**Title:**

Umbrella Systematic Review and meta-analysis: Physical Activity as an Effective Therapeutic Strategy for Improving Psychosocial Outcomes in Children and Adolescents

**Running title:**

Physical activity for mental health

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**Declaration of interests**

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**ABSTRACT**

**Objective:** Physical activity (PA) interventions are part of many interdisciplinary programs for the management of children and adolescents with or without physical or psychological conditions or disabilities. Aiming to summarize the available evidence, we conducted an umbrella review of meta-analyses of PA interventions that included psychosocial outcomes in populations of children and adolescents.

**Method:** Literature searches were conducted in PubMed, Cochrane Central, Web of Science, Medline, SportDiscus, and PsychInfo from Jan 1, 2010 to May 6, 2022. Meta-analyses of randomised and quasi-randomised studies investigating the efficacy of PA interventions for psychosocial outcomes in children and adolescents were included. Summary effects were recalculated using common metric and random-effects models. We assessed between-study heterogeneity, predictive intervals, publication bias, small-study effects, and whether the results of the observed positive studies were more than expected due to the chance. On the basis of these calculations, strength of associations was assessed using quantitative umbrella review criteria, and credibility of evidence using the GRADE approach. Quality was assessed using the AMSTAR-II tool. This study is registered with the Open Science Framework, <https://osf.io/ap8qu>.

**Results:** A total of112 studies from18 meta-analyses generating 12 new meta-analyses with 21232 children and adolescents with conditions or disabilities as ADHD, cancer, cerebral palsy, chronic respiratory diseases, depression, neuromotor impairment, obesity and in general populations were included. PA interventions were efficacious in reducing psychological symptoms in all meta-analyses across the different population groups using random-effects models. However, umbrella review criteria suggested a weak strength of association for this outcome, and GRADE credibility of evidence ranged from moderate to very low. For psychological wellbeing, three out of five meta-analyses identified significant effects, but the strength of these associations was weak, and GRADE credibility of evidence ranged from moderate to very low. Similarly, for social outcomes, meta-analyses reported a significant summary effect, but the strength of association was weak, and GRADE credibility of evidence ranged from moderate to very low. For self-esteem, one meta-analysis in children with obesity failed to show any effect.

**Conclusion:** Even though existing meta-analyses suggested a beneficial effect of PA interventions on psychosocial outcomes across different population groups, the strength of associations was weak, and the credibility of evidence was variable, depending on the target population, outcome, and condition or disability. Randomised studies of PA interventions in children and adolescents with and without different physical and psychological conditions or disabilities should always include psychosocial outcomes as an important dimension of social and mental health.

**Keywords**: physical activity, umbrella systematic review, psychosocial outcomes, children, adolescents

**INTRODUCTION**

According to the World Health Organization, physical activity (PA) is broadly defined as ‘any bodily movement produced by skeletal muscles that requires energy expenditure’.1 PA – which may include different types of activities like sport, aerobic and anaerobic exercise -has been considered as an important component in the management of several physical and psychological conditions or disabilities in children and adolescents, and it may also prevent the onset of chronic diseases in healthy children and/or reduce the incidence of future non-communicable diseases in adulthood.2 Additionally, PA interventions contribute to modify the progress of already diagnosed diseases (disease reversal, such as in type 2 diabetes) and/or help to manage symptoms associated with chronic conditions (such as in cancer).3 The benefits of an active lifestyle for youth are demonstrated also on cognitive4, attentive5, and executive functioning6. In addition, PA offers youth opportunities for enjoying experiences, enhancing positive emotional states, increasing self-efficacy and well-being7. Children and adolescents who are physically active may also benefit from improved psychological wellbeing and self-esteem, and build social and emotional skills.8,9 The relationships between physical fitness, psychosocial outcomes and interpersonal relationships have been established in a systematic review of 30 studies involving children and adolescents in school settings.9 The review developed a conceptual socio-ecological model on the link between psychological, psychosocial and social health domains, and their positive associations with PA participation. Authors found that PA may satisfy psychological needs, as for example needs for belongingness, resilience, and individual capacity to engage in interpersonal relationships, thus influencing psychological health.9

In children and adolescents, however, many interventions targeting improving psychosocial outcomes are traditionally using mostly verbal and cognitive processing of experiences, feelings and behaviors, often applying a cognitive-behavioral perspective10,11, and miss an integration of the body-mind (inter)connection which is central to PA and movement-based and non-verbal approaches. The available evidence on the impact of PA on psychosocial outcomes is still fragmented into several systematic reviews that focus on heterogeneous target groups, interventions, and outcomes, which makes it challenging to appraise the evidence using a similar metric across type of interventions and populations. Furthermore, the quality of evidence has never been evaluated using a formal methodological approach, with consequent lack of information on the credibility of effect sizes reported in previous systematic reviews and meta-analyses.

