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SYSTEMATIC REVIEW

Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis

María Rodriguez-Ayllon[1] · Cristina Cadenas-Sánchez[1] · Fernando Estévez-López[2,3] · Nicolas E. Muñoz[1] · Jose Mora-Gonzalez[1] · Jairo H. Migueles[1] · Pablo Molina-García[1,4] · Hanna Henriksson[1,5] · Alejandra Mena-Molina[1] · Vicente Martínez-Vizcaíno[6,7] · Andrés Catena[8,9] · Marie Löf[5,10] · Kirk I. Erickson[11] · David R. Lubans[12] · Francisco B. Ortega[1,10] · Irene Esteban-Cornejo[1,13]

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Abstract

Background Evidence suggests that participation in physical activity may support young people's current and future mental health. Although previous reviews have examined the relationship between physical activity and a range of mental health outcomes in children and adolescents, due to the large increase in published studies there is a need for an update and quantitative synthesis of effects.

Objectives The objectives of this study were to determine the effect of physical activity interventions on mental health outcomes by conducting a systematic review and meta-analysis, and to systematically synthesize the observational evidence (both longitudinal and cross-sectional studies) regarding the associations between physical activity and sedentary behavior and mental health in preschoolers (2–5 years of age), children (6–11 years of age) and adolescents (12–18 years of age).

Methods A systematic search of the PubMed and Web of Science electronic databases was performed from January 2013 to April 2018, by two independent researchers. Meta-analyses were performed to examine the effect of physical activity on mental health outcomes in randomized controlled trials (RCTs) and non-RCTs (i.e. quasi-experimental studies). A narrative synthesis of observational studies was conducted. Studies were included if they included physical activity or sedentary behavior data and at least one psychological ill-being (i.e. depression, anxiety, stress or negative affect) or psychological well-being (i.e. self-esteem, self-concept, self-efficacy, self-image, positive affect, optimism, happiness and satisfaction with life) outcome in preschoolers, children or adolescents.

Results A total of 114 original articles met all the eligibility criteria and were included in the review (4 RCTs, 14 non-RCTs, 28 prospective longitudinal studies and 68 cross-sectional studies). Of the 18 intervention studies, 12 (3 RCTs and 9 non-RCTs) were included in the meta-analysis. There was a small but significant overall effect of physical activity on mental health in children and adolescents aged 6–18 years (effect size 0.173, 95% confidence interval 0.106–0.239, $p < 0.001$, percentage of total variability attributed to between-study heterogeneity [I^2] = 11.3%). When the analyses were performed separately for children and adolescents, the results were significant for adolescents but not for children. Longitudinal and cross-sectional studies demonstrated significant associations between physical activity and lower levels of psychological ill-being (i.e. depression, stress, negative affect, and total psychological distress) and greater psychological well-being (i.e. self-image, satisfaction with life and happiness, and psychological well-being). Furthermore, significant associations were found between greater amounts of sedentary behavior and both increased psychological ill-being (i.e. depression) and lower psychological well-being (i.e. satisfaction with life and happiness) in children and adolescents. Evidence on preschoolers was nearly non-existent.

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Conclusions Findings from the meta-analysis suggest that physical activity interventions can improve adolescents' mental health, but additional studies are needed to confirm the effects of physical activity on children's mental health. Findings from observational studies suggest that promoting physical activity and decreasing sedentary behavior might protect mental health in children and adolescents. PROSPERO Registration Number: CRD42017060373.

Key Points

Physical activity interventions have a small positive effect on mental health in adolescents; however, well-designed intervention studies are needed to confirm these findings.

The majority of studies in this review involved adolescent populations; therefore, future research should focus on preschoolers and children.

Observational evidence suggests that promoting physical activity and decreasing sedentary behavior might support mental health in children and adolescents. Additional studies answering the questions *when, where, what, how much* and *with whom* are needed to better understand the relationship between physical activity, sedentary behavior and mental health in young people.

1 Introduction

Mental disorders are expected to be one of the main causes of disability in developed countries by 2020 [1]. Prevention of mental disorders not only depends on the absence of psychological ill-being but also on the presence of psychological well-being. For the purpose of this review, the term psychological ill-being will be used to represent unpleasant feelings or emotions that impact the level of functioning, as well as preclinical and clinically diagnosed psychological disorders (e.g. depression and anxiety) [2, 3]. Conversely, psychological well-being is the combination of positive affective states and functioning with optimal effectiveness in personal and social life [2, 3]. Childhood and adolescence represent periods of rapid growth and development characterized by neuronal plasticity [4, 5], development of identity [6], and the establishment of behavioral patterns that may enhance or diminish mental health [7]. Thus, it is of interest to identify environmental exposures during these ages that may decrease the development of mental health disorders later in life [8].

Physical activity and sedentary behavior are two independent but related lifestyle behaviors that occupy all waking hours of a day. Physical activity is defined as any bodily movement that increases energy expenditure above resting energy expenditure [9]. Exercise is a subset of physical activity that is planned, structured, repetitive and purposeful that might have a different effect on mental health depending on the constituent elements (e.g. competitive vs. non-competitive) [10]. Sedentary behavior is defined as any waking behavior characterized by an energy expenditure ≤ 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture [11].

The underlying mechanisms responsible for the effects of physical activity and sedentary behavior on mental health are unclear; however, several hypotheses have been proposed. For instance, it seems that participation in physical activity might enhance mental health via the release of endorphins [12], increases in brain-derived neurotrophic factor [13] and growth of new capillaries [14], which in turn might enhance the structural and functional composition of the brain. Other theoretical frameworks propose that increased levels of physical activity and reduced sedentary behavior might help to satisfy basic psychological needs (e.g. social connectedness, self-acceptance, and purpose in life), and consequently improve overall mental health in young people [15].

The recently published second edition of the Physical Activity Guidelines for Americans highlights that moving more and sitting less have enormous benefits for everyone [16]. However, the benefits of physical activity for mental health has received less attention in comparison to the physical health benefits. A previous review of reviews, published in 2011, showed that physical activity has beneficial effects on mental health in children and adolescents [17]. Nevertheless, the majority of included reviews were considered to be of low quality [17]. From 2010 to 2017, several systematic reviews and meta-analyses on this topic were published [18]. Most of the studies concluded there was a small significant overall association between physical activity and indicators of mental health [10, 19–24]; however, these systematic reviews and meta-analyses were focused on specific mental health outcomes (e.g. depression) [19–21, 24, 25], specific activities [26], mechanisms (i.e. neurobiological, psychosocial, and behavioral) [15] or specific age ranges (e.g. adolescents) [10]. Therefore, it is important to examine the overall effect of physical activity on the mental health of young people in order to guide health policies for this population.

Sedentary time has become a central component of our daily lives [27]. A review of reviews demonstrated that screen time was negatively associated with young people's mental health in cross-sectional studies [17]. A recent systematic review in adolescents showed that leisure screen-based sedentary behaviors were related to higher psychological distress and lower self-esteem [28]. However, time spent in leisure screen-based activities is only a small part of the total

sedentary time, and each sedentary activity may have a different effect on mental health [29]. For example, playing an instrument or reading a book may positively influence mental health, while excessive television viewing may diminish mental health. A previous systematic review concluded that, due to the low quality of the research conducted, the relationship between sedentary behavior and indicators of mental health in school-aged children and adolescents was indeterminate [30].

In summary, systematic reviews and meta-analyses have focused on specific lifestyle behaviors, mental health outcomes or a narrow age range, which dramatically limits their conclusions [31]. Therefore, it is imperative to extend and update all relevant literature, mapping the links between physical activity, sedentary behavior and mental health in preschoolers, children and adolescents. Although intervention studies can provide evidence for cause and effect, observational longitudinal studies provide complementary information, particularly about the longer-term effects of physical activity and sedentary behavior. Therefore, an integrated review of both intervention and observational studies is needed.

The aims of this review were to (1) determine the overall effect of physical activity on mental health in preschoolers, children and adolescents by conducting a systematic review and meta-analysis of available intervention studies; and (2) systematically synthesize recent observational evidence (both longitudinal and cross-sectional) on the association between physical activity and sedentary behavior with mental health in various pediatric age groups.

2 Methods

This study follows the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [32]. Inclusion and exclusion criteria, as well as analytical methods, were specified in advance and registered in the PROSPERO (http://www.crd.york.ac.uk/PROSPERO) database, an international database of systematic reviews (PROSPERO reference number, CRD42017060373).

2.1 Search Strategy and Inclusion Criteria

The search was conducted in the PubMed and Web of Science electronic databases, and the dates of the published articles included in the search were from 1 January 2013 to 9 April 2018. Search terms were selected based on the eligibility criteria and outcomes of interest described in the following paragraph (see electronic supplementary Table S1). Two researchers (MRA and NEM) independently identified relevant articles by screening the titles and reviewing the abstracts. Full-text articles deemed eligible for review were examined to determine final eligibility; this process was conducted by the same two individuals (MRA and NEM).

Inclusion criteria were (1) design: intervention studies (randomized controlled trials [RCT], non-RCTs), and prospective longitudinal and cross-sectional studies focused on physical activity, sedentary behavior and mental health; (2) language criterion: articles only published in English or Spanish; (3) age criterion: preschoolers (2–5 years of age), children (6–11 years of age) and adolescents (12–18 years of age); and (4) topic criterion: articles examining the association between physical activity and/or sedentary behavior and at least one psychological ill-being (i.e. depression, anxiety, stress or negative affect) and/or psychological well-being (i.e. self-esteem, self-concept, self-efficacy, self-image, positive affect, optimism, happiness and satisfaction with life) outcome. With regard to exclusion criteria, we did not include conference proceedings and other types of grey literature because of the feasibility and limitations in the quality of reporting in conference abstracts [33]. Studies including individuals with physical or psychological disorders diagnosed by medical records, elite athletes, and animals were also excluded. Lastly, multiple health behavior intervention studies were excluded (e.g. co-interventions such as a dietary program combined with physical activity) because they preclude drawing conclusions on the isolated effect of physical activity or sedentary behavior on mental health outcomes.

2.2 Data Extraction

One author (MRA) extracted the following information from each eligible study: study background (name of the first author, year, and study location), sample characteristics (number of participants, age of participants, and number of girls and boys), design (intervention [RCT or non-RCT], or observational [cross-sectional or longitudinal]), and instruments used to assess physical activity and/or sedentary behavior and mental health outcomes. For intervention studies (RCTs and non-RCTs), we also extracted weeks of intervention, description of the program, intensity, duration and frequency. For longitudinal studies, we also extracted years of follow-up.

To reduce heterogeneity, sedentary behavior data were combined into three groups: recreational screen time (i.e. viewing television, using computer games, playing video games, using a mobile phone, using the internet), non-recreational screen time (i.e. homework using a screen) and non-screen time (i.e. music, passive transport, homework, reading, creative hobbies, talking). In regard to physical activity, data from general physical activity, outdoor play and sport participation were combined.

2.3 Meta-Analysis of Intervention Studies

All statistical analyses were performed using the Comprehensive Meta-Analysis software (version 3; Biostat Inc.,

Englewood, NJ, USA). A p value < 0.05 was accepted to indicate statistical significance. The meta-analysis of the intervention studies (RCTs and non-RCTs) was performed comparing the intervention versus control groups. Mean difference (post-test minus baseline values) and standardized mean difference were calculated for each group.

