Association between cardiorespiratory fitness and depressive symptoms in children and adolescents: a systematic review and meta-analysis

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Abstract

Background: Higher cardiorespiratory fitness (CRF) is associated with lower depressive symptoms in adults. However, no systematic review with meta-analysis assessed the cross-sectional associations between CRF and depressive symptoms in children and adolescents. Therefore, this meta-analysis assessed the relationship between CRF and depressive symptom in these populations. **Methods:** Cross-sectional data evaluating the correlation between CRF and depression were searched, from database inception through 21/05/2020, on PubMed, PsycINFO, Web of Science, and SPORTDiscus. Age, sex, CRF and depression assessments, and correlations were extracted. A random-effects meta-analysis was conducted, and the potential sources of heterogeneity were also explored through meta-regression analysis. **Results:** Across 14 effects of 11 unique studies, including a total of 7,095 participants (median age=12.49) with nearly equal sex distribution (median=53% females), it was found that higher CRF was associated with lower depressive symptoms in children and adolescents (r=-0.174, 95%CI -0.221 to -0.126, p<0.001, I^2=75.09, Q value=52.19). No moderators were identified. **Conclusion:** Available evidence supports the notion that higher CRF is inversely associated with depressive symptoms in children and adolescents. Physical activity and exercise interventions targeting improving CRF should be promoted for these populations. Further studies, including clinical populations, should be conducted to assess objective measures of aerobic fitness and body composition, while controlling for puberty status, to better characterize this association.

Keywords: Cardiorespiratory Fitness; Depression; Children; Adolescents.

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1. Introduction

Depressive disorders have an estimated prevalence of 3.2% in children, and 6.7% in adolescents (aged between 12-17 years) [1]. Depressive disorders are among the most important antecedents of suicide, the second leading cause of death among young people aged 15-29 years in 2015 [2].

Longitudinal studies suggest that depressive symptoms during childhood increase the risk of adulthood depression [3], bipolar disorder [4], and substance abuse [5]. Moreover, depression arising during childhood and adolescence suggests an increased risk for chronic course of depressive illness in adulthood, therefore implying a longer burden and psychosocial impact [6]. Thus, understanding potential modifiable risk factors for depressive symptoms in children and adolescence is essential.

Physical activity (PA) can be defined as any form of muscular movement resulting in energy expenditure above basal levels [7]. Adults with depression have decreased levels of PA when compared to non-depressed individuals [8, 9]. Furthermore, PA has been shown to be a protective factor against the onset of depression at any age, and across all continents [10]. The association between PA and depression has been shown in previous studies assessing PA with questionnaires, which are more susceptible to recall and social desirability biases [11], and less frequently with objective measures of PA [12]. However, as the PA category in most previous studies did not differentiate between PA and exercise, a repetitive and structured PA designed to improve or maintain one or more components of the physical condition [13,14], evaluation of the effects of PA and exercise separately on depressive symptoms is not possible.

Cardiorespiratory Fitness (CRF), defined as the ability of the cardiorespiratory system to supply oxygen to the working muscles during sustained exercise, is mostly influenced by PA [15], and has some advantages over PA assessment, such as being less susceptible to recall or social desirability biases, while being directly and objectively determined from maximal (i.e. until exhaustion) and submaximal (i.e. without exhaustion) well-standardized tests in both laboratory and field conditions. Further, CRF is also an objective biological marker of overall health in adults, being inversely associated with all-cause mortality, incident myocardial infarction, hypertension, diabetes, atrial fibrillation, heart failure, stroke and various other conditions [16]. More recently, a growing body of evidence has suggested a link between CRF and mental health in adults, showing that higher levels of CRF are associated with reduced depressive symptoms [17], and that people with lower CRF have an increased risk of developing depression [11].

In children and adolescents, CRF has been linked to better cognitive function [18], lower adiposity [19], and improved cardiometabolic health [20]. Two previous systematic reviews have suggested that CRF is inversely associated with depressive symptoms in children and adolescents [21, 22]. However, they did not perform a meta-analysis on the strength of the association between CRF and depressive symptoms.

