Physical activity and mental health in children and adolescents: an updated review of reviews and an analysis of causality

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Abstract

Objectives. Evidence concerning physical activity and mental health remains less well documented for children and adolescents. An updated review of systematic reviews and meta-analyses was undertaken concerning physical activity and mental health in children and adolescents, and to judge the extent to which associations can be considered causal.

Methods. Systematic reviews and meta-analyses were identified to update our previous review of reviews (Biddle & Asare, 2011), with papers identified between November 2010 and the end of 2017. Criteria were used to judge causality (Hill, 1965), including strength of association, dose-response association, and experimental evidence.

Results. Since 2011, the quantity (k=42 reviews) and quality of research has increased in depression (evidence from 10 reviews), self-esteem (10 reviews) and cognitive functioning (25 reviews). Anxiety had only three new, small, reviews. Intervention effects for depression are moderate in strength while observational data show only small or null associations. Variable effect sizes are evident from interventions for the reduction of anxiety and improvement in self-esteem. Higher or improved fitness and physical activity are associated with better cognitive health and performance. There was partial support for a causal association with depression, a lack of support for self-esteem, but support for cognitive functioning.

Conclusions. There are significant increases in research activity concerning physical activity and depression, self-esteem, and cognitive functioning in young people. The strongest evidence for a causal association appears to be for cognitive functioning, and there is partial evidence for depression.

Keywords: anxiety; cognitive function; depression; self-esteem

Data from developed countries suggest that the mental health of many young people is less than optimal. For example, in Australia, the latest data (2008-09) suggest that there have been 1.2 million mental health-related general practice encounters for young people (aged 16-24 years) annually, and that this has increased by 21% during the 2000s. The most frequently managed mental health problems concern depression and anxiety (Australian Institute of Health and Welfare, 2011). Moreover, the second National Survey of the Mental Health and Wellbeing of Australian Children and Adolescents, conducted 2013-14, reported that a mental disorder was experienced by 14% of children and adolescents aged 4-17 years, including major depressive and anxiety disorders (Lawrence et al., 2015).

Links between physical activity and psychological benefits have been made over many centuries and even back into antiquity. In an early academic paper Layman (1974) stated that the psychological benefits of physical activity had been “a part of the literature … for over 2000 years” but that claims “were often quite extravagant, without the benefit of supporting scientific evidence” (p. 33) (Biddle & Vergeer, in press). While the field has expanded considerably over the past 30-40 years, it remains replete with simplistic claims and lacks a more nuanced approach that recognises its inherent complexity. For example, it is common to see claims in national guidelines and educational contexts that physical activity in essentially ‘good’ for young people without recognising that positive mental health benefits may depend on the experience of physical activity and the context it takes place in. As the research field develops better evidence, it is important to synthesise current findings.

In January 2011, the International Olympic Committee (IOC) convened a meeting on ‘Fitness & Health of Children through Physical Activity and Sport’. Invited experts reviewed and summarised evidence and a consensus paper was published alongside individual topic reviews (Mountjoy et al., 2011). In evaluating the evidence linking involvement in physical activity with mental health in young people, Biddle and Asare (2011) conducted a review of reviews concerning depression, anxiety, self-esteem, and cognitive functioning. The paper has been well cited (e.g., 446 citations on Scopus and 862 on Google Scholar), and has a Field-Weighted Citation Impact score of 11.85 (data at May 29, 2018). These data suggest that the paper is popular and well used, at least by academics, and is also suggestive of a demand for such omnibus reviews. However, with continued interest and developments concerning the health of young people, and regular production of national and international physical activity guidelines, it is important to update the evidence, given that Biddle and Asare (2011) synthesised findings from reviews dating from 1986 to 2010.

In addition to summarising evidence from more recent reviews, it is important to investigate whether any associations between physical activity and mental health outcomes in youth can be considered causal. This requires assessment of the evidence on a number of criteria, such as those proposed by Sir Austin Bradford Hill (Hill, 1965). Typically, assessments are made concerning strength of association, consistency, temporal sequencing, coherence and biological plausibility, dose-response association, and experimental evidence. While commentaries on physical activity and mental health in adults have used these criteria (Dishman, Heath, & Lee, 2013; Mutrie, 2000), they are lacking for young people.

Consequently, the purpose of this paper is to update the review of reviews by Biddle and Asare (2011). In addition, we assess whether each mental health outcome addressed can be considered to be causally associated with physical activity in children and adolescents. In the 2011 paper, we also reviewed primary studies concerning sedentary behaviour and mental health in youth. Given that systematic reviews are only just emerging on this topic (see Hoare, Milton, Foster, & Allender, 2016; Suchert, Hanewinkel, & Isensee, 2015), we have not provided an update in the current paper.