We also calculated the effect size (ES) using Cohen's d and 95% confidence intervals (CIs) for standardized mean difference (post minus pre) on overall mental health (i.e. psychological ill-being and psychological well-being outcomes). For overall analyses, we reversed the ES obtained in studies focused on psychological ill-being in order to present results in the same direction (the higher the ES, the better the effect, as occurs with psychological well-being outcomes). Pooled ES of the effect of physical activity on psychological ill-being and psychological well-being was obtained using random-effects models. Heterogeneity was measured using the I^2 statistic (total variability attributed to between-study heterogeneity, i.e. $I^2 < 25\%$, 50% and 75% was considered as low, moderate and high heterogeneity, respectively) [34]. In addition, we examined how the duration of the physical activity interventions (grouped as < 60 or ≥ 60 min) could influence mental health. Funnel plots were calculated and the Egger's test was conducted to assess risk of publication bias. The trim and fill procedure was also performed to adjust for the suspected publication bias where the pooled ES was recalculated to incorporate hypothetical missing studies if necessary.

Subgroup analyses were performed comparing the RCT and non-RCT studies. In addition, we performed a sensitivity analysis excluding those studies categorized as high risk of bias. As secondary analysis, we performed one meta-analysis of only those studies that measured psychological ill-being outcomes and another meta-analysis of only those studies that measured psychological well-being outcomes. Lastly, we performed a subgroup analysis examining preschoolers, children and adolescents, separately.

2.4 Data Synthesis of Observational Studies

Findings from observational studies were rated using the method first employed by Sallis et al. [35], and more recently used by Lubans et al. [36] and Smith et al. [37]. If 0–33% of studies reported a statistically significant association for the outcome of interest, the result was classified as no association (Ø); if 34–59% of studies reported a significant association, or if fewer than four studies reported on the outcome, the result was classified as being inconsistent/uncertain (?); and if $\geq 60\%$ of studies found a statistically significant association, the result was classified as positive (+) or negative (−), depending on the direction of the association. When the association was examined only in girls or boys, we specified it as '♀' or '♂', respectively. If the association between independent and dependent variables was tested or was significant in only one sex (girls or boys), we quantified it with a 0.5 score instead of 1.

2.5 Criteria for Risk of Bias Assessment

Risk of bias was individually assessed for each eligible study by two researchers (MRA and FEL) and disagreements were solved in a consensus meeting. Inter-rater agreement for the risk of bias assessment was determined by the percentage agreement between evaluators (MRA and FEL). Furthermore, an intraclass correlation coefficient (ICC) analysis was conducted using SPSS software, version 21.0 (IBM Corporation, Armonk, NY, USA).

Different checklists, depending on the study design, were used to assess the risk of bias. First, the Cochrane Collaboration's tool was used for assessing risk of bias in RCTs. The scores for each criterion were summed to provide a total score out of 7, using the following categories: 1–2 'low risk', 3–4 'medium risk', and 5–7 'high risk' [38]. The criteria for assessing risk of bias in non-RCTs, prospective longitudinal studies and cross-sectional studies were created based on the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) criteria [39] and the Effective Public Health Practice Project (EPHPP) [40]. A risk of bias score was calculated based on the following five criteria, first employed by Smith and Madden [41]: (1) adequate description of the study sample (i.e. number of participants, mean age and sex); (2) adequate assessment/reporting of physical activity (i.e. validity/reliability of physical activity measurement reported and/or detailed description of the testing protocol); (3) adequate assessment of the mental health outcomes (i.e. validity/reliability of the outcome measure reported and/or measurement procedure adequately described); (4) adequate adjustment of confounders (i.e. age and sex); and (5) description of both the numbers and reasons for withdrawals and dropouts. Based on previous methodology, the scores were summed to provide a total score out of 5, using the following categories: 0–2 'low risk', 3 'medium risk', and 4–5 'high risk'.

3 Results

3.1 Selection Process

The search yielded 4624 original articles, from which 282 were screened in full-text (see Fig. 1 for full search details). Finally, a total of 114 original articles were included in the systematic review: 4 RCTs, 14 non-RCTs, 28 prospective longitudinal studies and 68 cross-sectional studies. Of the 18 intervention studies, 12 (3 RCTs [42–44] and 9 non-RCTs [45–53]) were included in the meta-analysis and 6

were excluded (3 did not report the ES data needed [54–56], 2 included an active control group performing other types of physical activity [57, 58] (i.e. yoga vs. combined exercise [57] and Tai-Chi vs. gymnastics [58]) and 1 did not include a control group [59]). The list of excluded articles categorized based on the exclusion criteria can be seen in electronic supplementary Table S2.

3.2 Summary of Included Studies

A detailed description of the intervention studies (RCTs and non-RCTs) is provided in Table 1. We conducted a meta-analysis of the RCT and non-RCT studies (see Fig. 2) to determine the overall effect of physical activity on mental health in different pediatric age groups. A summary of the associations of different types of physical activities (i.e. physical activity, sport participation and outdoor play) and different types of sedentary behaviors (i.e. recreational screen time, non-recreational screen time and non-screen time) with psychological ill-being and psychological well-being in the different pediatric age groups is reported in Tables 2 and 3, respectively. Further details on the study characteristics of prospective longitudinal studies and cross-sectional studies are presented in electronic supplementary Tables S3 and S4, respectively. Moreover, the results of the risk of bias assessment can be found in electronic supplementary Tables S5–S8.

3.3 Characteristics of Intervention Studies (Randomized Controlled Trials [RCTs] and Non-RCTs)

3.3.1 Sample Characteristics

Sample sizes of intervention studies ($n = 18$) ranged from 20 [48] to 420 [50]. One study did not have a control group [59], while two studies included an active control group performing other types of physical activity [57, 58] (i.e. yoga vs. combined exercise [57] and Tai-Chi vs. gymnastics [58]). Lastly, 10 studies included adolescents [42–46, 49–52, 58], while 8 studies included children [47, 48, 53–57, 59], of whom 4 were focused on overweight/obese adolescents [43, 46] or children [48, 55]. We did not find any studies focused on preschoolers (2–5 years of age).

3.3.2 Outcome Characteristics

Of the 18 studies included in the systematic review, 8 provided data on psychological ill-being [44, 45, 47, 49, 51, 54, 55, 58]. Specifically, 5 studies provided data on generic psychological ill-being [44, 47, 49, 51, 54], 2 on depression [49, 55], 3 on anxiety [49, 55, 58] and 1 on stress [45]. On the other hand, 13 studies provided data on psychological well-being [42–44, 46, 48, 50–53, 56–59]. Specifically, 1 study focused on a total score of psychological well-being [44], 7 on self-esteem [42, 43, 46, 48, 51, 53, 57], 6 on self-image [43, 44, 48, 52, 58, 59], 1 on self-concept [56], 1 on self-efficacy [50, 56], 2 on happiness [53, 58] and 2 on positive emotions [43, 44].

3.3.3 Exposures and Comparison Conditions

Most of the study interventions ranged from 8 to 28 weeks [42–46, 48, 49, 51–57, 59]; however, two studies lasted for more than 28 weeks [47, 58] and one study lasted for < 8 weeks [50]. Of note, our search also included physical activity and sedentary behavior interventions, yet only exercise and sport interventions were available: mind-body exercise programs [45, 50, 52, 53, 57, 58], aerobic exercise programs [43, 44, 55], resistance exercise programs [43], combined exercise programs (aerobic + resistance) [42–44, 47, 49, 56], football [48, 59], exergames [46, 54] and CrossFit [51]. The majority of the studies (80%) implemented exercise sessions for 60 min [42, 46, 48, 51, 52, 55, 58], two to three times per week (80%) [42–44, 46–49, 51–53, 56, 59]. Finally, only five studies reported the intensity during the program (50–80% maximum heart rate) [42, 44, 48, 49, 51]; however, none of them controlled individual intensity, for instance by heart rate monitors, to estimate the time spent in 50–80% of their maximum heart rates.

3.4 Synthesis of Findings

3.4.1 Meta-Analysis of Intervention Studies

Figure 2 presents the meta-analysis of the exercise versus control effects, showing a small significant pooled ES for the efficacy of the exercise on overall mental health (ES = 0.173, 95% CI 0.106–0.239; $p < 0.001$, $I^2 = 11.3\%$). No significant publication bias was detected based on Egger's test ($p = 0.139$) and visual inspection of the funnel plot (Fig. 3). Moreover, the trim and fill procedure showed that the ES estimate was not changed, and thus no correction for potential publication bias was needed. The analysis conducted by meeting the physical activity recommendations during the exercise program (< 60 or ≥ 60 min) showed that those programs with ≥ 60 min of exercise activities significantly improved the overall mental health compared with those peers who engaged in an exercise program of < 60 min (ES = 0.277, 95% CI 0.138–0.415; $p < 0.001$, $I^2 = 37.22\%$) (Fig. 4).

When the analyses were performed separately for RCTs and non-RCTs, the results were ES = 0.094, 95% CI 0.017–0.172; $p = 0.017$, $I^2 = 0\%$ for RCTs, and ES = 0.269, 95% CI 0.137–0.400; $p < 0.001$, $I^2 = 31.8\%$ for non-RCTs. Furthermore, after removing the studies with a high