Aiming to quantitatively summarise the efficacy of PA interventions in reducing psychological symptoms and improving psychological wellbeing, defined as perceived positive emotions, feelings, and quality of life, self-esteem, and social outcomes in children and adolescents with or without any physical and/or mental health conditions or disabilities, a review of existing systematic reviews was conducted. We hypothesised that PA interventions would be effective in improving psychosocial outcomes in this target group. Additionally, we aimed at accurately quantifying the strength of associations and credibility of evidence, using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.12,13

**METHOD**

**Eligibility criteria and search strategy**

We used an umbrella review methodology to systematically review all available systematic reviews and meta-analyses on the topic.14-16 This review methodology was chosen because it could provide an overall picture of a broad health-care area and highlight whether the evidence base is consistent or contradictory.17 We systematically reviewed all available systematic reviews and meta-analyses evaluating PA interventions delivered through any means of interaction between the participant(s) and the trainer(s), including, for example, face-to-face sessions, internet, or self-help interventions facilitated by trainers.18 Both individual and group PA interventions delivered to healthy children and adolescents (0-18 years) or to those with any mental and/or physical health conditions were eligible for inclusion, with no limit to the number of sessions. Comparison groups included any types of non-active interventions, usual care, waitlist controls, or any other types of controls.

Only systematic reviews and meta-analyses including at least one psychosocial outcome in children and adolescents were included. Systematic reviews without statistical re-analysis of psychosocial outcomes were excluded.1 Meta-analyses without study-level effect sizes (ESs) and 95% confidence intervals (CIs) were excluded, as they do not allow data re-analysis. When two meta-analyses presented overlapping datasets on the same comparison, the meta-analysis with the largest number of component studies providing study-level ESs were retained for the main analysis, in agreement with umbrella review methodology.14,19,20

PubMed, Cochrane Central, Web of Science Medline, SportDiscus, PsychInfo were searched from Jan 1, 2010 to May 6, 2022 to identify up-to-date systematic reviews. The timeframe for the search strategy was set according to umbrella review methodology.14,21 No language restrictions were applied. Electronic database searches were supplemented by a manual search of reference lists from studies focused on PA and/or sport interventions. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting standards (PRISMA)22,23 were followed to document the process of selection of meta-analyses. The selection of potentially eligible systematic reviews was made by titles and abstracts inspection by two reviewers working independently (EP, CC). In case of discrepancies, a third review author (MP or CB) was involved, and consensus reached by discussion. When titles and abstracts did not provide information on the inclusion and exclusion criteria, the full articles were obtained to check for eligibility. The full-text of potentially eligible systematic reviews was obtained and carefully appraised by at least two reviewers (EP, CC, or MP). The reference lists of included articles were analysed for additional items not retrieved by the database searches.

The protocol of the present umbrella review was registered with the Open Science Framework platform: <https://osf.io/ap8qu>.

**Data analysis**

From each included meta-analysis, two investigators (MP, CC, or EP) independently extracted information on first author, year of publication, outcomes, number of included studies and reported summary meta-analytic estimates. The following information was extracted from each primary study: year of publication, health condition, type of intervention, psychosocial outcomes defined as changes in mood and/or behaviours (psychological symptoms such as depression, anxiety, and distress; psychological wellbeing defined as perceived positive emotions/feelings/quality of life; self-esteem; social outcomes and/or prosocial behaviour, such as changes in attitudes and/or behaviours towards others), sample size and study-specific effect size with the corresponding 95% confidence interval.