Further, although the correlation association between CRF and depressive symptoms in adult has been found to be moderated by various factors (such as sex [17]), potential moderators of the association between depressive symptoms and CRF in children and adolescents have not been explored yet.

Therefore, the aims of this review were: 1) to meta-analyze studies testing the cross-

sectional correlation between CRF and depressive symptoms in children and adolescents; and 2) to explore whether sex, age, and body composition are potential moderators of this correlation.

2. METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) [23] and the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) [24] statement.

2.1. Inclusion and exclusion criteria

The following inclusion criteria were defined for the selection of articles: (1) Studies that assessed CRF using maximal or submaximal tests; (2) assessed depressive symptoms using validated instruments; (3) have included participants up to 18 years old; (4) have tested the cross-sectional association between CRF and depressive symptoms, presenting the value of the correlation tests, such as the *r* value. Excluded studies were those that 1) did not use original data (e.g.: reviews, commentaries, editorials); (2) were written in languages other than English, Portuguese or Spanish; and (3) thesis, dissertations, abstracts of conferences and symposiums .

2.2. Searches

Searches were conducted on PubMed, Web of Science, PsycINFO and SportDiscus databases, from inception to 21/05/2020, using combinations of keywords involving fitness, depression and children/adolescents. The full strings can be seen at the supplementary materials. Additional hand searches were performed in the references of included studies and previous reviews on CRF and health outcomes in children and adolescents [21, 22].

2.3. Study selection

The authors searched the titles and abstracts of all publications resulting from the initial search in order to identify those that fulfilled the inclusion criteria. Each title and abstract of the articles were evaluated independently by two blind reviewers. Thereafter, the remaining articles were read in full. The disagreements were re-evaluated by the authors to reach consensus among them.

2.4. Data extraction

Data on the country, study design, sample size, mean age, % of females, % of body fat, body mass index (BMI), fitness test used, and depressive symptoms instrument were gathered. The correlational data, expressed by the Pearson (r) or Spearman (rho) tests, were extracted altogether with the total sample size. The data were extracted using a pre-defined Excel® spreadsheet by two independent reviewers. In case of missing outcomes data, authors were contacted (up to three times within a 3-week period).

2.5. Meta-analysis

A random-effects meta-analysis was performed using the *r* value and the sample size. The meta-analysis was conducted using the transformation of *r* values into Fischer z scores

and then reconverting to *r values*. Outcomes were pooled in *r* values, together with the 95% confidence interval (95%CI). The associations were classified as weak (*r*=0.10-0.29), medium (*r* =0.30-0.50) or strong (*r* >0.50) [25]. The Q and I^2 statistic were used to assess and to quantify the heterogeneity, respectively. Scores of <25%, 25-50% and >50% indicated low, moderate and high heterogeneity, respectively [26]. In case of moderate or high heterogeneity, meta-regression exploring the role of age and sex (%females) as moderators were conducted. We evaluated the publication bias using the Begg and Mazumdar [27] and Egger tests [28]. All analyses were performed using Comprehensive Meta-Analysis software (version 3). The Cohen's kappa coefficient was used to calculate the inter-rater agreement rate between reviewers.

3. RESULTS

3.1. Search results

The initial search yielded 1,447 results. After the removal of duplicates and exclusion at the title and abstract level, 1,188 abstracts were considered. After the full-text review stage, 64 studies were considered. Five studies have assessed CRF and depression in children and adolescents and were not included in meta-analysis because they did not present the r values [29-33]. The full list of excluded articles and the reasons for exclusion after full-text read, can be seen in supplementary material. Finally, a total of 11 unique studies were included in the meta-analysis [34-44]. The selection process is described in Figure 1. The inter-rater agreement rates were 0.92 and 0.95 at the first and second stages, respectively.

Insert Figure 1 about here

3.2. Studies and participants characteristics

Across the 11 unique studies, a total of 7,095 children/adolescents (median age=12.49) were included, with nearly equal sex distribution (53% females). Most studies were conducted in the US (63.6%, n=7) [35, 37, 39, 40, 42, 44], and used the Fitnessgram battery for fitness assessment (55.5%, n=6) [37, 40, 43, 44]. The most used scale for assessing depressive symptoms was the center for epidemiologic studies depression scale for children (CES-DC) (44.4%, n=4). The description in detail of the included studies is summarized in Table 1.