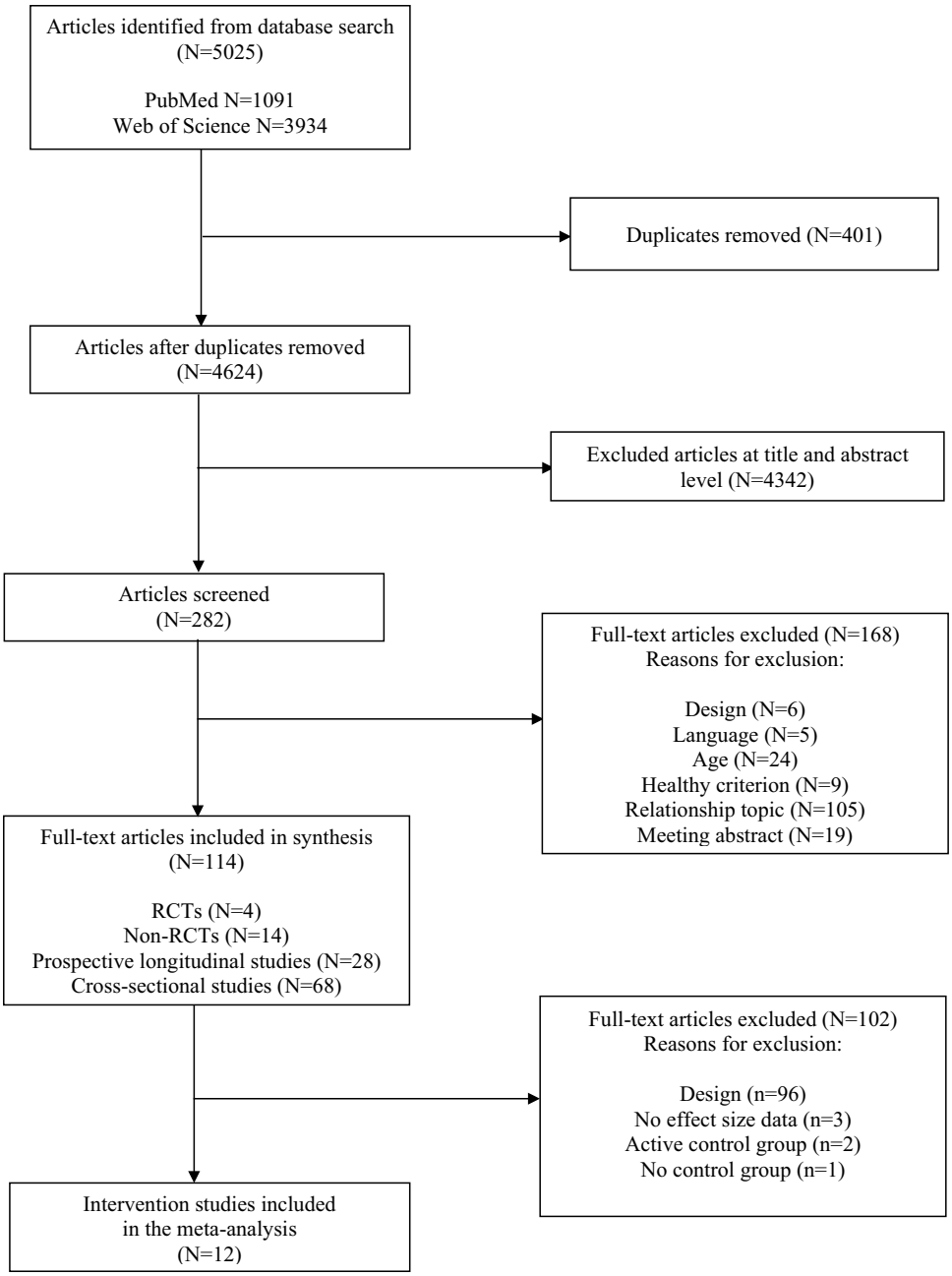


Fig. 1 Results of the study selection process. *RCT* randomized controlled trial

risk of bias, the result was similar (ES = 0.165, 95% CI 0.098–0.232; $p < 0.001$, $I^2 = 10.3\%$) [data not shown].

Secondary analyses showed that exercise improved psychological ill-being (ES = 0.130, 95% CI 0.036–0.224; $p = 0.007$, $I^2 = 0\%$) and psychological well-being (ES = 0.189, 95% CI 0.084–0.294; $p < 0.001$, $I^2 = 32.3\%$) when they were considered as two independent constructs (electronic supplementary Figs. S1a and b, respectively). No significant publication bias was observed for either psychological ill-being or psychological well-being (Egger's test, $p = 0.906$ and 0.138, respectively). Funnel plots are shown in electronic supplementary Fig. S2a and b. Therefore, the trim and fill procedure showed no correction for potential publication bias for psychological ill-being and psychological well-being, respectively.

Lastly, when the analyses were performed separately for children and adolescents (no studies were found in preschoolers), the results were similar for adolescents (ES = 0.181, $p \leq 0.001$; $I^2 = 15.7\%$) and children (ES = 0.209, $p = 0.141$; $I^2 = 0\%$); however, the summary effect for children was not statistically significant.

Table 1 Summary of RCT and non-RCT research investigating the effect of exercise on mental health ($n = 18$)

Risk of bias	Study, year, country	Cases/*n* (age range; % girls) Design; target population	Weeks of intervention; description; intensity; duration; frequency	Mental health indicators Instruments	Main findings
Medium	Telles et al., 2013 [57], India	49/98 (8–13 years; 30.8% girls) RCT; children	12; yoga vs. physical exercise; data not shown; 45 min; 5 d/w	Self-esteem Battle's Self-Esteem Inventory	There was only one significant difference between the groups in social self-esteem that was higher in the exercise group; all other differences were not significant
High	Hasanpour et al., 2014 [42],[a] Iran	33/66 (13–19 years; 100% girls) RCT; adolescents living with no natural family	8; vs. control; 60–80% maximum heart rate; 60 min; 3 d/w	Self-esteem Coopersmith Self-Esteem Inventory	A significant difference between groups was obtained in post self-esteem scores ($p = 0.001$). One month after intervention, results showed that despite the amount of time elapsed, the effects of aerobic exercise still persisted ($p = 0.002$)
Medium	Goldfield et al., 2015 [43],[a] Canada	Aerobic 75/304, resistance 78/304, combined 75/304, controls 76/304 (14–18 years; 70% girls) RCT; obese adolescents	22; aerobic exercise vs. control, resistance exercise vs. control, combined exercise vs. control; data not shown; 45 min; 3 d/w	Mood; body image; global self-esteem Brunel Mood Scale; Multiple Body Self-Relations Questionnaire; Physical Self-Perceptions Questionnaire	All groups (including the control group) improved on body image. Only the resistance group showed a significant reduction in depressive symptoms ($p = 0.02$). The resistance group showed greater increases than controls on global self-esteem but all groups (excluding the control group) improved on vigor and global self-esteem
Medium	Costigan et al., 2016 [44],[a] Australia	Aerobic 21/65, combined 22/65, controls 22/65 (14–16 years; 13% girls) RCT; adolescents	8; high-intensity interval training with aerobic vs. control and combined vs. control); > 85% maximum heart rate; 8–10 min; 3 d/w	Psychological well-being; psychological distress; physical self-concept; feelings state Flourishing; Kessler Psychological Distress; Physical Self-Description; One-item Feelings State	Results were not significant but a small improvement in psychological well-being was observed in the aerobic exercise group (mean change 2.81 [95% CI −2.06 to 7.68], $d = 0.34$). Small improvements in psychological well-being (mean change 2.96 [95% CI −1.82 to 7.75], $d = 0.36$) and perceived appearance (mean change 0.32 [95% CI −0.25 to 0.86], $d = 0.35$], were observed in the combined group. Feelings improved in both groups but were significant only in the aerobic group ($p = 0.001$)

Table 1 (continued)

Risk of bias	Study, year, country	Cases/*n* (age range; % girls) Design; target population	Weeks of intervention; description; intensity; duration; frequency	Mental health indicators Instruments	Main findings
Low	Lee et al., 2013 [45],[a] China	32/69 (11–16 years; 27.5% girls) Non-RCT; adolescents	10; Chen-style Tai Chi vs. control; data not shown; 80 min; 1 d/w.	Stress Perceived Stress Scale	No significant difference was noted in changes in stress levels before and after the intervention between the two groups
Low	Staiano et al., 2013 [46],[a] USA	19/54 competitive, 19/54 cooperative, 16/54 control (15–19 years; 55.6% girls) Non-RCT; overweight/obese adolescents	20; active video-game program (competitive vs. control and cooperative vs. control); data not shown; 30–60 min; 3 d/w	Self-esteem Rosenberg Self-Esteem Scale	The growth curve analysis of self-esteem change yielded no condition effects. There were no significant changes in self-esteem in any group
High	Tubić and Đorđić, 2013 [47],[a] Serbia	17/167 (5–7 years, data not shown) Non-RCT; preschoolers/children	72; exercise vs. control; data not shown; 60 min; 3 d/w	Internalizing problems The Aberrant Behavior Questionnaire	The intervention program had a significant but weak effect on indicators of internalizing problems
Low	Seabra et al., 2014 [48],[a] USA	12/20 (8–12 years; 0% girls) Non-RCT; overweight children	20; football vs. control; > 80% maximum heart rate; 60–90 min; 2 d/w	Body image; self-esteem Collins' Child Figure Drawings Scale; Rosenberg Self-Esteem Scale	Intervention group participants improved their body image (lower values represent better body image) [$F = 6.79$, $p = 0.021$, Cohen's $d = -1.44$] and self-esteem [$F(1, 18) = 4.96$, $p = 0.046$, Cohen's $d = -1.27$]
Low	Bao and Jin et al., 2015 [58], China	80/160 (13–16 years; 53.2% girls) Non-RCT; adolescents	48; Tai Chi vs. gymnastic; data not shown; 60 min; 5 d/w	Physical appearance; anxiety; happiness I am good looking; I cry easily; I am a happy person	Significant reduction of anxiety in the experimental group compared with the control group was observed. No significant differences, in relation to physical appearance and happiness, between the Tai Chi and control groups were found
Low	Bunketorp Käll et al., 2015 [54], Sweden	182/349 (10–12 years; 47% girls) Non-RCT; children	24; non-competitive games vs. control; data not shown; 30–45 min; 4 d/w	Internalizing problems The Strengths and Difficulties Questionnaire	There were no significant differences between the intervention and control groups in internalizing problems (all $p > 0.05$)
Low	Peng et al., 2015 [49],[a] China	62/121 (14–19 years; 50% girls) Non-RCT; adolescents	12; exercise vs. control; 50–80% maximum heart rate; 80 min; 2 d/w	Depression; anxiety stress; emotional problems; psychological distress Mental Health Scale by Wang	The intervention group was superior to the control group in terms of anxiety, depression, emotional imbalance, and psychological imbalance, and the difference was statistically significant ($p < 0.05$)

Table 1 (continued)

Risk of bias	Study, year, country	Cases/*n* (age range; % girls) Design; target population	Weeks of intervention; description; intensity; duration; frequency	Mental health indicators Instruments	Main findings
Medium	Romero-Pérez et al., 2015 [55], México	59/119 (8–11 years, 60% girls) Non-RCT; obese children	20; aerobic exercise vs. controls; 60–80% maximum heart rate; 60 min; 2 d/w	Anxiety; depression Spence Children's Anxiety Scale; Children Depression Scale	The intervention program had a significant but weak effect on total depressive symptoms ($p < 0.05$). There were no significant differences between the intervention and control groups in anxiety levels (all $p > 0.05$)
High	Kyle et al., 2016 [56], Spain	31/63 (10–12 years; 52% girls) Non-RCT; children	28; exercise vs. control; data not shown; data not shown; 2/4 d/w	Self-concept; self-efficacy The Self-Concept Form 5; the Self-Efficacy Scale for Children	The results indicated a significant effect on physical self-concept and academic self-concept. In addition, a significant effect was observed in academic self-efficacy and social self-efficacy
High	Rinaldo et al., 2016 [59], Italy	60 (9–10 years; 0% girls) Pre- and post-intervention; children	12; football without a control group; data not shown; 120 min; 2 d/w	Body image dissatisfaction Discrepancy between the self-perceived figure and the ideal figure	No difference was found in the 9-year-old age group. In the 10-year-old age group, the feel–ideal difference index significantly decreased. The mean index values showed underestimations in both age groups, represented as negative values, especially in the 10-year-old boys
Medium	Das et al., 2016 [50],[a] India	210/420; (11–16 years; 33.3% girls) Non- RCT; adolescents	2; yoga vs. control; data not shown; 60–120 min; every weekday	Self-efficacy (social, academic and emotional self-efficacy) Self-Efficacy Scale for Children	Yoga group showed a significant increase in academic self-efficacy ($p < 0.001$), social self-efficacy ($p < 0.001$), and emotional self-efficacy ($p < 0.001$), whereas there were no significant changes in the scores of the control group
Low	Eather et al., 2016 [51],[a] Australia	51/96 (15.4 years; 51.5% of girls) Non-RCT; adolescents	8; CrossFit vs. control; high intensity; 60 min; 2 d/w	Internalizing problems; self-esteem Strength and Difficulties Questionnaire; Physical Self-Description Questionnaire	There were no significant intervention effects on mental health or potential mediators in the full study sample. Intervention participants categorized as 'at risk' of internalizing problems demonstrated improvements in self-esteem, perceived body fat, perceived appearance, physical self-concept, and total difficulties score. A medium–large positive effect on perceived body fat was also observed in boys