The quality of systematic reviews including meta-analyses was independently assessed by two reviewers (EP, CC) using the AMSTAR-II (A Measurement Tool to Assess Systematic Reviews), a 16-point assessment tool of the methodological quality of systematic reviews. AMSTAR-II has good interrater agreement, test–retest reliability and content validity.24

Summary standardised mean differences (SMDs) with 95% CI were re-estimated using common metric and random effects models because high heterogeneity was expected.25,26 We also estimated the 95% prediction interval for the summary random-effects estimates.27 Prediction intervals further account for heterogeneity between studies and specify the uncertainty for the effect that would be expected in a new study examining that same research question. Heterogeneity was evaluated with Cochran’s Q-statistic28,29 (statistically significant for p-value <0.10) and the percentage of heterogeneity due to real heterogeneity quantified with the I² metric.26,29 Egger’s test was used to evaluate potential publication and small-study effects biases.30,31 A p-value of 0.10 or less in the regression asymmetry test with a more conservative effect in the largest study was considered evidence for small-study effects bias.16 We evaluated the excess significance to examine whether the observed number of studies with statistically significant results (positive studies, p<0.05) in each meta-analysis was larger than their expected number. For each meta-analysis, the expected number was calculated as the sum of the statistical power estimates for each study in the meta-analysis. The power of each study was calculated by an algorithm using a non-central t distribution.32 The estimated power depends on the plausible SMD. Because the true SMD for any meta-analysis is unknown, we assumed that the most plausible effect was given by the largest study. Excess significance for each meta-analysis was claimed at a p-value of 0.10 or less.32 On the basis of these calculations, we classified the strength of each association as “convincing”, “highly suggestive”, “suggestive”, or “weak”.15,33,34 Specifically, associations identified in meta-analyses were classified as convincing (Class I) if they met the following criteria: p-value of less than 10-⁶ based on random effects meta-analysis, more than 1000 participants, low or moderate between-study heterogeneity (I² <50%), 95% prediction interval that excluded the null-value, and no evidence of small-study effects and excess significance. Highly suggestive association (Class II) criteria required more than 1000 participants, highly significant summary associations (p-value <10-⁶ by random-effects) and 95% prediction interval not including the null-value. Suggestive evidence (Class III) criteria required only more than 1000 participants and a p-value of 0.001 or less by random-effects. Weak association (Class IV) criteria required only a p-value of 0.05 or less. Associations were considered non-significant if the p-value was higher than 0.05. Statistical analyses and power calculations were done using Stata version 17.0. P-values were all two-tailed. In addition to these quantitative criteria, the overall credibility in the estimates was qualitatively assessed by two reviewers (EP, CC) using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) method (see Table S7, available online).12,13 GRADE produces a credibility of estimate for each outcome and supplies a tabular overview of findings easily understandable for intervention participants, policy makers, research planners, guideline developers, and other interested stakeholders. Summary of findings tables were developed using the GRADEProGDT app (https://www.gradepro.org/).

**RESULTS**

The systematic search yielded 6202 records. After duplicate removal and inspection of titles and abstracts, 234 full-text articles were assessed for eligibility. Eighteen meta-analyses including 112 primary studies (89 RCTs and 23 controlled clinical trials) and 21232 participants met the umbrella review inclusion criteria and were re-analysed producing 12 meta-analyses (Figure 1). Details on the excluded reviews and the reasons for exclusion are provided in the Table S3.

In terms of population groups, PA interventions were studied in children and adolescents with ADHD35, cancer36-38, cerebral palsy39,40, chronic respiratory diseases41-43, depression44,45, neuromotor impairment46, obesity47-49, and in general populations of children and adolescents50-52 (Table 1).

Studies were implemented in a diverse range of settings including home (face-to-face, or online/telephone meetings), schools, community settings, in- and out-patient clinics, physiotherapy clinics, recreation camps, and other settings. Studies were focused on implementing a variety of PA programs, as yoga, body and body-mind education, balance and coordination training; resistance training, task-specific gross motor skills, aerobic exercise including running, swimming, walking, football, dance, and cycling, strengthening exercises, and others (Table 1). The length of interventions ranged from one week to ≥ one year. In terms of outcomes, we identified the following categories of psychosocial outcomes: psychological symptoms of common mental disorders (i.e., depression, anxiety, distress, emotional problems), psychological wellbeing, self-esteem, and social outcomes (Table 1).