Insert Table 1 about here

3.3. Correlation between CRF and depressive symptoms

A correlational meta-analysis, including 14 correlation effect sizes from 11 original studies found a weak inverse correlation between high CRF and low depressive symptoms in children and adolescents (*r*=-0.174, 95%CI -0.221 to -0.126, p<0.01, I^2=75.09, Q value=52.19). The Egger (intercept=-1.59, p=0.38) and Begg and Mazumdar (Tau=-0.21, p=0.27) tests did not identify potential publication bias. The forest plot can be seen in Figure 2.

Insert Figure 2 about here

3.4. Moderators analysis

Nether BMI (coefficient=0.0171, 95%CI - 0.0084 to 0.0426, R^2=0.10, p=0.1895, n=8), age (coefficient=-0.0149, 95%CI -0.0142 to 0.0439, R^2=0.02, p=0.31, n=12), nor sex (coefficient=0.0004, 95%CI -0.0010 to 0.0018, R^2=0.00, p=0.58, n=14) were significant moderators.

4. DISCUSSION

This is, to the best of our knowledge, the first meta-analysis assessing the correlation between CRF and depressive symptoms in children and adolescents. In the present analysis, we found a small but statistically significant correlation between CRF and depressive symptoms in children and adolescents (*r*= -0.174, 95%CI -0.221 to -0.126, p<0.01). This correlation is similar to the correlation found in previous studies in adults (*r*=-0.16, 95%CI -0.21 to -0.10, p=0.041) [17]. However, in adults, sex moderated the association, being more strongly associated with depressive symptoms in men (*r*=-0.22, 95 % CI -0.26 to -0.18) than in women (*r* =-0.12, 95 % CI -0.19 to -0.05) [17]. The differences between the finding in adults may be explained by the lower prevalence of depressive symptoms in children and adolescents, which might result in reduced variability and, consequently, a reduced chance of detecting significant differences [17]. This difference is reinforced by the fact that the meta-analysis in adults included studies with samples exclusively composed of clinically depressed participants, while we did not include any study limited to depressed participants [17].

The observed results highlight the potential role for promoting PA in children and adolescents, since PA is the major determinant of CRF [15]. Although this study only examined cross-sectional associations, and therefore cannot determine directionality of relations, previous studies in adults have demonstrated that CRF is associated with a decreased risk of incident depression [11]. Thus, it is plausible that high CRF in children and adolescents may be protective against the development of depression. However, the opposite view of depression favoring reduced PA and physical fitness should not be disregarded [29]. Further studies are required to objectively estimate the expected protective effects of an increased CRF on depressive symptoms.

There are some factors that may explain the association between CRF and depression in children and adolescents, including biological and psychosocial factors. First, depression is associated with impaired brain function [45] and structure [46] in children and adolescents [47]. In contrast, CRF is associated with increased cortical brain development in adolescents [48], improved brain structure and functioning in children and adolescents [49, 50], and cognitive capacity in adolescents [51]. Specifically, there is robust evidence, from both animal and human studies, suggesting the key role of aerobic PA and exercise on neurobiological mechanisms associated to preserved brain functioning and reduced chronic stress and depressive symptoms [52-53]. Second, children and adolescents with higher CRF are more likely to be more physically active,

and more engaged in group sports, thus having more social relationships and connections with peers [54], which is protective against depression. This means that the identified association could be directly or indirectly related to other biological and social influences, and their interactions, as a consequence of enhanced PA levels and probably reduced sedentary behaviors [55]. Therefore, further studies are required to provide these and other measures to better understand the link between CRF and depression.

The present study presents some potential limitations. First, this is a meta-analysis of cross-sectional studies. Therefore, no direction or causality of the association can be determined. Second, the associations were not adjusted for confounding factors (e.g. socioeconomic status), and few moderators could have been tested, with most of them including a reduced number of studies. Third, the majority of studies were conducted in the US, Europe, and Asia. No studies from Africa, Oceania or South America were included, so the generalization of these data is limited.