Methods

To update the 2011 review of reviews, the Cochrane Library, EBSCOhost, ISI Web of Science, MEDLINE (PubMed), ScienceDirect, and Scopus databases were searched for papers between November 2010 and the end of 2017 to identify systematic reviews and meta-analyses examining relationships between chronic involvement in physical activity and the psychological outcomes of depression, anxiety, self-esteem, and cognitive functioning. Groups of thesaurus terms and free terms for physical activity (e.g., exercise), psychological outcomes (e.g., mental health, cognitive functioning), age group (e.g., young people), and publication type (e.g., meta-analysis, systematic review) were used. This resulted in the following example search: TITLE-ABS-KEY youth? OR child* OR "young people" OR adolescen* OR boy? OR girl? OR (paediatric OR pediatric) OR juvenile OR teen* OR school?age AND TITLE-ABS-KEY physical activity OR exercise OR sport OR movement OR activit* OR behavio?r OR fitness OR motor activit* OR physical effort OR physical exertion AND TITLE-ABS-KEY "mental health" OR cognitive health OR depressi* OR anxiety OR stress OR self?esteem OR self?perception OR self?concept OR cognitive function* OR academic achievement OR executive function AND review? OR systematic OR meta?analys* PUBYEAR > 2010. Additional reviews and meta-analyses were identified up to March 2018 by manually checking the reference lists of included papers and searching the authors' own literature databases.

To be included in the present analysis, review papers had to meet the following criteria: 1) population to include school-age children or adolescents, typically defined as 5-18 years; 2) report associations of at least one measure of physical activity with one or more measures of depression, anxiety, self-esteem, or cognitive function; and 3) be a systematic review or a meta-analysis. We excluded pre-school children (usually less than 5 years of age) on the basis that their environmental and social context differs considerably from those attending school. Reviews focusing on the mental health outcomes from acute bouts of physical activity were also excluded as this is considered a different research question.

Only full text peer reviewed articles were considered for inclusion but all languages were eligible. All references were downloaded into Endnote X8. Titles and abstracts of the identified references were reviewed independently by two people to exclude articles out of scope. Subsequently, two people independently reviewed the full text of all potentially relevant references for eligibility. Any disagreements were discussed until a consensus decision was reached. Data extraction was conducted by three of the authors.

The methodological quality of each systematic review was assessed using the Quality Assessment Tool for Systematic Reviews and Meta-Analyses of the National Institutes of Health (NIH)/National Heart, Lung and Blood Institute (see https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools). The NIH tool contains 8-items (7 for non meta-analytic reviews) to appraise the following: the research question; specification of eligibility criteria; the literature search; screening of titles, abstracts and papers; quality assessment of primary studies included in reviews; summaries of included studies; publication bias; and, in the case of a meta-analysis, assessment of heterogeneity. Reviews were assessed as ‘good’, ‘fair’, or 'poor' (see footnote to Tables 1, 3, 4, and 6). Each of the included systematic reviews was assessed independently by two researchers. Disagreements were resolved through discussion.

Results

Searches revealed 162 full-text papers after screening titles and abstracts (see Figure 1). Further screening left 42 review papers meeting inclusion criteria with 8 reviews addressing depression only, 5 for self-esteem, and 20 for cognitive functioning. An additional nine reviews covered more than one mental health outcome, including depression (k=2), anxiety (k=3), self-esteem (k=5), and cognitive functioning (k=5).

Insert Figure 1 about here

Results are presented separately for each psychological outcome (depression, anxiety, self-esteem, cognitive functioning). Within each outcome, results from the Biddle and Asare (2011) review of reviews are summarised, and the updated synthesis of reviews since November 2010 is provided. Finally, and to extend the analyses from the prior review paper, an assessment is made concerning to what extent each psychological outcome can be considered causally associated with physical activity for young people.

Depression. Biddle and Asare (2011) concluded from four systematic reviews that "physical activity over no intervention seems to be potentially beneficial for reduced depression, but the evidence base is limited" (p. 888). Primary studies in these reviews ranged from 3-11 studies and interventions were assessed as low quality. In the current update, we located a further 10 systematic reviews – a 2.5-fold increase – (Ahn & Fedewa, 2011; Bailey, Hetrick, Rosenbaum, Purcell, & Parker, 2017; Brown, Pearson, Braithwaite, Brown, & Biddle, 2013; Bursnall, 2014; Carter, Morres, Meade, & Callaghan, 2016; Janssen & Leblanc, 2010; Johnson & Taliaferro, 2011; Korczak, Madigan, & Colasanto, 2017; Poitras et al., 2016; Radovic, Gordon, & Melvin, 2017), of which only two did not synthesise evidence concerning interventions (Korczak et al., 2017; Poitras et al., 2016) (see Table 1). Regarding the quality of the reviews, two of the six meta-analytic reviews were assessed as ‘good’ and four as ‘fair’. For the non meta-analytic systematic reviews, three were ‘fair’ and one was judged as ‘poor’ (see Table 1). The most common reason for lower quality ratings was the lack of article screening or assessment of study quality by more than one person.