Table 1 (continued)

Risk of bias	Study, year, country	Cases/*n* (age range; % girls) Design; target population	Weeks of intervention; description; intensity; duration; frequency	Mental health indicators Instruments	Main findings
Low	Cox et al., 2017 [52],[a] USA	20/43, (13–17 years, 72% girls) Non-RCT; adolescents	12; yoga vs. control; data not shown; 60 min; 2 d/w	Body surveillance; physical self-worth; body appreciation Objectified Body Consciousness Scale; Physical Self-Description Questionnaire; The Body Appreciation Scale	Results showed significant ($p=0.004$), moderate decreases in trait body surveillance and minimal, non-significant ($p=0.110$) increases in physical self-worth. Change in trait body surveillance was inversely related to change in physical self-worth and body appreciation in yoga participants
Medium	Yook et al., 2017 [53],[a] Korea	23/46 (9–11 years; 46% girls) Non-RCT; children	8; Kinball and yoga vs. control; data not shown; 40 min; 2 d/w	Self-esteem; happiness Rosenberg Self-Esteem Scale; Korean version of the Psychological Well-Being Scale	Participants in the experimental group increased self-esteem ($F=3.47$, $p=0.049$) and happiness ($F=31.61$, $p=0.001$)

RCT risk of bias was assessed using The Cochrane Collaboration's tool. The scores for each criterion were summed to provide a total score out of 7. For rating the overall risk of bias of the RCT studies, the following categories were used: 0 = no risk, 1–2 = low risk, 3–4 = medium risk, and 5–7 = high risk. The non-RCT risk of bias was assessed using the STROBE criteria and a quality assessment tool for quantitative studies from the Effective Public Health Practice Project. The scores for each criterion were summed to provide a total score out of 5. Studies that scored 0–2 = low risk, 3 = medium risk, and 4–5 = high risk. For the risk of bias for each item specifically, see electronic supplementary Tables S3 and S4

RCT randomized controlled trial, *d/w* days per week, *CI* confidence interval, *STROBE* STrengthening the Reporting of OBservational studies in Epidemiology

[a]Article was included in the meta-analysis

3.4.2 Summary of Findings from Observational Studies: Prospective Longitudinal and Cross-Sectional Studies

3.4.2.1 Association Between Physical Activity and Mental Health The association between physical activity and psychological ill-being components (i.e. depression, anxiety, stress, negative affect, total psychological distress) was investigated in 52 studies, of which 13 studies were longitudinal, 35 were cross-sectional, and 4 studies reported both longitudinal and cross-sectional data. Furthermore, the association between physical activity and psychological well-being components (i.e. self-esteem, self-concept, self-efficacy, self-image, positive affect, satisfaction with life and optimism) was investigated in 39 studies, of which 8 were longitudinal and 31 were cross-sectional.

No studies were conducted on preschoolers, while 11 studies were conducted on children, 63 studies were conducted on adolescents, and three studies were conducted on children and adolescents together. Only five studies evaluated objectively measured physical activity by accelerometry [60–63]. Depression was the most studied psychological ill-being outcome (80%), while self-esteem, self-image and satisfaction with life were the most studied psychological well-being outcomes (28%, 23%, and 30%, respectively).

There was evidence for a statistically significant association between physical activity and depression (28.5 of 43 studies, 66.3%), stress (6 of 6 studies, 100%), negative affect (3 of 4 studies, 75%) and a total psychological distress (5 of 8 studies, 62.5%). There was an unclear association between physical activity and anxiety (7 of 12 studies, 58.3%) in children and adolescents. Regarding psychological well-being outcomes, there was evidence for a statistically significant association between physical activity and self-image (6.5 of 9 studies, 72.2%), satisfaction with life (10 of 12 studies, 83.3%) and total psychological well-being (7 of 7 studies, 100%). There was also an unclear association between physical activity and self-esteem (5 of 11.5 studies, 43.5%). Lastly, there were insufficient studies (< 4 studies) to determine the association between physical activity and self-concept, self-efficacy, positive affect and optimism in children and adolescents.

3.4.2.2 Association Between Sedentary Behavior and Mental Health The association between sedentary behavior and psychological ill-being outcomes (i.e. depression, anxiety, stress, negative affect) was investigated in 32 studies, of which 8 were longitudinal, 19 were cross-sectional, and 5 reported both longitudinal and cross-sectional data. The association between sedentary behavior and psychological well-being outcomes (i.e. self-esteem, self-concept, self-efficacy, self-image, positive affect, satisfaction with life and optimism) was investigated in 16 studies, of which 3 were longitudinal and 13 were cross-sectional.

Only 3 studies were conducted on preschoolers, 8 studies were conducted on children, 28 studies were conducted on adolescents, and 3 studies were conducted on children and adolescents. Only 3 studies evaluated objectively sedentary behavior by accelerometry [64–66]. Depression was the most studied psychological ill-being outcome examined (65%), while self-esteem and self-image were the most studied psychological well-being outcomes (35% and 32%, respectively).

There was only evidence for a statistically significant positive association between sedentary behavior and depression (35 of 21.5 studies, 61.4%). However, the associations between sedentary behavior and anxiety (4.5 of 10 studies, 45%) and total psychological distress (7 of 17 studies, 41.1%) were considered to be unclear. Insufficient studies were found testing the association between sedentary behavior and stress [67] and negative affect [68] in children and adolescents. Regarding psychological well-being, there was evidence for a statistically significant inverse association between sedentary behavior and satisfaction with life (4 of 5 studies, 80%). There was an unclear association between sedentary behavior and self-esteem (7 of 14.5 studies, 48%), self-image (5 of 13.5 studies, 37%) and total psychological well-being score (4 of 9 studies, 44.4%). There were insufficient studies (< 4 studies) testing the association between sedentary behavior and self-concept, self-efficacy, and positive affect, and optimism in children and adolescents.

3.5 Risk of Bias Assessment

There was a strong agreement among researchers in the risk of bias assessment (ICC 0.80). Overall, three RCTs showed medium risk of bias [43, 44, 57], while only one RCT showed a high risk of bias [42]. Furthermore, eight non-RCTs showed low risk of bias [45, 46, 48, 49, 51, 52, 54, 58], three showed medium risk of bias [50, 53, 55] and three showed high risk of bias [47, 56, 59]. Most studies included an adequate description of the study sample (95%), as well as an adequate assessment of outcome measures (93%).

In addition, 20 prospective longitudinal studies showed a low risk of bias (71.4%), and 8 studies showed a medium risk of bias (28.6%). Additionally, 33 cross-sectional studies showed a low risk of bias (48.5%), 19 cross-sectional studies showed a medium risk of bias (28%) and 16 cross-sectional studies showed a high risk of bias (23.5%). Only 46.5% of longitudinal cohort studies used a validated and/or reliable tool to evaluate physical activity or sedentary behavior, while 44% of cross-sectional studies used a validated and/or reliable tool to evaluate physical activity or sedentary behavior.

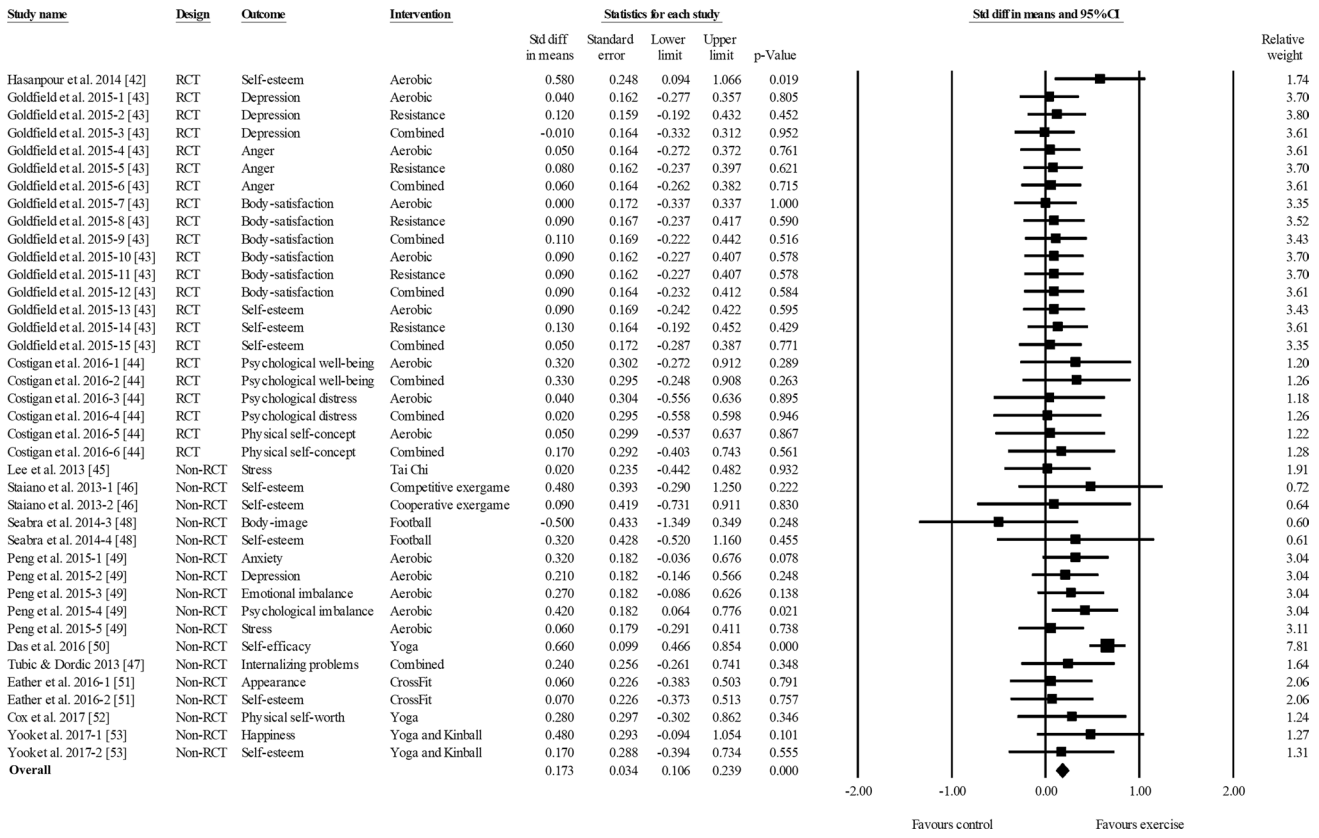


Fig. 2 Forest plot of the pooled effect size and confidence intervals of exercise on overall mental health. *RCT* randomized controlled trial, *Std Diff* standard difference, *CI* confidence interval

4 Discussion

The aims of this review were to (1) determine the overall effect of physical activity on mental health in preschoolers, children and adolescents; and (2) synthesize recent observational evidence (both longitudinal and cross-sectional studies) examining the association between physical activity, sedentary behavior and mental health in these pediatric age groups. The main findings of this review are as follows: (1) there was a small positive effect of exercise interventions on mental health outcomes (i.e. psychological ill-being and psychological well-being) in adolescents; (2) physical activity was inversely associated with psychological ill-being (i.e. depression, stress, negative affect, total physiological distress) and positively associated with psychological well-being (i.e. self-image, satisfaction with life and happiness, and psychological well-being); and (3) there was a positive association between sedentary behavior and depression, and an inverse association between sedentary behavior and satisfaction with life and happiness in children and adolescents. Therefore, findings from the present research suggest that increased physical activity and decreased sedentary behavior may enhance mental health in children and adolescents.

