but were tested on all outcomes | RE significantly benefited role-physical, role-emotional, and PWB, whereas AE increased physical function and energy. PE training improved multiple aspects of quality of life for GAD patients, with the most significant impacts observed in role impairment, physical function, energy, and PWB. |
| Plag et al., 2020 | SD: blinded RCT<br>TP: 33<br>PIA: 33<br>FUP: 29<br>Age: 18 +<br>ID: 12 days | Patients diagnosed with GAD according to DSM-IV criteria | HI-PE or LI-PE | **Intervention:** HI-AE was performed every second day within a period of 12 days on a bicycle ergometer. Each session lasted about 20 min.<br>LI-AE included separated units of stretching and adapted yoga figures which were performed on a training mat. LI-AE was matched to HI-AE with respect to frequency and duration.<br>**Control:** N/A | Both AE groups showed a moderate to significant impact on anxiety, comorbid depression, stress-related physical symptoms, worry, and perceived control. However, the benefits of HI-AE were often approximately double those of LI-AE. |

**Table 1.** (*Continued*).

| Studies | Study Characteristics | Diagnosis | Exercise Intensity | Condition | Primary results |
|---|---|---|---|---|---|
| Henriksson et al., 2022 | SD: Parallel RCT<br>TP: 223<br>PIA: N/A<br>FUP: 153<br>Age: 18–65<br>ID: 12 weeks | Patients diagnosed with AD according to DSM-IV-V criteria | LI-PE and MHI-PE | **Intervention**: I: 12-week LI-RE, 3 times per week.<br>II: 12-week with MHI-RE, 3 times per week.<br>**Control:** single session with a physiotherapist provided general PE advice based on public health recommendations. | Patients in both RE groups experienced higher reductions in anxiety and depressive symptoms than the control group, with no significant differences in effect sizes between LI and MHI-RE. |
| Ji et al., 2022 | SD: RCT<br>TP: 109<br>PIA: 84<br>FUP: N/A<br>Age: 19–29<br>ID: 6 weeks | Patients diagnosed with AD according to DSM-IV criteria | LI-LF, LI-MF, LI-HF HI-LF, HI-MF, HI-HF | **Intervention:** PE program consisted of a total of 8 repetitions of circuit training, repeated three times. Cardiorespiratory PE included high leg running, small step running, lunges, and skipping rope. RE included planks, sit-ups, push-ups, and elastic band exercises.<br>**Control:** N/A | PE intensity is more effective at reducing anxiety and depression symptoms than PE frequency. Additionally, sleep quality was more closely related to PE intensity. These data indicate that PE intensity and frequency have unique effects on anxiety, sadness, and sleep quality in college students. |
| Gaudlitz et al., 2015 | SD: Double-blind RCT<br>TP: 58<br>PIA: 47<br>FUP: 47<br>Age: 18–70<br>ID: 8 weeks | Patients diagnosed with PD with and without AG according to DSM-IV-V criteria | MI-PE and LI-PE | **Intervention:** 08 weeks AE for three times a week, 30min each time with 70%VO2max.<br>**Control:** AE with very low intensity, three times a week, 30 min each, for 8 weeks. | AE group with MI-AE indicated better improvement in PD symptoms, anxiety sensitivity, and AG avoidance than those in the control group who engaged in LI-AE. |
| LeBouthillier et al., 2017 | SD: RCT<br>TP: 48<br>PIA: N/A<br>FUP: N/A<br>Age: 18–65<br>ID: 4 weeks | Patients diagnosed with AD according to DSM-IV criteria | MHI-PE | **Intervention:** 40 minutes of AE on a spin cycle at 60–80% age-adjusted maximum heart rate reserve.<br>RE involved 2–3 sets of 10–12 repetitions of machine leg press, machine chest press, machine hamstring curl, dumbbell single arm row, machine shoulder press, machine triceps extension, and machine bicep curl.<br>**Control:** Completed online questionnaires weekly from home for the duration of the trial phase | Both PE groups were beneficial in improving disorder status. AE improved general psychological distress and anxiety, while RE improve disorder symptoms, anxiety sensitivity, distress tolerance, and intolerance to inconsistency. These findings show the specific benefits of each PE technique in treating anxiety-related symptoms. |

Study Design (SD), Randomized Controlled Trial (RCT), Total Participant (TP), Participant in Analysis (PIA), Follow-Up Participant (FUP), Intervention Detail (ID), Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-V), Panic Disorder and Agora Phobia (PD/AG), Obsessive compulsive disorder (OCD), Generalized Anxiety Disorder (GAD), Anxiety Disorder (AD), Aerobic exercise (AE), Resistance exercise (RE), Low intensity physical exercise (LI-PE), Moderate intensity physical exercise (MI-PE), High intensity physical exercise (HI-PE), Moderate to high intensity physical exercise (MI-PE), Low intensity and low frequency (LI-LF), Low intensity and moderate frequency (LI-MF), Low intensity and high frequency (LI-HF), High intensity and low frequency (HI-LF), High intensity and moderate frequency (HI-MF), High intensity and high frequency (HI-HF).