Across the seven reviews that summarised interventions and provided details on the studies reviewed (the review by Ahn and Fedewa did not specifically identify the primary studies that were used in their analysis of depression), 25 intervention papers were included, of which 11 were featured across more than one review (44%). There were 57 observational study papers included, of which 14 were featured across more than one review (25%).

Insert Table 1 about here

For interventions, six of seven meta-analytic effect sizes (ES) varied between -0.41 to -0.61, with a lower value reported by Brown et al. (2013) (-0.26). This suggests that interventions for reducing depression in young people are moderate in strength and similar to that reported from reviews on adults (e.g., Cooney et al., 2013). It is noteworthy that reviews of depressed participants seemed to show slightly stronger effects (ES = -0.43 to -0.61) than those from mixed or healthy samples (-0.26 to -0.52).

Reviews continue to lament the low quality of trials – a statement made in the Biddle and Asare (2011) review. However, in the present update, of the five reviews explicitly reporting on intervention trial quality, two reviews rated trial quality as low, two as mixed, and one as moderate-to-high, which might suggest a small improvement in trial quality. Our update also shows that recent reviews are analysing and reporting intervention effects separately from those of observational studies, in contrast to much of the earlier evidence.

The largest review of observational (cross-sectional and longitudinal) evidence was by Korczak et al. (2017). From cross-sectional evidence, the association between physical activity and depression was small (ES (r) = -0.17) but larger than for longitudinal studies (ES (r) = -0.07), although both values were significant. Only one review (Poitras et al., 2016) focussed on observational studies using wearable technology to assess physical activity, although the number of studies reviewed was small (K=5). Results showed null or mixed findings for cross-sectional studies and no longitudinal association.

In summary, observational evidence shows that associations range from null to small. This may be a true reflection of the association or a function of weak measurement, particularly with self-reported levels of physical activity, or assessment of largely healthy populations.

Depression: analysis of causality. Table 2 shows a summary of the evidence regarding the criteria for judging whether physical activity can be considered causally associated with depression in young people. From the reviews assessed in the current update, there is partial support showing causality. Evidence for strength of association is shown, but is somewhat mixed with support from interventions but not observational studies. There is biological plausibility, but with a lack of definitive evidence in young people. This was rarely addressed in the reviews. Consistency of findings is evident, if somewhat limited, but there is no evidence to support temporal sequencing from longitudinal or prospective evidence (Korczak et al., 2017) or a dose-response relationship (Bailey et al., 2017; Carter et al., 2016). For example, physical activity intensity is reported in only 4 of 11 RCTs reviewed by Carter et al. (2016). Only one tested between different intensities and both showed similar effects. Moreover, sub-group analyses reported by Bailey et al. (2017) showed significant effect sizes (SMD) for light (ES=-1.53, k=1), moderate (ES=-0.76, k=6), and vigorous (ES=-1.04; k=4) intensities.

Experimental evidence does exist, with moderate strength effect sizes. The last criterion – experimental evidence – provides the most convincing support for causality, but overall we can only conclude partial support for causality when all criteria proposed by Hill (1965) are considered.

Insert Table 2 about here

Overall, the field is still rather immature, at least in comparison to the literature concerning adults. Some evidence does exist for a causal association, but this is weakened by no evidence for temporal sequencing from longitudinal studies, and no evidence for a dose-response relationship. That said, there is plenty of evidence showing strength of effect and support from experiment trials, and many have recommended physical activity use as an anti-depressant (Bailey et al., 2017; Carter et al., 2016).

Anxiety. Biddle and Asare (2011) concluded from four systematic reviews that "physical activity interventions for young people have been shown to have a small beneficial effect for reduced anxiety. However, the evidence is limited and in need of development" (pp. 888-889). Primary studies in these reviews ranged from 3-20 studies and interventions were assessed as low quality. In the current update, we located only three new systematic reviews (Ahn & Fedewa, 2011; Cerrillo-Urbina et al., 2015; Ferreira-Vorkapic et al., 2015) (see Table 3). Regarding the quality of the reviews, two were assessed as 'fair' and one as 'good'. Across the two reviews providing data for meta-analysis, there were five primary studies with no overlap across reviews.