4.1 Effects of Intervention Studies on Mental Health

Our meta-analytical approach allowed us to determine the overall effect of exercise interventions on mental health in children and adolescents. The results suggest that there are small significant effects of exercise on reducing psychological ill-being and improving psychological well-being, as separate effects. Larger effects may not be expected due to the good levels of mental health experienced by the majority of young people. Future interventions are warranted to determine if physical activity effects are consistent in youth with poor mental health. It is important to note that not all young people will experience increased physical competence or improved perceived appearance after completing a physical activity regimen (e.g. by not gaining strength, not experiencing weight loss, or losing games all the time). Indeed, poorly designed physical activity interventions may thwart the satisfaction of young people's needs and lead to decreases in perceived competence and global self-esteem [71]. Therefore, future intervention studies might consider the use of evidence-based physical activity strategies to maximize the positive effect of physical activity on mental health outcomes, e.g. the Supportive, Active, Autonomous,

Table 2 Relationship summary between physical activity and mental health outcomes

Activity	Study	*N*	Population	Psychological ill-being					Psychological well-being							
				Depression	Anxiety	Stress	Negative affect	Distress	Self-esteem	Self-concept	Self-efficacy	Self-image	Positive affect	SWL	Optimism	WB
Longitudinal																
Physical activity	Brunet et al. [78]	1293	Adol	Ø												
	Raudsepp et al. [109]	272	Adol									+♀				
	Stavrakakis et al. [110]	1396	Adol	Ø												
	Toseeb et al. [60][a]	736	Adol	Ø												
	Carter et al. [76]	6504	Adol	–												
	McPhie and Rawana [75]	3676	Adol	–												
	Van Dijk et al. [61][a]	158	Adol	Ø					Ø							
	Hoare et al. [111]	634	Adol	–♂Ø♀												
	Ishii et al. [112]	292	Child		Ø		Ø				+♀–♂					
	Reddon et al. [113]	2278	Child						+							
	Ahn et al. [64]	6153	Child					–								
Sports	Brunet et al. [78]	1293	Adol	–												
	Conn et al. [114]	134	Adol													
	Adachi and Willoughby [81]	1492	Child						Ø							
	Wagnsson et al. [82]	1358	Adol						+							
	Jewett et al. [115]	853	Adol	–		–										
	Vella et al. [116]	4042	Child					–								
	Sabiston et al. [77]	860	Adol	–												
	Vella et al. [80]	4023	Adol					–								
Outdoor play	Shin and You [117]	3188	Adol			–								+		
	Poulsen et al. [118]	1589	Adol	Ø♂–♀												
	Gunnell et al. [93]	236	Adol	Ø	Ø											
Cross-sectional																
Physical activity	Brunet et al. [78]	1293	Adol	–												
	Stavrakakis et al. [110]	1396	Adol	–												
	Bilinski et al. [62]	269	Child											+		
	Bilinski et al. [62][a]	269	Child											Ø		
	Bulhões et al. [119]	1988	Adol	Ø												
	Shriver et al. [120]	214	Child						Ø							
	Fararouei et al. [121]	8159	Adol											+		
	Martikainen et al. [63][a]	252	Child			–										
	Haugen et al. [122]	1207	Adol									+				
	Skrove et al. [123]	7639	Adol	Ø	Ø											
	Altintas et al. [124]	1012	Adol		+♂Ø♀				+♂Ø♀			+♂Ø♀				
	Marques et al. [125]	1082	Adol									–♀				

Table 2 (continued)

Activity	Study	*N*	Population	Psychological ill-being					Psychological well-being							
				Depression	Anxiety	Stress	Negative affect	Distress	Self-esteem	Self-concept	Self-efficacy	Self-image	Positive affect	SWL	Optimism	WB
	Gomes et al. [126]	192	Adol		–							+				
	Kovacs et al. [127]	881	Adol	Ø										Ø	Ø	
	Wang et al. [128]	3096	Adol	–	–											
	Park [129]	73,238	Adol			–										
	Kremer et al. [99]	8256	Adol	–												
	Moljord et al. [130]	11,005	Adol	Ø♂–♀												
	Reigal et al. [83]	2079	Adol								+			+		
	Zach and Netz [131]	48	Adol		Ø											
	Sun et al. [132]	30,399	Adol	–												
	Hoare et al. [133]	800	Adol	Ø												
	Carter et al. [76]	6504	Adol	–												
	Trinh et al. [134]	2660	Adol	Ø				Ø	Ø							
	Ho et al. [84]	775	Adol								Ø					+
	Esmaeilzadeh [135]	456	Child	–♂												
	Reid et al. [136]	20,000	Child/adol				–						+			
	Asare and Danquah [137]	296	Adol	–								+				
	Hyakutake et al. [138]	409	Adol	–												
	Alghadir et al. [139]	150	Child/adol	–												
	Wu et al. [96]	5200	Child					Ø	+							
	Mak et al. [140]	905	Adol						+♂–♀							
	Mouissi [141]	256	Adol													+
	Hayward et al. [142]	3295	Adol	–♂Ø♀												
	Baldursdottir et al. [143]	32,860	Adol	–												
	Szamreta et al. [144]	120	Child									+♀				
	Chae et al. [145]	848	Adol	–												
	McDowell et al. [146]	481	Adol	–	–											
	Khan and Burton [147]	898	Adol	–												
	Martin et al. [148]	13,486	Adol											+		
	Min et al. [149]	370,568	Adol			–								+		
	Taik et al. [150]	1747	Adol	Ø	–	–										
	McMahon et al. [151]	11,110	Adol	–	–											+
	Brunet et al. [78]	1293	Adol	–												
Sports	Noack et al. [152]	595	Adol						Ø			Ø				
	Karr et al. [153]	627	Adol									+♀				
	Gigisladottir et al. [154]	10,987	Adol									+				+
	Booker et al. [155]	4899	Adol				–							+		

Table 2 (continued)

Activity	Study	*N*	Population	Psychological ill-being					Psychological well-being							
				Depression	Anxiety	Stress	Negative affect	Distress	Self-esteem	Self-concept	Self-efficacy	Self-image	Positive affect	SWL	Optimism	WB
	Fatiregun and Kumapayi [156]	1713	Adol	–												
	Dalton et al. [157]	639	Adol					–								
	Booker et al. [158]	4899	Adol											+		
	Sipos et al. [159]	1091	Adol						+							
	Asfou et al. [160]	575	Adol					Ø								
	Baldursdottir et al. [143]	32,860	Adol	–												
	Sabiston et al. [77]	860	Adol	–												
	McMahon et al. [151]	11,110	Adol	–	–											+
	Reverdito et al. [161]	821	Adol								+					
	Schneider et al. [74]	451	Adol									+♀				
AC	Sun et al. [162]	21,596	Child/adol	–												
Dance	Monteiro et al. [163]	283	Adol						Ø♀			−♀				
Outdoor play	Herman et al. [164]	7725	Adol													+
	Badura et al. [165]	10,503	Adol											+		
	Gunnell et al. [93]	236	Adol	Ø	–											
	Janssen [68]	20,122	Adol				–							+		
	Asfour et al. [160]	575	Adol					–								
Summary																
+				0	0.5	0	0	0	5	0	2.5	6.5	1	10	0	7
–				28.5	7	6	3	5	0.5	0	0.5	1	0	0	0	0
Ø				14.5	4.5	0	1	3	6	0	1	1.5	0	2	1	0
Total score				–	?	–	–	–	?	?	?	+	?	+	?	+

If 0–33% of studies reported a significant association, the result was classified as no association (Ø). If 34–59% of studies reported a significant association, or if fewer than four studies reported on the outcome, the result was classified as being inconsistent/uncertain (?). If ≥ 60% of studies found a significant association, the result was classified as positive (+) or negative (−), depending on the direction of the association

SWI satisfaction with life and happiness, *WB* well-being, *AC* active commuting, *Child* children, *Adol* adolescents, + indicates positive association (all samples), – indicates negative association (all samples), Ø indicates no association (all samples), Ø♂ indicates no association (100% boys). Ø♀ indicates no association (100% girls). +/−♂ indicates positive/negative association (100% boys), +/−♀ indicates positive/negative association (100% girls), +/−♂ Ø♀ indicates positive/negative association boys and no association for girls (all samples) Ø♂ +/−♀ indicates no association for boys and positive/negative association girls (all sample)

[a]Objectively measured physical activity

Fair, Enjoyable (SAAFE) principles and practical strategies designed by Lubans et al. [72].

Of note, when the analyses were performed separately for children and adolescents (no studies were found in preschoolers), the results were similar. However, the summary effect was not statistically significant for children. This finding is likely due to the small number of studies including children (only three studies). As such, more studies are needed in preschoolers (2–5 years of age) and children (6–11 years of age) to test the effect of physical activity on mental health.

The relationship between interventions and overall mental health (i.e. both psychological ill-being and psychological well-being) has not been previously studied using meta-analyses. As such, this work complements previous meta-analyses and reviews focused on specific mental health components. For instance, our findings are consistent with the meta-analysis published by Brown et al. [19], who found a small positive effect of exercise on depression. Similarly, our findings are in accord with the review conducted by Larun et al. [69], who found a significant moderate effect of exercise on depressive symptoms. The larger ESs observed in the review by Larun et al. [69] may be explained by their inclusion of children and adolescents with major depression symptoms, who were not included in this review. This hypothesis is consistent with the findings of Carter et al. [70], who found that exercise appears to improve depressive symptoms in adolescents, especially in clinical samples diagnosed with major psychological disorders.

In the present review, we found that compared with those peers who engaged in exercise activities for < 60 min/day, participants who met the physical activity recommendations significantly improved their overall mental health. In the context of the literature, this review expands on the compelling evidence of general cardiometabolic health benefits of physical activity recommendations by providing further evidence for the mental health benefits for children and adolescents [73]. However, it is important to note that most of the intervention studies were non-RCTs (9 of 13 studies, 70%) and none had a low risk of bias. Moreover, most of the intervention studies included adolescents (11 of 13 studies, 85%). Therefore, well-designed intervention studies are needed to confirm our findings, especially in preschoolers and children.

4.2 Observational Studies on the Association Between Physical Activity and Mental Health

Physical activity was inversely associated with psychological ill-being (i.e. depression, stress, negative affect, overall physiological distress) and positively associated with psychological well-being (i.e. self-image, satisfaction with life and happiness, and overall psychological well-being) in children and adolescents. Therefore, findings from the present systematic review suggest that increased levels of physical activity may have a positive effect on mental health in children and adolescents.