Based on the current and previous studies, we may suggest a number of issues to be considered in further studies for the improvement of the current level of evidence. First, it would be recommended that the authors of experimental studies report all their results to be easily processed. This is a problem that has affected the number of studies that were finally included in our meta-analysis (see supplementary material). Second, one potentially important confounder which determines the different rates of depression between sexes is puberty [56], therefore further studies should assess the effect of puberty onset on depressive symptoms. Third, only two studies [39, 42] directly recorded oxygen consumption, therefore more studies with this and other objective indices (e.g. anaerobic threshold) of CRF are needed. In this regard, attention should be paid to the selection of the protocols, as children with greater BMI and body fatness could be limited in locomotor activities. Lastly, BMI is not a good measure for body composition assessment, especially in growing individuals [57, 58], therefore further studies should include objective measures of body composition to better explore the potential moderator role of adiposity and muscle mass.

5. CONCLUSION

The current meta-analysis has revealed a weak inverse correlation between depressive symptoms and CRF as previously observed in adults. Future studies with objectives measures of CRF and body composition, including both sexes and clinical populations, while controlling for puberty and other confounding factors, would allow the identification of the biological features that have been demonstrated to impact the relationships between depression and CRF in adults.

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Tables and Figures

Figure 1: PRISMA flowchart of studies selection

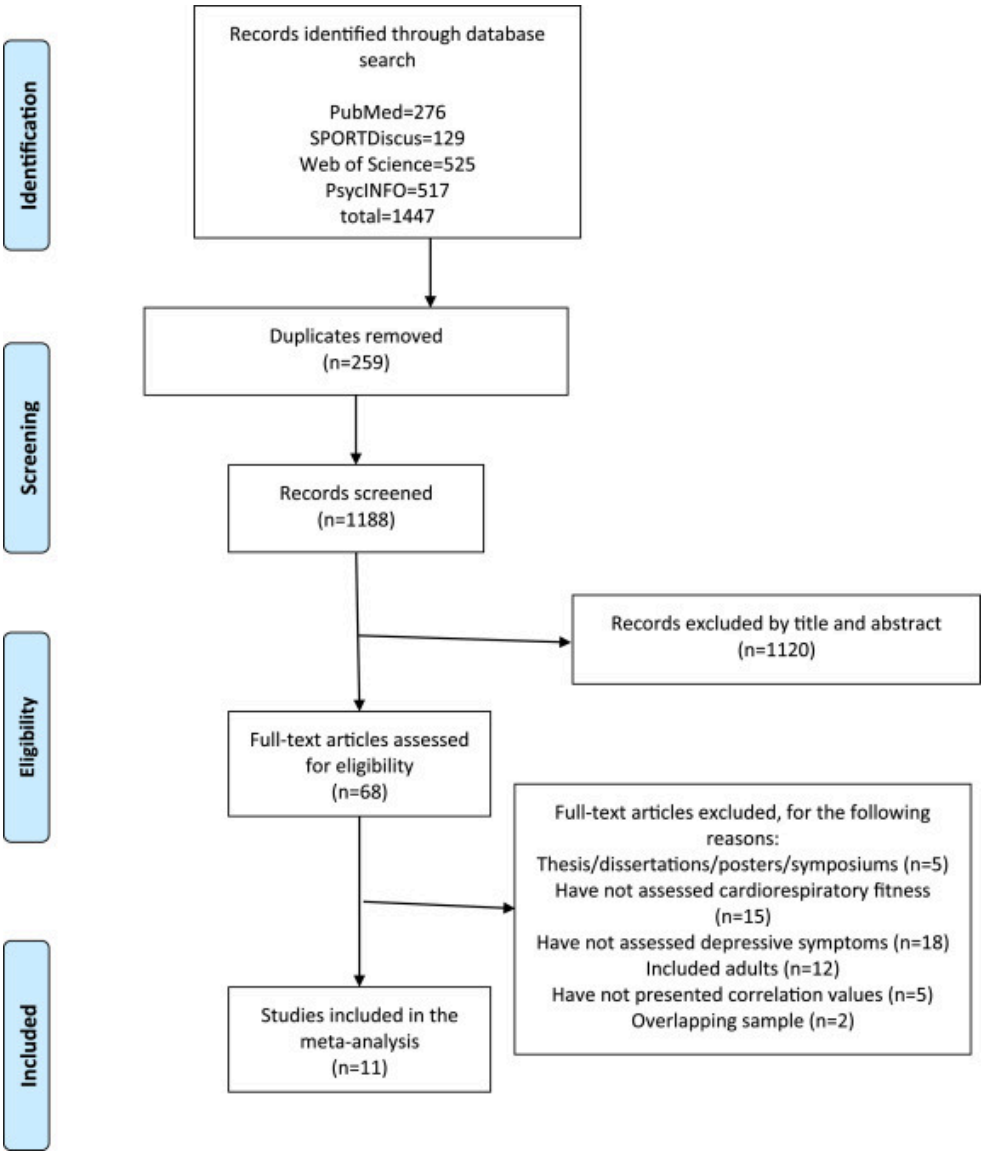
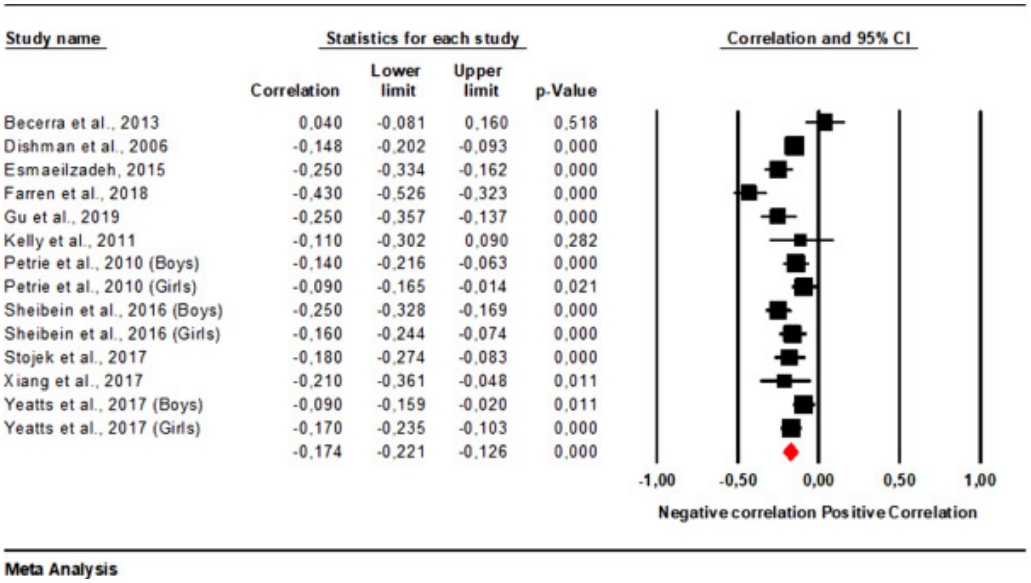


Figure 2: Forest plot of studies testing the correlation between cardiorespiratory fitness and depressive symptoms in children and adolescents