The methodological quality of the included systematic reviews appraised with the AMSTAR-2 tool was high for three systematic reviews, moderate for one systematic review, while the remaining 14 reviews received a low or critically low-quality rating (see Table S4, available online). AMSTAR-2 detected that in nine reviews the protocol was not available, in five the literature search strategy did not specify potential language restrictions and justification, in nine reviews the references of excluded studies were not reported. Additionally, in nine reviews the risk of bias tool was not taken into account when discussing the results, and seven reviews did not consider publication bias.

**Summary of effect sizes**

Re-analyses of study-level data produced 12 new meta-analyses (Figure 2). Ten out of twelve meta-analyses reported a nominally statistically significant summary effect using random effects models (p<0.05) (Table 2). For the outcome “psychological symptoms”, all meta-analyses using random-effects models reported a significant (p<0.05) summary effect across the different population groups that are children and adolescents with ADHD, depression, neuromotor impairment, and children and adolescents of the general population. For psychological wellbeing, three out of five meta-analyses identified a significant effect of PA interventions over control conditions in children and adolescents with obesity, chronic respiratory diseases, and in children and adolescents of the general population. Similarly, for social outcomes meta-analyses were available for children and adolescents with ADHD and cerebral palsy and reported a significant summary effect (p<0.05). For self-esteem one meta-analysis of studies conducted in children with obesity failed to show and effect. In all the meta-analyses in which the 95% prediction intervals could be calculated (n=10), the intervals included the null-value, which means that future observations could fall into the area with no statistically significant effect (Table 2).

Significant heterogeneity (I²>50%) was observed in seven meta-analyses, while low heterogeneity (I²<50%) was observed in meta-analyses on the efficacy of PA interventions in children with ADHD, cancer patients/survivors, children with cerebral palsy for social outcomes, and children with obesity for self-esteem (Table 2). Risk of small study effects bias was observed in eight meta-analyses, while the excess of significance bias was identified in two. Some meta-analyses (n= 4) consisted of few studies (n≤4; 433 participants). On the basis of these calculations, the strength of association was categorized as weak (Class IV) in all the meta-analyses when an association was detected (n=9). According to GRADE, the credibility of evidence was moderate for evidence contributing to self-esteem outcome, and ranged from moderate to very low for the other outcomes (Figure 2). The main reasons for evidence downgrading were inconsistency (with two meta-analyses with heterogeneity > 85%) and the risk of publication bias.

**DISCUSSION**

The present umbrella review generated 12 meta-analyses from 112 studies assessing the efficacy of PA interventions on a range of psychosocial outcomes in 21232 children and adolescents. To our knowledge, this umbrella review is the first to systematically and quantitatively report on the effects of PA interventions on psychosocial outcomes across different population groups of children and adolescents. Overall, available experimental evidence appeared to suggest that PA interventions might have beneficial effects on a spectrum of psychosocial outcomes, ranging from lowering psychological symptoms of common mental disorders (i.e., depression, anxiety) to improvement of psychological wellbeing and social outcomes. Interventions included in the present work are innovative multidisciplinary strategies for children and adolescents to promote psychological wellbeing considered along a continuum from ill-health to positive mental health, in line with a recent Lancet Commission on Global Mental Health and Sustainable Development which advocated the importance of implementing different intervention strategies for promoting mental health in a developmental perspective.53 Among these strategies, PA interventions might be considered for improving psychosocial outcomes, although traditionally interventions targeting psychosocial outcomes were mostly based on verbal and cognitive processing of experiences, feelings and behaviors, often applying a cognitive-behavioral perspective10,11 instead of an integration of the body-mind (inter)connection.