Each type of physical activity (e.g. sports participation, outdoor play or active commuting) may contribute in distinct ways to mental health in children and adolescents. For instance, Schneider et al. [74] found that adolescents who participated in non-aesthetic sports (e.g. swimming, horseback, judo or hockey) were satisfied with their physical appearance, while participation in aesthetic activities such as ballet and rhythmic gymnastics was significantly correlated with body dissatisfaction [74]. This is perhaps not surprising considering the strong focus on physical appearance inherent in aesthetic activities. In addition, it seems that adolescents who continue to participate in team sports during high school report lower levels of depression in early adulthood [75, 76]. In contrast, number of years participating in individual sports was not significantly associated with depressive symptoms in early adulthood [76, 77]. Moreover, Brunet et al. [78] found that sport participation during adolescence, but not overall physical activity, was associated with decreased levels of depression in adulthood. Therefore, it seems that sport participation, especially team sports without any aesthetic implication, is the type of physical activity most strongly associated with mental health in young people. This result may be explained by the fact that team sports provide important peer support during childhood and adolescence, which might help to buffer the effects of stressful life events that occur during adolescence [79]. Of note, the relationship between sport and mental health might be potentially bidirectional [80]. Specifically, it seems that young people who experience greater levels of psychological ill-being have lower subsequent levels of sport participation [80]. Therefore, experimental studies on sport participation and mental health are required to draw conclusions about the causality of our findings.

Interestingly, the relation between physical activity and mental health may be influenced by several potential moderators and mediators. For instance, Adachi and Willoughby [81] suggested that enjoyment of physical activity positively influences self-esteem, while Wagnsson et al. [82] demonstrated that perceived sport competence plays an important mediating role in the relationship between sport participation and self-esteem. In addition, Reigal et al. revealed that the association between physical activity and satisfaction with life may be influenced by the social context [83]. Moreover, Ho et al. [84] found that resilience was a significant mediator of the association between physical activity and psychological well-being in young people.

In the present review, we observed a paucity of studies analyzing the relationship between physical activity and anxiety, self-esteem, self-concept, self-efficacy, positive affect

Table 3 Relationship summary between sedentary behavior and psychological health outcomes

Activity	Behavior	Study	*N*	Population	Psychological ill-being					Psychological well-being				
					Depression	Anxiety	Stress	Negative affect	Global distress	Self-esteem	Self-efficacy	Self-image	SWL	WB
Longitudinal														
Recreational ST	TV	Hinkley et al. [90]	3604	Preschoolers					Ø	Ø				Ø
	C	Hinkley et al. [90]	3604	Preschoolers					Ø♂ + ♀	Ø				Ø
	TV and C	Allen and Vella [91]	3956	Preschoolers					+					
	TV and C	Allen and Vella [91]	3956	Child					Ø					
	TV	Bickham et al. [101]	126	Adol	+									
	C	Bickham et al. [101]	126	Adol	Ø									
	M	Bickham et al. [101]	126	Adol	+									
	TV and C	Carter et al. [76]	6504	Adol	Ø									
	TV	Grøntved et al. [102]	435	Child	+									
	C	Grøntved et al. [102]	435	Child	Ø									
	TV and C	Hamer et al. [166]	2038	Adol					Ø					-
	TV	McVeigh et al. [67]	2411	Preschoolers	Ø	Ø	Ø							
	TV and C	Hoare et al. [111]	634	Adol	+♂Ø♀									
	TV and C	Gunnell et al. [93]	236	Adol	Ø	Ø								
Non-ST	Music	Bickham et al. [101]	126	Adol	Ø									
	Homework	Hamer et al. [166]	2038	Adol					Ø					Ø
Total SB		Raudsepp [167]	253	Adol	+									
		Ahn et al. [64][a]	6153	Child					Ø					
		Ishii et al. [112]	292	Child		Ø			Ø		Ø			
Cross-sectional														
Recreational ST	TV and C	Nihill et al. [65]	357	Adol						–				
	TV	Nihill et al. [65]	357	Adol						–				
	C	Nihill et al. [65]	357	Adol						–				
	TV	Schneider et al. [74]	451	Adol								–♀		
	I	Schneider et al. [74]	451	Adol								Ø♀		
	TV and C	Benson et al. [98]	117	Child/adol	+									
	TV and C	Kremer et al. [99]	8256	Adol	+									
	TV and C	Wang et al. [128]	3096	Adol	+	+								
	TV and C	Hoare et al. [133]	800	Adol	+									
	TV and C	Allen and Vella [91]	3800	Preschoolers					Ø					
	TV and C	Allen and Vella [91]	3800	Child					+					
	TV	Bickham et al. [101]	126	Adol	Ø									
	C	Bickham et al. [101]	126	Adol	Ø									

Table 3 (continued)

Activity	Behavior	Study	*N*	Population	Psychological ill-being					Psychological well-being				
					Depression	Anxiety	Stress	Negative affect	Global distress	Self-esteem	Self-efficacy	Self-image	SWL	WB
	M	Bickham et al. [101]	126	Adol	+									
	TV and C	Carter et al. [76]	6504	Adol	+									
	TV, C, M	Babic et al. [104]	322	Adol								–		–
	TV	Babic et al. [104]	322	Adol								Ø		Ø
	C	Babic et al. [104]	322	Adol								Ø		–
	M	Babic et al. [104]	322	Adol								–		Ø
	TV, C, M	Trinh et al. [134]	2660	Adol	+				+	–				
	TV	Booker et al. [158]	4899	Adol									Ø	
	C	Booker et al. [158]	4899	Adol									–	
	I	Booker et al. [158]	4899	Adol									–	
	TV and C	Herman et al. [164]	7725	Adol										–
	TV	Maras et al. [95]	2482	Adol	–	–								
	C	Maras et al. [95]	2482	Adol	+	+								
	TV and C	Maras et al. [95]	2482	Adol	+	+								
	TV, C, M	Suchert et al. [168]	1296	Adol	Ø♂ + ♀					+♂ – ♀	–	Ø♂ – ♀		
	TV	Padilla-Moledo et al. [169]	680	Child/adol									–	
	TV, C, M	Asfour et al. [160]	575	Adol					Ø					
	TV and C	Wu et al. [96]	5200	Child					+	–				
	TV	Wu et al. [96]	5200	Child					+	–				
	C	Wu et al. [96]	5200	Child					Ø	Ø				
	TV	Goldfield et al. [103]	358	Adol	–									
	C	Goldfield et al. [103]	358	Adol	+									
	TV and C	Goldfield et al. [103]	358	Adol	+									
	TV and C	Suchert et al. [170]	1228	Adol								–		
	TV and C	Gunnell et al. [93]	236	Adol	+	+								
	TV and C	Hayward et al. [142]	3295	Adol	Ø♂ + ♀									
	C	Janssen [68]	20,122	Adol				+						
	I	Hoare et al. [97]	5500	Child/adol	Ø♂ + ♀				+					
	TV and C	Khan and Burton [147]	898	Adol	+									
	TV and C	Martin et al. [148]	13,486	Child/adol									–	
	C	Mundy et al. [171]	876	Child					+♂Ø♀					
	C	Ohannessian [172]	411	Adol		–♂ + ♀								
	TV and C	Szamreta et al. [144]	120	Child								Ø♀		

Table 3 (continued)

Activity	Behavior	Study	*N*	Population	Psychological ill-being					Psychological well-being				
					Depression	Anxiety	Stress	Negative affect	Global distress	Self-esteem	Self-efficacy	Self-image	SWL	WB
Non-recreational ST	Homework	Babic et al. [104]	322	Adol								Ø		
Non-ST	Magazines	Schneider et al. [74]	451	Adol								Ø♀		
	Music	Bickham et al. [101]	126	Adol	Ø									
	¥	Suchert et al. [168]	1296	Adol	+					Ø	Ø	Ø		
Total SB		Webb et al. [173]	238	Adol						Ø♀		−♀		
		Nihill et al. [65][a]	357	Adol						Ø				
		Suchert et al. [168]	1296	Adol	Ø♂ + ♀					Ø♂ − ♀	−	Ø♂ − ♀		
		Asare and Danquah [137]	296	Adol	+					Ø		Ø		
		Ishii et al. [66][a]	967	Child		Ø								
		Raudsepp [167]	253	Adol	+									
Summary														
+					21.5	4.5	0	1	7	0.5	0	0	0	0
−					2	1.5	0	0	0	7	2	5	4	4
Ø					11.5	4	1	0	10	7	2	8.5	1	5
Total score					+	?	?	?	?	?	?	?	−	?

No studies with self-concept and positive affect outcomes were identified

If 0–33% of studies reported a significant association, the result was classified as no association (Ø). If 34–59% of studies reported a significant association, or if fewer than four studies reported on the outcome, the result was classified as being inconsistent/uncertain (?). If ≥ 60% of studies found a significant association, the result was classified as positive (+) or negative (−), depending on the direction of the association

SWI satisfaction with life and happiness, *WB* well-being, *ST* screen time, *Child* children, *Adol* adolescents, *C* computer, *TV* television, *M* mobile, *I* internet, *SB* Sedentary Behavior, ¥ music, transport, homework, reading, creative hobbies, talking, + indicates positive association (all samples), − indicates negative association (all samples), Ø indicates no association (all samples), Ø♂ indicates no association (100% boys), Ø♀ indicates no association (100% girls), +/−♂ indicates positive/negative association (100% boys), +/−♀ indicates positive/negative association (100% girls), +/−♂Ø♀ indicates positive/negative association boys and no association for girls (all samples), Ø♂ +/♀ indicates no association for boys and positive/negative association girls (all samples)

[a]Objectively measured sedentary time

and optimism. Although experimental studies are considered to provide the highest level of evidence, observational studies may be useful for determining the relationship between physical activity and less-studied mental health outcomes. Of note, type of physical activity (e.g. sports participation, outdoor play or active commuting) might be considered when studying the relationship between physical activity and mental health in young people. Lastly, further studies might consider the interrelationship between other environmental factors, such as enjoyment or perceived sport competence, that could differently influence the mental health of children and adolescents.

4.3 Possible Mechanisms for the Role of Physical Activity in Mental Health

While the evidence examining the relationship between physical activity and mental health is growing, the underlying plausible mechanisms of this association cannot be elucidated in our review. In this context, a range of neurobiological, psychosocial and behavioral mechanisms have been previously proposed by Lubans et al. [15].

First, physical activity may have a positive effect on the structure and function of the brain, which is now quantifiable as a result of technological advancement (e.g. magnetic resonance imaging [MRI]). Using this technology, for instance, a recent RCT in children showed that a 9-month physical exercise intervention improved the structure and function of brain networks related to cognitive function [85]. Therefore, it is possible that physical activity changes brain structure and function, which in turn has a positive effect on mental health. Regarding the cellular and molecular bases of mental health, it is well-known that decreased levels of brain-derived neurotrophic factor (BDNF), which plays a crucial role in the growth and healthy maintenance of neurons [86], is associated with increased levels of anxiety and depression [87]. Exercise is known to increase BDNF levels in the central nervous system, which may improve anxiety and depressive symptoms [13]. Another explanation might be that exercise, by increasing brain dopamine, serotonin, and noradrenaline concentrations, might not only improve mood but also protect against the onset of mental disorders [88]. More research is needed to understand the neurobiological mechanisms that elicit the positive effects of physical activity on mental health in young people.