Study	Country	Design	Sample size	Mean age	% Females	Fitness assessment	Fitness results	Depressive symptoms assessment	Depression results
Becerra et al., 2013	Spain	Cross-sectional	264	15.05	50.7	EUROFIT (Course Navette)	VO_2max=43.19^{+}	GHQ-28** (depression domain)	severe depression (0.31)
Dishman et al., 2006	US	Cross-sectional	1250	17.66	100	PWC_{170}	11.38 ($kgm \cdot min^{-1} \cdot kg^{-1}$)	CES-D**	14.48
Esmaeilzadeh, 2015	Iran	Cross-sectional	456	9.3	0	One-mile walk/run test	669.5 (seconds)	CDI**	10.50
Farren et al., 2016	US	Cross-sectional	249	12.85	54	Fitnessgram	VO_2max=47.31^{++} VO_2max=42.42^{+++}	CES-DC$^{\neq}$	13.30
Gu et al., 2019	US	Cross-sectional	279	12.49	53	Fitnessgram	VO_2max=38.60^{+}	CES-DC$^{\neq}$	14.40
Kelly et al., 2011	US	Longitudinal (Baseline data used)*	98	13.66	68.4	Maximal effort graded treadmill test	Baseline VO_2max=23.99	CDI**	10.16
Petrie et al., 2010	US	Cross-sectional	1288	12.38	51.1	Fitnessgram	Boys VO_2max=38.23^{+} Girls VO_2max=30.77^{+}	CES-DC$^{\neq\neq}$	Boys=10.81 Girls=14.12
Sheibein et al., 2016	US	Cross-sectional	1045	12.3	48.5	Fitnessgram	VO_2max=41.45^{+}	CES-DC$^{\neq\neq}$	13.50
Stojek et al., 2017	US	Cross-sectional	397	9.5	59.5	Modified Balke Protocol for Poorly Fit Children	VO_2peak=28.43	CDI$^{\neq\neq\neq}$ RCDS$^{\neq\neq\neq\neq}$	CDI=7.9 RCDS=51
Xiang et al., 2017	China	Cross-sectional	144	14.55	33.33	Fitnessgram	VO_2max=45.49^{+}	CES-DC$^{\neq\neq}$	17.64
Yeatts et al., 2017	US	Cross-sectional	1625	12.23	0	Fitnessgram	Boys VO_2max=39.85^{+} Girls VO_2max=30.89^{+}	CES-DC$^{\neq\neq}$	Boys=12.23 Girls=15.11

Table 1. Description of included studies

*only the baseline association data were used, VO_2max=Maximum oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$), VO_2peak=peak oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$), CDI=Children Depression Inventory, CES-D=Center for Epidemiologic Studies Depression Scale, GHQ=General Health Questionnaire CES-DC= Center for Epidemiologic Studies Depression Scale for Children, PWC170=Physical work capacity corresponding to a HR of 170 bpm, RCDS=Reynolds Child Depression Scale, $^{+}VO_2$max estimated. $^{++}VO_2$max estimated with CES-DC<15, $^{+++}VO_2$max estimated with CES-DC≥15, $^{\neq}$score≥15 indicative of symptoms of depression, $^{\neq\neq}$score 0 (no symptoms) 60 (high level of depressive symptoms), $^{\neq\neq\neq}$score≥19 indicative of symptoms of depression, $^{\neq\neq\neq\neq}$score≥74 indicative of symptoms of depression. **Not reported.

Supplementary materials 1: Search strings

PubMed (21/05/2020):
("cardiovascular capacity" OR "cardiovascular fitness" OR "maximum oxygen uptake" OR "vo2" OR "aerobic capacity" OR "Exercise capacity" OR "CRF" OR "cardiorespiratory fitness" OR "fitness") AND ("MDD" OR depression[mesh]) AND (child OR adolescent OR young)
Total articles: 252

Web of Science (21/05/2020):
("cardiovascular capacity" OR "cardiovascular fitness" OR "maximum oxygen uptake" OR "vo2" OR "aerobic capacity" OR "Exercise capacity" OR "CRF" OR "cardiorespiratory fitness" OR "fitness") AND ("MDD" OR depression) AND (child OR adolescent OR young)
Total articles: 497

Psycinfo (21/05/2020):
("cardiovascular capacity" OR "cardiovascular fitness" OR "maximum oxygen uptake" OR "vo2" OR "aerobic capacity" OR "Exercise capacity" OR "CRF" OR "cardiorespiratory fitness" OR "fitness") AND ("MDD" OR depression) AND (child OR adolescent OR young)
Total: 489

SportDiscus (21/05/2020):
("cardiovascular capacity" OR "cardiovascular fitness" OR "maximum oxygen uptake" OR "vo2" OR "aerobic capacity" OR "Exercise capacity" OR "CRF" OR "cardiorespiratory fitness" OR "fitness") AND ("MDD" OR depression) AND (child OR adolescent OR young)
Total: 123