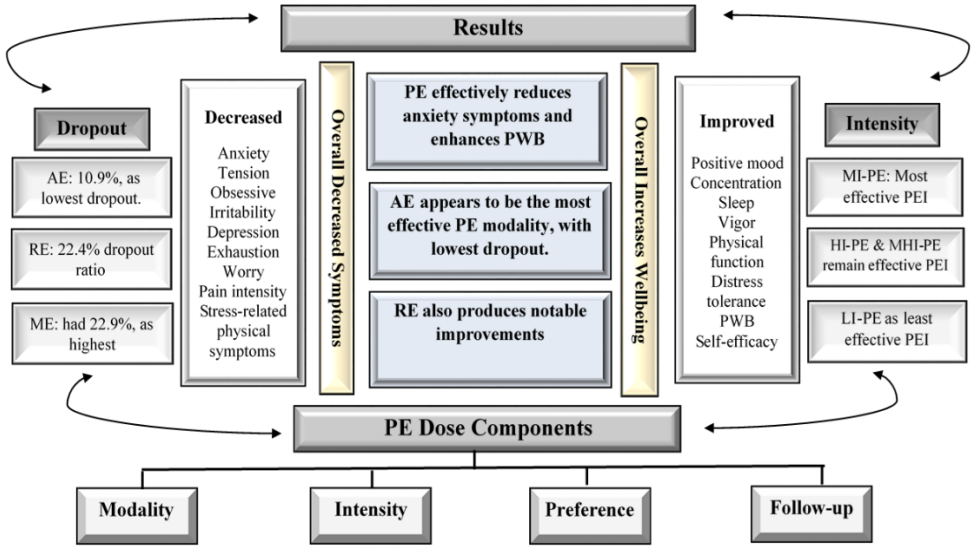


**Figure 3.** Represents the effects of PE on AD, describing how different PE modalities and regimens alter outcomes at specific dosage levels.

### 3.5. Summary of findings

When compared to other types of PE regimens, MI-PE was found to be the most effective in significantly lowering anxiety symptoms. Additionally, HI-PE outperforms LI-PE in terms of anxiety symptom reduction. However, MI-PE is the most effective at reducing the substantial association between PE intensity and the reduction of anxiety symptoms. **Table 2** evaluates the efficacy of several PE regimens for reducing the symptoms of AD.

**Table 2. C**ompares the outcomes of different PE regimens for managing AD symptoms.

| Exercise Intensities | Findings |
|---|---|
| LI-PE | Bischoff et al. (2018) found that MI-AE appeared to be the most successful during intervention while the LI-AE group improved during follow-up. Another study found no significant differences in effect sizes between LI-RE and MHI-RE (Henriksson et al., 2022), whereas Plag et al. (2020) discovered that the benefits of HI-AE were typically twice as substantial as those of LI-AE. Furthermore, LI-PE produces more effects than LI-LF, while LI-PE does not produce effects when compared to MI-PE (Gaudlitz et al., 2015; Ji et al., 2022). |
| MI-PE | According to the findings, MI-AE may improve the efficiency of exposure-based CBT for AG and PD in reducing anxiety symptoms (Bischoff et al., 2018). Patients with OCD reported a significant decrease in obsessions and an increase in positive mood after receiving MI-AE (Abrantes et al., 2018). MI-AE considerably lower symptoms of anxiety-tension, irritability, depression, tiredness, vigor, and pain severity. It also improved concentration and sleep patterns in people with GAD. PE improved quality of life by increasing physical and emotional role performance, physical ability, strength, and PWB (Herring et al., 2011; Herring et al., 2012; Herring et al., 2015; Herring et al., 2016). Future MI-PE decreased AG avoidance, anxiety sensitivity, and symptoms of PD (Gaudlitz et al., 2015). |
| HI-PE | HI-PE was found to be more suitable in mitigating the symptoms of GAD compared to LI-PE. Patients in the HI-PE group saw a considerable decrease in worry, with benefits that were roughly twice as strong as those observed in the LI-PE group (Plag et al., 2020). Moreover, HI-PE appeared as the most effective strategy for reducing anxiety symptoms in college students (Ji et al., 2022). |
| MHI-PE | The MHI-PE group had a higher OR, indicating a greater link to decreased anxiety symptoms. PE not only relieves anxiety, but also considerably reduces inner tension, psychological stress, and depression (Henriksson et al., 2022). Furthermore, LeBouthillier and Asmundson (2017) found that MHI-PE improves disorder status, reduces overall psychological distress, increases distress tolerance, and decreases anxiety sensitivity and related symptoms. These findings highlight the broad spectrum of psychological benefits associated with MHI-PE. |