Second, evidence suggests a causal link between physical self-concept (i.e. perceived appearance, perceived fitness and perceived competence) and mental health (e.g. global self-concept, self-esteem) [15]. Social support and autonomy are also plausible psychosocial contributors to mental health in young people [89]. Therefore, the effects of physical activity on mental health in young people might be mediated by several psychosocial paths.

Finally, a range of potential behavioral mechanisms might explain the effect of physical activity on mental health outcomes, including sleep duration, sleep efficiency, sleep onset latency, and reduced sleepiness [15]. However, there are insufficient studies to draw firm conclusions about any of these behavioral mechanisms.

4.4 Observational Studies on the Association Between Sedentary Behavior and Mental Health

Significant associations were found between higher time spent in sedentary behaviors and higher depression, lower satisfaction with life and lower happiness in children and adolescents, while other psychological ill-being and psychological well-being outcomes (i.e. stress, anxiety, negative affect, self-esteem, self-concept, self-efficacy, positive affect and optimism) have not been studied. Therefore, the present research suggests that decreasing sedentary behavior may have a positive effect on depression, satisfaction with life and happiness in children and adolescents [67, 90, 91]. There is a lack of data for preschoolers (2–5 years of age). Given that there are a variety of developmental changes happening in the brain during the early stages of human life [5], more studies involving preschoolers are warranted.

The findings of this systematic review are consistent with those from Hoare et al. [28], who provided strong evidence for the positive relationship between sedentary behavior and depressive symptoms among adolescents [28]. These findings were also reported by Liu et al. [92] in a meta-analysis of observational studies in children and adolescents. However, these investigators found that compared with the reference group who had no sedentary behavior, there was a non-linear dose–response association of screen time-based sedentary behavior (i.e. watching television, computer/internet use, and video gaming) with a decreasing risk of depression at sedentary time < 2 h/day, with the lowest risk being observed for 1 h/day. These findings suggest that recreational screen time in moderation is not harmful. On the other hand, a number of longitudinal studies suggested that lower levels of sedentary behavior were weakly associated or not associated with lower levels of anxiety [67, 93], stress [67] and total psychological distress [94]. A stronger association between sedentary behavior and anxiety [93, 95] and total psychological distress [96, 97] was found in cross-sectional studies. Moreover, as discussed for physical activity, the association between sedentary behavior and psychological distress may be bidirectional. Therefore, experimental studies on sedentary behavior and mental health are required to elucidate the causality of these associations.

While the eligibility criteria allowed for a broad range of sedentary behaviors, the most frequently examined behavior in children and adolescents was a measure of total

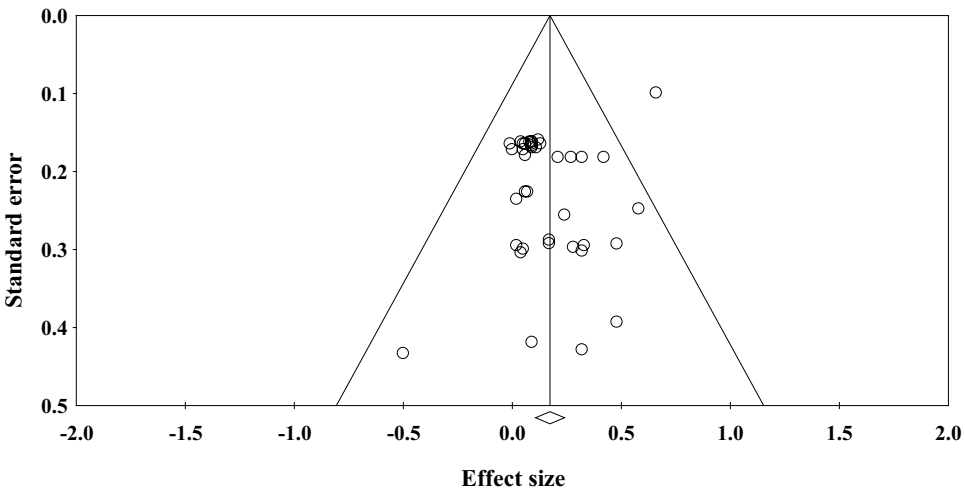
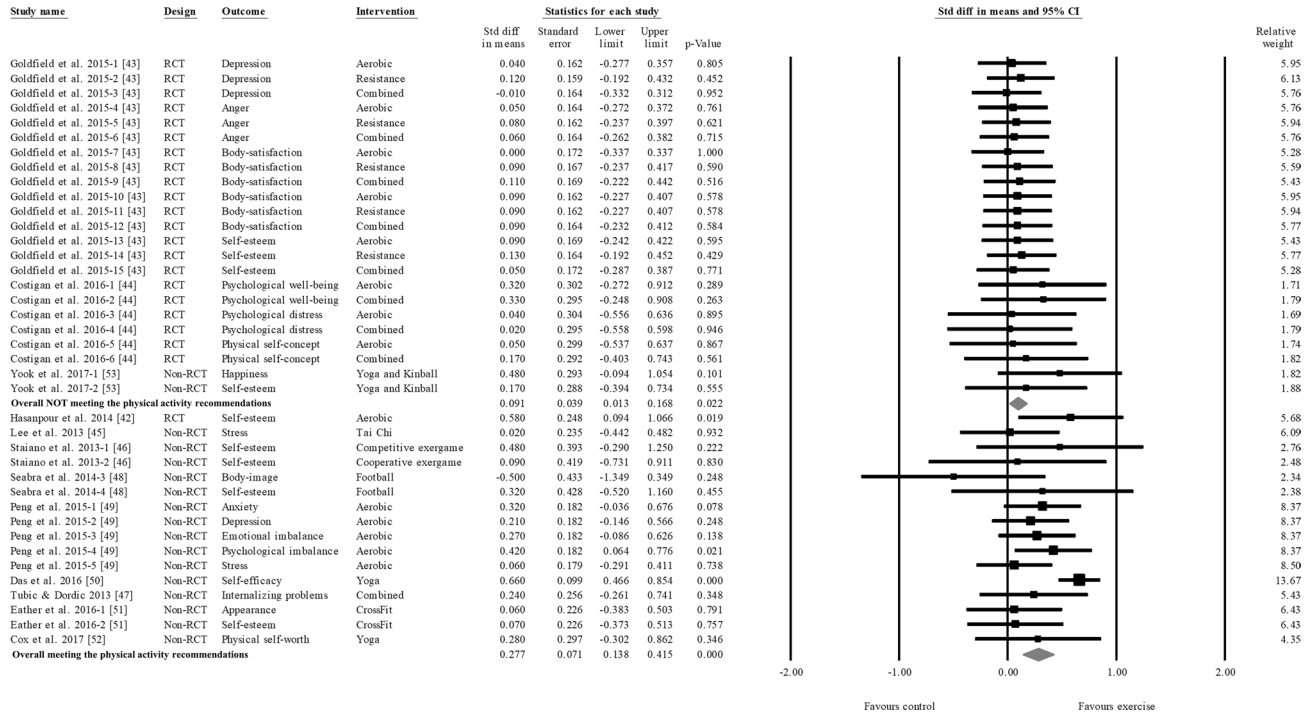


Fig. 3 Funnel plot to assess publication bias in the effects of exercise on overall mental health. Diagonal lines represent pseudo-95% confidence intervals. The *y*-axis represents the standard error (weight in the pooled analysis), and the *x*-axis shows the effect size; thus, the vertical line represents the calculated estimated effect of overall mental health



Study name	Design	Outcome	Intervention	Std diff in means	Standard error	Lower limit	Upper limit	p-Value	Relative weight
Goldfield et al. 2015-1 [43]	RCT	Depression	Aerobic	0.040	0.162	-0.277	0.357	0.805	5.95
Goldfield et al. 2015-2 [43]	RCT	Depression	Resistance	0.120	0.159	-0.192	0.432	0.452	6.13
Goldfield et al. 2015-3 [43]	RCT	Depression	Combined	-0.010	0.164	-0.332	0.312	0.952	5.76
Goldfield et al. 2015-4 [43]	RCT	Anger	Aerobic	0.050	0.164	-0.272	0.372	0.761	5.76
Goldfield et al. 2015-5 [43]	RCT	Anger	Resistance	0.080	0.162	-0.237	0.397	0.621	5.94
Goldfield et al. 2015-6 [43]	RCT	Anger	Combined	0.060	0.164	-0.262	0.382	0.715	5.76
Goldfield et al. 2015-7 [43]	RCT	Body-satisfaction	Aerobic	0.000	0.172	-0.337	0.337	1.000	5.28
Goldfield et al. 2015-8 [43]	RCT	Body-satisfaction	Resistance	0.090	0.167	-0.237	0.417	0.590	5.59
Goldfield et al. 2015-9 [43]	RCT	Body-satisfaction	Combined	0.110	0.169	-0.222	0.442	0.516	5.43
Goldfield et al. 2015-10 [43]	RCT	Body-satisfaction	Aerobic	0.090	0.162	-0.227	0.407	0.578	5.95
Goldfield et al. 2015-11 [43]	RCT	Body-satisfaction	Resistance	0.090	0.162	-0.227	0.407	0.578	5.94
Goldfield et al. 2015-12 [43]	RCT	Body-satisfaction	Combined	0.090	0.164	-0.232	0.412	0.584	5.77
Goldfield et al. 2015-13 [43]	RCT	Self-esteem	Aerobic	0.090	0.169	-0.242	0.422	0.595	5.43
Goldfield et al. 2015-14 [43]	RCT	Self-esteem	Resistance	0.130	0.164	-0.192	0.452	0.429	5.77
Goldfield et al. 2015-15 [43]	RCT	Self-esteem	Combined	0.050	0.172	-0.287	0.387	0.771	5.28
Costigan et al. 2016-1 [44]	RCT	Psychological well-being	Aerobic	0.320	0.302	-0.272	0.912	0.289	1.71
Costigan et al. 2016-2 [44]	RCT	Psychological well-being	Combined	0.330	0.295	-0.248	0.908	0.263	1.79
Costigan et al. 2016-3 [44]	RCT	Psychological distress	Aerobic	0.040	0.304	-0.556	0.636	0.895	1.69
Costigan et al. 2016-4 [44]	RCT	Psychological distress	Combined	0.020	0.295	-0.558	0.598	0.946	1.79
Costigan et al. 2016-5 [44]	RCT	Physical self-concept	Aerobic	0.050	0.299	-0.537	0.637	0.867	1.74
Costigan et al. 2016-6 [44]	RCT	Physical self-concept	Combined	0.170	0.292	-0.403	0.743	0.561	1.82
Yook et al. 2017-1 [53]	Non-RCT	Happiness	Yoga and Kinball	0.480	0.293	-0.094	1.054	0.101	1.82
Yook et al. 2017-2 [53]	Non-RCT	Self-esteem	Yoga and Kinball	0.170	0.288	-0.394	0.734	0.555	1.88
Overall NOT meeting the physical activity recommendations				0.091	0.039	0.013	0.168	0.022	
Hasanpour et al. 2014 [42]	RCT	Self-esteem	Aerobic	0.580	0.248	0.094	1.066	0.019	5.68
Lee et al. 2013 [45]	Non-RCT	Stress	Tai Chi	0.020	0.235	-0.442	0.482	0.932	6.09
Staiano et al. 2013-1 [46]	Non-RCT	Self-esteem	Competitive exergame	0.480	0.393	-0.290	1.250	0.222	2.76
Staiano et al. 2013-2 [46]	Non-RCT	Self-esteem	Cooperative exergame	0.090	0.419	-0.731	0.911	0.830	2.48
Seabra et al. 2014-3 [48]	Non-RCT	Body-image	Football	-0.500	0.433	-1.349	0.349	0.248	2.34
Seabra et al. 2014-4 [48]	Non-RCT	Self-esteem	Football	0.320	0.428	-0.520	1.160	0.455	2.38
Peng et al. 2015-1 [49]	Non-RCT	Anxiety	Aerobic	0.320	0.182	-0.036	0.676	0.078	8.37
Peng et al. 2015-2 [49]	Non-RCT	Depression	Aerobic	0.210	0.182	-0.146	0.566	0.248	8.37
Peng et al. 2015-3 [49]	Non-RCT	Emotional imbalance	Aerobic	0.270	0.182	-0.086	0.626	0.138	8.37
Peng et al. 2015-4 [49]	Non-RCT	Psychological imbalance	Aerobic	0.420	0.182	0.064	0.776	0.021	8.37
Peng et al. 2015-5 [49]	Non-RCT	Stress	Aerobic	0.060	0.179	-0.291	0.411	0.738	8.50
Das et al. 2016 [50]	Non-RCT	Self-efficacy	Yoga	0.660	0.099	0.466	0.854	0.000	13.67
Tubic & Dordic 2013 [47]	Non-RCT	Internalizing problems	Combined	0.240	0.256	-0.261	0.741	0.348	5.43
Eather et al. 2016-1 [51]	Non-RCT	Appearance	CrossFit	0.060	0.226	-0.383	0.503	0.791	6.43
Eather et al. 2016-2 [51]	Non-RCT	Self-esteem	CrossFit	0.070	0.226	-0.373	0.513	0.757	6.43
Cox et al. 2017 [52]	Non-RCT	Physical self-worth	Yoga	0.280	0.297	-0.302	0.862	0.346	4.35
Overall meeting the physical activity recommendations				0.277	0.071	0.138	0.415	0.000	