Even though positive results for PA interventions have been identified on the majority of outcomes, effect sizes were only one element of the overall methodological evaluation of the included systematic reviews. The overall evaluation qualifying our certainty surrounding the identified effects, and consequent interpretation of results is composed of effect sizes, umbrella review criteria, and GRADE methodology. Umbrella review criteria highlighted a weak (Class IV) strength of associations for all populations, interventions and outcomes, and GRADE assessment suggested a variable certainty of evidence. In particular, umbrella review criteria such as between-study heterogeneity, prediction intervals including the null-value, and risk of small-study effects bias were the main factors bringing down the overall strength of associations to the weak category. This brings out specific areas where top tier evidence is currently lacking. Firstly, we identified a general research gap in the population of children and adolescents, as many meta-analyses were excluded in the screening process because of a focus on adults, where most evidence is available.54 Similar conclusions were reached by a narrative overview of reviews which synthesized evidence on chronic PA participation and mental health in youths and young adults. Authors collected five reviews concerning PA and depression, four reviews on anxiety, three focused on self-esteem, seven focused on cognitive functioning, and two reviews covering multiple mental health outcomes (i.e., depression and anxiety). Only a minority of the included reviews focused on children and adolescents, with young adults and mixed populations of children and young adults mostly represented.55 Secondly, there are clinically relevant population groups of children and adolescents who could not be included in this umbrella review, because of the absence of quantitative data. For example, we were able to identify systematic reviews on relevant clinical conditions or disabilities such as epilepsy56, down syndrome57, diabetes58-60, HIV61, burns consequences62, and other types of disabilities or impairments, but psychosocial outcomes were not reported or not available in a form suitable for re-analyses, or were available for adults only. Moreover, there is a set of psychosocial outcomes like self-esteem, general functioning, and self-perception/competence63 that are crucially important in the developmental phase, but they were only considered in isolated trials or not assessed. Thirdly, almost no information was available in terms of interventions type and dosage, as well as on PA intervention acceptability, risks and benefits in more vulnerable groups like children and adolescents with multiple clinical conditions or exposed to traumatic events64. A recent overview collecting six systematic reviews with a focus on organized activities (sport and non-sport) in children and adolescents reached similar conclusions, as it narratively highlighted a small positive impact of organized activities on mental health, but also underlined the high heterogeneity across studies in terms of intervention intensity/dosage, duration, aims, and implementation settings65. Fourthly, we were not able to summarize the long-term effects/effectiveness of PA interventions on psychosocial outcomes, as almost no studies collected follow-up data. We argue that this gap in knowledge is particularly relevant, as long-term data would be particularly useful to inform on the value of the integration of PA activities into the routine activities of existing services. A recent systematic review and meta-analysis by Bernal et al.3, who analysed the long-term effectiveness of PA and exercise interventions on cognitive functioning in people affected by childhood cancer, demonstrated the positive role of PA in managing/buffering cancer-related cognitive impairment over the years. Similarly, the effects of PA interventions on psychosocial outcomes over time may generate important knowledge for their appropriate scale up in practice.

Our findings should be considered in light of some limitations. Firstly, we included meta-analyses that pooled together different types of PA interventions, which differed in terms of physical movement, exercises, but also in terms of dosage, administration mode, and implementation setting. Similarly, different age groups were pooled together. As these variables were only fragmentarily reported, no subgroup analyses could be performed to test whether they contributed to differences in interventions effectiveness and heterogeneity. Secondly, the included systematic reviews had methodological shortcomings that might be a source of bias. Frequently reported review shortcomings, detected by AMSTAR-2, were absence of a review protocol describing review methods before the review was done, lack of details on language restrictions in the search strategies, and lack of reporting of the references of excluded studies. Additionally, the risk of bias tool and publication bias were not taken into account by authors of original systematic reviews when discussing the results. These limitations decreased the strength of associations and credibility of evidence. Thirdly, as the umbrella review methodology is often based on statistical re-analysis of meta-analyses, we only included systematic reviews that applied a quantitative approach to data presentation, whereas systematic reviews providing qualitative descriptions of the included studies, without applying metanalytic techniques, were excluded. For example, systematic reviews that assessed the efficacy of PA interventions in clinical conditions or disabilities such as epilepsy, congenital heart disease, down syndrome, post-burn and concussion, chronic pain, diabetes and disabilities were excluded, because of the absence of meta-analysis.

In conclusion, the benefit of PA interventions on psychosocial outcomes in children and adolescents with or without any physical or mental health conditions is supported by evidence of variable certainty with weak strength of associations. In terms of clinical implications, our results suggest that PA interventions may be considered a promising intervention strategy for improving psychological outcomes in healthy children and in those with disabilities. In addition, PA may become a complement to other interventions for complex clinical conditions, such as those requiring pharmacologic treatments. Clinicians should be aware of the importance of psychological outcomes as an integral part of the evaluation process of any PA intervention. This is especially in light of the long-term consequences of psychological symptoms on the general health of individuals. Consequently, and in order to obtain more detailed insights, future studies in this population group should always include psychosocial outcomes as an important dimension of social and mental health, and should separately report the effects of PA interventions in children and adolescents. Details on intervention type, dosage and acceptability, as well as the maintenance of effect in the long-term, should be better documented, aiming to eventually generate a whole body of evidence to effectively inform policy decisions and everyday social and health care.