## 4. Discussion

This comprehensive review provides persuasive evidence that structured PE effectively decreases anxiety symptoms while improving PWB in people with AD. The review compares several PE modalities and regimens in order to discover the best effective therapeutic choice for anxiety-related disorders. They emphasize the significant therapeutic effects of structured PE in reducing anxiety symptoms across a variety of anxiety disorders. These findings strongly support PE as a beneficial supplementary therapy for those with AD, contributing to enhanced PWB, improved mood, and reductions in symptoms like anxiety, depression, irritability, stress, and perceived lack of control. Consistent with established research, Goodwin (2003) found that self-reported regular PE significantly reduced anxiety symptoms in people with PD and GAD compared to the less frequent PE group. These findings highlight the benefit of frequent PE in reducing anxiety within this population. Additionally, engaging in PE sessions results in significant acute improvements in OCD patients, such as reduced negative mood, anxiety, and self-reported obsessions and compulsions (Bottoms et al., 2023). PE also helps with a variety of anxiety symptoms, including difficulties concentrating, frustration, tense muscles, tiredness, and worry (Gordon et al., 2017; Mahindru et al., 2023; Sabri et al., 2023). These cumulative effects emphasize the importance of PE on MH, particularly for people who suffer from anxiety and OCD. The immediate effects of PE in lowering negative feelings and anxiety (Masellis et al., 2003; Weissman et al., 1994) further highlight its significance. These findings emphasize the importance of increased PE as a strategy for maintaining and improving PWB, as well as its therapeutic potential as an additional treatment option in the comprehensive treatment of AD.

Our review findings further underscore the enormous benefits of PE for those with AD, notably in terms of improving sleep quality and reducing anxiety. These results support previous findings, notably Youngstedt (2005), that identified PE as a vital factor in improving sleep quality. The observed increase in sleep is mostly due to a reduction in anxiety, underscoring the relevance of PE in promoting good sleep. Furthermore, PE therapies show potential in improving sleep quality and alleviating anxiety and depression symptoms in PTSD patients (McGranahan and O'Connor, 2021). Research has indicated that 190 minutes of MI-AE each week can considerably improve sleep quality (Kline et al., 2012). These findings highlight the interrelated benefits of regular PE on PWB and sleep habits. In our analysis, outcomes indicated moderate to significant progress in anxiety scores as well as improvements in sleep quality, which is consistent with previous research confirming the effectiveness of PE in reducing anxiety symptoms (Gordon et al., 2017; Petruzzello et al., 1991). Moving forward, there is a definite need for additional research to investigate the dose-response effects of PE on sleep quality and symptom relief in a wide sample of AD.

Our review findings convincingly show that AE is the most beneficial modality for treating the symptoms usually associated with AD; however, the influence of RE is also noteworthy. AE can be used as a supplementary treatment option for persons suffering from AD, and it has been shown to reduce anxiety symptoms while improving PWB. This conclusion maintains consistency with previous studies, which demonstrate AE participation in improving MH and lowering anxiety symptoms (Lin

and Gao, 2023; Moura et al., 2015). Regular AE has been shown to improve particular anxiety symptoms such as excessive worry, restlessness, and tension (Crombie et al., 2021). Both qualitative and quantitative research has shown that AE reduces anxiety symptoms and improves cognitive skills (Masley et al., 2009; Sternfeld et al., 2014). Furthermore, AE has been linked to higher self-esteem and lower levels of anxiety and sadness (Larun et al., 2006; Smits et al., 2008; White et al., 2017). Also, our data revealed a lower dropout rate of 10.9% for AE, indicating that it not only successfully mitigates anxiety symptoms but also has favorable acceptability among patients when compared to other forms of PE modalities. In our analysis, the results of RE are also notable as they demonstrated significant benefits in reducing anxiety, depression, tiredness, and improving focus of attention and overall wellbeing. Our findings corroborate earlier studies, proving that RE had a statistically significant, small-to-moderate positive impact on lowering anxiety symptoms and increasing MH outcomes (Gordon et al., 2017, 2020). This validates RE efficacy as a therapeutic intervention and highlights its potential role in comprehensive MH care systems.