Fig. 4 Grouping analysis of not meeting (<60 min) and meeting (≥60 min) the physical activity recommendations against the effect size on overall mental health. The more positive the effect size, the better the changes in overall mental health. Overall effect size for each group (meeting or not meeting the recommendations) is shown in *grey*. *RCT* randomized controlled trial, *Std Diff* standard difference, *CI* confidence interval

recreational screen time (i.e. recreational use of computer and television viewing) [76, 91, 97–99]. It is widely known that prolonged television viewing is the most prevalent and pervasive sedentary behavior in developed countries and has been associated with morbidity and mortality [100]. This finding is consistent with that of Bickham et al. [101] who found that television viewing, and not recreational use of computers during adolescence, was associated with depressive symptoms over time. In addition, similar findings were reported by Grøntved et al. [102] for children. However, this finding is contrary to other studies that have suggested that recreational use of computers was more strongly associated with poorer mental health than television viewing in children and adolescents [95, 103]. In addition, social media

technology commonly used by young people on tablets/mobile phone (e.g. Facebook, Instagram and Snapchat) may encourage adolescents to compare themselves with their peers [104], and consequently increase their body dissatisfaction when discrepancies are found between perceived and ideal body shape. Therefore, research is required to examine if the type (e.g. watching television, using the computer/internet, or playing video games) of sedentary behavior versus sedentariness itself explains the association between sedentary behavior and mental health in young people.

Due to the lack of research, it was not possible to determine the strength of association between sedentary behavior and stress, anxiety, negative affect, self-esteem, self-concept, self-efficacy, positive affect and optimism; more research (including observational studies) is warranted. As such, experimental research is needed to elucidate the effect of reducing sedentary behavior on young people's mental health. Future studies are encouraged to explore the following: (1) how much screen time is acceptable for young people (e.g. > 2 h vs. < 2 h); (2) to what extent does screen-time content influence young people's mental health (e.g. violence vs. non-violence); and (3) are the effects of screen time consistent if young people are watching or playing with others (e.g. gaming alone vs. gaming with friends).

4.5 Possible Mechanisms for the Role of Sedentary Behavior in Mental Health

Although the underlying mechanisms responsible for the effects of sedentary behavior on mental health in children and adolescents are still unclear, several hypotheses have been proposed. First, given that it often takes place alone, sedentary behavior may elicit feelings of loneliness and, consequently, negatively impacts on mental health [105]. Thus, it seems that higher levels of screen time (e.g. time spent watching television and using the internet) may lead to social isolation, and hence to mental health problems [107]. Second, cultural messages transmitted through media may affect other behaviors related to mental health (e.g. eating disorders and aggressive behavior) [106]. Third, excessive media exposure often occurs at day or night. During the day, time spent on screen-based activities may replace time participating in more productive and/or active activities, especially activities involving physical activity [107] and interpersonal communication [108]. At night, screen-based activities can displace sleep, which is crucial for normal cognitive and emotional development [106]. In both scenarios, the replacement of healthy with unhealthy behaviors may have negative consequences on the mental health of young people. Given the limited evidence, more studies focused on potential mechanisms explaining the relationship between sedentary behavior and mental health are needed to confirm these hypotheses. Since nothing is known about them, studies focusing on neurobiological mechanisms are of particular interest.

4.6 Literature Gaps and Future Research

- Most of the studies included in this review were focused on adolescents. Therefore, future research is required, especially in preschoolers and children.
- Well-designed physical activity interventions are needed to confirm our findings. In addition, experimental studies on sedentary behavior and mental health are required to draw conclusions in regard to cause and effect.
- Mediation models are needed to identify the mechanisms (i.e. neurobiological, psychological and behavioral) responsible for any changes in mental health resulting from physical activity and sedentary behavior.
- Type of physical activity (e.g. sports participation, outdoor play or active commuting) and type of sedentary behavior (e.g. television viewing, playing video games, social media technology) might be considered when the relationship between physical activity, sedentary behavior and mental health is studied in young people.
- More studies focused on the relationship between physical activity and mental health (i.e. anxiety, self-esteem, self-concept, self-efficacy, positive affect and optimism), for which we currently have minimal or unclear evidence, are required. Likewise, research focused on the relationship between sedentary behavior and mental health (i.e. stress, anxiety, negative affect, self-esteem, self-concept, self-efficacy, positive affect and optimism), for which there is also minimal evidence, are also needed. Even observational studies may be worthwhile, given the lack of research to date.

4.7 Limitations and Strengths

Our review has several limitations. First, the so-called grey literature (i.e. System for Information on Grey Literature in Europe [SIGLE] database, dissertations, conference proceedings, and trial registries) was not included in the review. Second, the search was conducted in only two databases (PubMed and Web of Science), although this is consistent with the AMSTAR critical appraisal tool for systematic reviews, i.e. at least two electronic sources should be searched to perform a comprehensive literature search. However, we could have missed eligible studies from other databases. Third, studies written in languages other than English and Spanish were excluded from our review. In addition, because of the heterogeneity of the outcome measures, it was not possible to conduct a meta-analysis of the prospective longitudinal studies. Lastly, because most of the intervention studies were focused on adolescents (12 in adolescents vs. 3 in children), and no studies were found in preschoolers, we

cannot rule out a cause and effect relationship between physical activity and mental health in preschoolers and children.

The present review also has several strengths. First, this review employed stringent systematic review methodology as per the PRISMA guidelines to ensure relevant literature was identified and evaluated with the greatest possible scientific rigor. Second, this review provided an a priori design registered in the Prospero database. Therefore, research questions and inclusion criteria were established before conducting this review. Third, two electronic sources were searched, and the search strategies are reported in this article. Moreover, we provided a list of the studies included and excluded (together with the specific reason for exclusion per study) in electronic supplementary Table S2. In addition, the quality of the included studies was examined, and hence conclusions drawn by this review are strengthened by the use of the quality assessment tool. Finally, a meta-analysis was performed including intervention studies (RCTs and non-RCTs), making it possible to map the link between exercise and global mental health across childhood and adolescence for the first time.

5 Conclusions

Findings from the present research suggest that physical activity has a small but significant positive effect on adolescents' mental health. Due to the small number of studies, it was not possible to determine the effect of physical activity on preschoolers' and children's mental health. In addition, physical activity (i.e. active commuting, outdoor play or sport participation) may influence mental health in children and adolescents. In regard to the type of physical activity, participation in team sports was found to be a consistent positive correlate of mental health in children and adolescents. Conversely, sedentary behavior was negatively associated with mental health in children and adolescents. In particular, higher levels of recreational screen time (i.e. beyond 2 h/day of recreational screen time) were associated with poorer mental health outcomes in children and adolescents. In summary, there is sufficient evidence to conclude that interventions targeting increases in physical activity, and decreases in sedentary behavior, are justified and will support the current and future mental health of children and adolescents.

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Compliance with Ethical Standards

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Affiliations

María Rodriguez-Ayllon[1] · Cristina Cadenas-Sánchez[1] · Fernando Estévez-López[2,3] · Nicolas E. Muñoz[1] · Jose Mora-Gonzalez[1] · Jairo H. Migueles[1] · Pablo Molina-García[1,4] · Hanna Henriksson[1,5] · Alejandra Mena-Molina[1] · Vicente Martínez-Vizcaíno[6,7] · Andrés Catena[8,9] · Marie Löf[5,10] · Kirk I. Erickson[11] · David R. Lubans[12] · Francisco B. Ortega[1,10] · Irene Esteban-Cornejo[1,13]

✉ María Rodriguez-Ayllon
rodriguezm@ugr.es

[1] PROFITH "PROmoting FITness and Health through physical activity" research group, Department ofPhysical Education and Sports, Faculty of Sport Sciences, University of Granada, Granada, Spain

[2] Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain

[3] Institute of Nursing and Health Research, School of Health Sciences, Ulster University, Northern Ireland, UK

[4] Department of Rehabilitation Sciences, KU Leuven–University of Leuven, Leuven, Belgium

[5] Department of Medical and Health Sciences, Linköping University, Linköping, Sweden

[6] Health and Social Research Center, Universidad de Castilla-La Mancha, Cuenca, Spain

[7] Universidad Autónoma de Chile, Facultad de Ciencias de la Salud, Talca, Chile

[8] Mind, Brain, and Behaviour Research Centre-CIMCYC, University of Granada, Granada, Spain

[9] Department of Clinical Psychology, University of Granada, Granada, Spain

[10] Department of Biosciences and Nutrition, Karolinska Institutet, Group MLO, SE-14183 Huddinge, Sweden

[11] Department of Psychology, University of Pittsburgh, Pittsburgh, PA, USA

[12] Priority Research Centre for Physical Activity and Nutrition, Faculty of Education and Arts, University ofNewcastle, Callaghan Campus, Australia

[13] Center for Cognitive and Brain Health, Department of Psychology, Northeastern University, Boston, MA, USA