**Data sharing**

All data included in this umbrella review were extracted from publicly available systematic reviews.

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**Table 1.** Characteristics of the 18 included meta-analyses that were re-analysed producing 12 new meta-analyses

|  |  |  |  |
| --- | --- | --- | --- |
| **Study** | **Population** | **Intervention** | **Mental Health Outcomes** |
| **Condition** | **Age range** | **Type of physical activity** | **Type of outcomes** |
| **Cerrillo-Urbina 2015** | ADHD | 6-18 years | aerobic exercise and yoga programmes  | psychological symptoms (anxiety, depression, emotional disorders); social outcomes |
| **Dias Do Lago 2020** | cancer |  3-18 years | endurance, strenghtening, stretching training,  and relaxation exercices  | psychological wellbeing |
| **Mizrahi 2017** | cancer  | 4-18 years | physiotherapy plus home exercise and stretching, home-based aerobic exercise | psychological wellbeing  |
| **Zhi 2019** | cancer  | 13-18 years | online exercise, active exercise intervention | psychological wellbeing  |
| **Ryan 2017** | cerebral palsy | <10- 18 years | aerobic exercise, resistance training, mixed training (aerobic, anaerobic and muscle strenghtening). | psychological wellbeing; social outcomes |
| **Toovey 2017** | cerebral palsy | school-aged children | Task-specific gross motor skills training (Motor learning coaching; Hand arm bimanual intensive training including lower extremity; Swimming skills programme; overground walking; functional therapy; regular physiotherapy + sit-to-stand task | psychological wellbeing |
| **Beggs 2013** | chronic respiratory disease (asthma) | 5-18 years | swimming training | psychological wellbeing |
| **Joschtel 2018** | chronic respiratory disease (asthma and cistic fybrosis) | 5-17 years | exercise training, running, cycling, swimming, circuit training, a combination of aerobic training and strength training, balance and coordination, group exercises, basketball, thai chi and running relays games | psychological wellbeing |
| **Radtke 2017** | chronic respiratory disease (cistic fybrosis) | 8-16 years | supervised aerobic and anaerobic (and combined) exercise | psychological wellbeing |
| **Carter 2016** | depression | 13-17 years | dance movement therapy, aerobic and strengthening exercises, sport, yoga, walking | psychological symptoms (depressive symptoms) |
| **Radovic 2017** | depression | 13-18 years | aerobic exercise, mixed aerobic exercise and sports training, and resistance exercise | psychological symptoms (depressive symptoms) |
| **Andermo 2020** | general population | 4-18 years | body, body-education, body-mind, body-mind education. Physical exercise, sport and recreation, yoga and playground modifications, more extensive programmes | psychological symptoms (anxiety, depression, emotional problems, negative affect and internalizing mental health problems); psychological wellbeing, self-esteem and self-worth, resilience, positive mental health) |
| **Kallapiran 2015** | general population | 8-18 years | yoga, mindfulness (mindfulness-based stress reduction (MBSR),  mindfulness-based cognitive therapy (MBCT)), meditation | psychological wellbeing; psychological symptoms (stress, anxiety, depressive symptoms) |
| **Rodriguez-Ayllon 2019** | general population | 13-18 years | aerobic, resistance and combined exercise, yoga, sports | Psychological symptoms (generic ill-being, depression, anxiety, stress); psychological well-being  |
| **Yu 2018** | neuromotor impairments | 5-12 years | motor skill interventions (fundamental movement skills training; aquatic physiotherapy; pure motor skills training, psychological training on self-concept, integrated psychomotor training; kinesthetic training, sensorymotor training) | psychological symptoms |
| **Al-Khudairy 2017** | obesity |  12-17 years | simple physical activity and multi-component programs (involving also diet), counselling, online interventions, yoga  | psychological wellbeing; self-esteem |
| **Colquitt 2016** | obesity |  0-18 years | "LAUNCH" (Learning about Activity and Understanding Nutrition for Child Health) home visits' project | psychological wellbeing |
| **Mead 2017** | obesity | 6-11 years | family-based behavioral treatment; low-intensity intervention (not specified); football training programme; "Mind, Exercise, Nutrition, Do it" program | psychological wellbeing; self-esteem |

**Table 2.** Characteristics, quantitative synthesis and umbrella review criteria of the meta-analyses assessing the efficacy of physical activity interventions on psychosocial outcomes.