Current literature underlines the comparison of AE and RE in terms of effectiveness. Our findings disclose that both AE and RE establish similar outcomes, with no statistically significant differences observed between them. The results of our study align closely with existing research, which found that both types of PE greatly improved physical fitness and reduced anxiety levels (Bhurka and Shukla, 2023). Furthermore, research has indicated that combining AE and RE interventions can successfully manage symptoms of diseases, potentially providing greater psychological benefits, particularly in obese teenagers (Goldfield et al., 2015). These interventions are thought to have important physiological and psychological consequences, notably in their ability to address a variety of associated health issues (Meyer and Schuch, 2018). These calming effects of PE on AD emphasize its potential for sustained management of anxiety levels over time.

One of the primary goals of our review is to investigate the efficacy of PE intensity in order to establish which PE regimens are more beneficial than others for AD patients. Our data indicate that participation in the MI-PE program significantly improves the PWB of AD patients. Our results are completely consistent with previous studies, suggesting that MI-PE programs are useful for people suffering from neurotic symptoms, acting as a valuable supplement to managing acute depressive episodes and chronic anxiety (Moura et al., 2015). Another RCT found that participating in MI-AE increased not only enjoyment over time but also adherence, potentially alleviating symptoms of OCD and promoting overall well-being (Szuhany et al., 2023). Similarly, Brown et al. (2007) found that participants in the MI-AE intervention saw a significant decrease in OCD symptoms and improved general well-being, which lasted up to six months after the intervention.

Finally, the current review's findings provide a thorough analysis of the benefits of PE on the PWB for those suffering from AD. Future research should focus on a variety of aspects, including specific PE modalities, ideal duration, and intensity levels. This inclusive approach seeks to identify the most effective PE modalities and regimens for AD, ultimately improving therapy procedures and optimizing clinical outcomes.

## 5. Strengths, limitations, and future directions

This review article has several outstanding strengths, which increase its contribution to the field. Firstly, our review is limited to RCT, assuring a high level of evidence and rigorous methodology. Second, we selectively included papers that compared different PE modalities, resulting in a complete study of the relative efficacy of various PE programs. Third, our review only includes studies that identify PE intensities, which allows for a more refined understanding of how varied levels of PE affect outcomes. Finally, we have carefully chosen studies involving patients diagnosed with AD to ensure that the findings are directly applicable to this population. Collectively, these strengths contribute to a thorough and well-rounded investigation into the effects of PE on AD. Our review also had significant limitations that impacted the clarity and generalizability of its findings. Many of the research we considered had small sample numbers and short intervention periods, limiting the strength of their findings. Furthermore, the absence of blinding in many RCT raises concerns about potential biases and reduces the dependability of the results. Although we attempted to compare various PE modalities, the studies chosen for comparison were not evenly distributed, which may affect how effectively our findings may be generalized. These difficulties underscore the necessity for more rigorous and consistent research into the efficacy of PE for AD.

Future research should focus on strong methodology, clearly specifying the dosage of PE, including PE intensities and frequency, to determine the optimal quantity required for anxiety reduction in diagnosed patients, transforming it into a therapeutic intervention to be used as a supplementary tool to treat anxiety and other disorders. Larger sample sizes are also required to improve the generalizability of the findings. Longitudinal studies are essential to determine the long-term consequences of PE as well.

## 6. Conclusion

Current findings suggest that PE is a safe, efficient, and supplementary treatment choice for individuals with AD. It improves positive mood, sleep quality, and concentration and decreases obsessions, worry, and stress while alleviating anxiety symptoms. Among the different PE modalities, AE is the most successful and can be combined with other psychotherapies to treat anxiety and related illnesses. Furthermore, the review documented that MI-PE is particularly beneficial for lowering anxiety symptoms and improving PWB in AD patients. However, the existing data lacks sufficient scientific objectivity to officially endorse PE as a treatment choice for anxiety disorders. To develop effective exercise programs, rigorous experimental methods, appropriate control groups, adequate sample sizes, optimal exercise intensity, and individual preferences must be considered. A multidisciplinary strategy that involves working with experts in sports psychology and medicine is essential. Use of validated instruments and comprehensive documentation of training effects are also required prior to generalization.

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