Note: ADHD = attention deficit and hyperactivity disorder; NA = not applicable; SMD = standardized mean difference

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Meta-analysis, by first-author name** | **Population** | **Outcome** | **Studies** | **Participants (intervention/control)** | **Significance threshold reached (random-effect model)** | **I2** | **Predictive interval** | **Random-effects SMD (95% CI) of the largest study** | **Egger’s test P** | **Significant studies: observed** | **Significant studies: expected** |
| **Cerrillo-Urbina 2015** | ADHD  | Psychological symptoms | 2 | 64 (28/36) | 0.371  | 0.00 | NA | 0.84 (0.18 to 1.51) | / | 0.87 | 1.00 |
| **Cerrillo-Urbina 2015** | ADHD  | Social outcomes | 2 | 53 (26/27) | 0.400 | 0.00 | NA | 0.41 (-0.29 to 1.12) | / | 0.71 | 0.00 |
| **Lago 2020, Mizrahi 2017, Zhi 2019** | Cancer  | Psychological wellbeing | 6 | 234 (132/102) | N/A | 42.70 | -1.57 to 3.20 | 0.99 (-7.27 to 9.25) | 0.400 | 1.00 | 3.29 |
| **Ryan 2017** | Cerebral palsy | Social outcomes | 3 | 192 (100/92) | 0.015 | 0.00 | -1.50 to 2.21 | 0.25 (-0.17 to 0.67) | 0.050 | 1.00 | 0.00 |
| **Ryan 2017, Toovey 2017** | Cerebral palsy | Psychological wellbeing | 4 | 124 (66/58) | 0.407 | 54.80 | -2.20 to 2.76 | 0.11 (-0.38 to 0.94) | 0.397 | 2.00 | 1.00 |
| **Andermo 2020, Kallapiran, Rodriguez-Ayllon 2019** | General population | Psychological symptoms | 29 | 7340 (3790/3550) | 0.013 | 73.30 | -0.35 to 0.63 | -0.09 (-0.20 to 0.02) | 0.005 | 12.00 | 12.00 |
| **Andermo 2020, Rodriguez-Ayllon 2019** | General population | Psychological wellbeing | 35 | 15753 (7641/7151) | N/A | 94.80 | -0.60 to 1.33 | 0.02 (-0.06 to 0.09) | 0.023 | 13.95 | 12.00 |
| **Joschtel 2018, Beggs, 2018, Radke 2017** | Chronic respiratory diseases | Psychological wellbeing | 8 | 257 (145/112) | 0.001 | 85.80 | -0.22 to 1.22 | 0.26 (-0.05 to 1.58) | 0.010 | 3.47 | 4.00 |
| **Carter 2016, Radovic 2017** | Depression | Psychological symptoms | 15 | 612 (330/282) | 0.004 | 56.60 | -1.32 to 0.45 | -0.21 (-0.63 to 0.20) | 0.415 | 4.98 | 4.00 |
| **Yu 2018** | Neuromotor impairments | Psychological symptoms | 7 | 362 (168/194) | 0.015 | 71.90 | -0.92 to 2.09 | 0.63 (0.04 to 1.22) | 0.075 | 4.00 | 4.00 |
| **Al-Khudairy 2017, Mead 2017, Colquitt 2016**  | Obesity | Psychological wellbeing | 13 | 1174 (675/489) | 0.010 | 76.90 | -0.61 to 1.35 | 0.19 (-0.12 to 0.51) | 0.110 | 2.00 | 5.51 |
| **Al-Khudairy 2017, Mead 2017** | Obesity | Self-esteem | 8 | 757 (427/330) | 0.050 | 4.60 | -0.06 to 0.33 | 0.27 (-0.04 to 0.58) | 0.047 | 1.00 | 1.48 |