Insert Table 3 about here

Overall, results show some anxiety reduction effects from physical activity, with effect sizes ranging from a significant, but very small, effect for yoga across two studies, to a moderate effect for young people with ADHD, and moderate-to-large intervention effects for healthy young people. However, the literature remains small and fragmented. It appears not to have progressed much since the 2011 review.

Anxiety: analysis of causality. Given the small amount of research developed since the 2011 review, and the small number and diversity of studies and populations, a full analysis of causality is considered premature. At this stage, it appears that strength of association and experimental evidence do exist, but further work is required to elucidate other elements of causality.

Self-Esteem. Biddle and Asare (2011) concluded from three systematic reviews that "physical activity can lead to improvements in self-esteem. However, there is a paucity of good quality research" (p. 889). Primary studies in these reviews ranged from 20-27 studies and were assessed as generally low quality. In the current update, we located an additional 10 systematic reviews – a 3.3-fold increase

– (Ahn & Fedewa, 2011; Babic et al., 2014; Bassett-Gunter, McEwan, & Kamarhie, 2017; Burkhardt & Brennan, 2012; Ferreira-Vorkapic et al., 2015; Liu, Wu, & Ming, 2015; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Ruotsalainen, Kyngas, Tammelin, & Kaariainen, 2015; J. J. Smith et al., 2014; Spruit, Assink, van Vugt, van der Put, & Stams, 2016) (see Table 4). This suggests that the field has expanded quite considerably over this time. Regarding quality, five reviews were assessed as 'good' and five as 'fair'. Across the 10 reviews, there were 191 primary studies of which 23 featured across more than one review (12%).

Insert Table 4 about here

The field of self-esteem is complex and replete with definitional and conceptual ambiguity. Typically, global self-esteem is defined as an evaluation of oneself and can be comprised of more specific sub-domains, such as physical and social self-perceptions. While the term self-concept refers to self-description, rather than self-evaluation, many authors use it interchangeably with self-esteem. For the purposes of this review, we are unable to differentiate between these constructs based on their usage in studies and reviews. In addition, we will also comment on results that focus on physical self-perceptions, including body image.

Overall, results suggest a mixed picture for whether aspects of self-esteem are related to, or affected by, physical activity. Effect sizes for self-esteem interventions ranged between 0.12 to 0.78, while observational studies reported lower effects of between 0.04-0.14. For physical self-perceptions, effects ranged between 0.04 and 0.33. Moreover, given that it is plausible that those with positive self-perceptions may choose to be more physically active, reviews question whether any relationship might be bi-directional (Babic et al., 2014). From the 10 reviews analysed, six report largely positive conclusions about the role of physical activity, while four report largely inconclusive, mixed, or null findings from reviews of leisure-time physical activity, recreational dance, and outdoor and sport/fitness programs. One review focussed only on resistance or weight training activities and found clear associations with self-esteem (J. J. Smith et al., 2014).

Self-Esteem: analysis of causality. Table 5 shows a summary of the evidence regarding the criteria for judging whether physical activity can be considered to be causally associated with self-esteem in young people. From the reviews assessed in the current update, there appears to be a lack of support for causality. Evidence for strength of association is partial, with support from interventions but less so from observational studies. The case for coherence is only partial, while experimental evidence does exist, with a range of small to large effect sizes. Other criteria are not met, therefore, overall, we cannot conclude that associations between physical activity and self-esteem in young people are causal.

Insert Table 5 about here

Cognitive Functioning. Biddle and Asare (2011) concluded from seven systematic reviews, including one narrative review, that "routine physical activity can be associated with improved cognitive performance, classroom behaviour and academic achievement in young people, but these associations are usually small and not entirely consistent" (p. 894). Primary studies in these reviews ranged from 3-50 and were often either observational or interventions of low quality. In the current update, we located a further 25 systematic reviews – a 3.6-fold increase and essentially 3-4 new reviews per year (Alvarez-Bueno, Pesce, Cavero-Redondo, Sanchez-Lopez, Garrido-Miguel, et al., 2017; Alvarez-Bueno, Pesce, Cavero-

Redondo, Sanchez-Lopez, Martinez-Hortelano, et al., 2017; Busch et al., 2014; Bustamante, Williams, & Davis, 2016; Cerrillo-Urbina et al., 2015; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Den Heijer et al., 2017; Donnelly et al., 2016; Esteban-Cornejo, Tejero-Gonzalez, Sallis, & Veiga, 2015; Fedewa & Ahn, 2011; Ferreira-Vorkapic et al., 2015; Jackson, Davis, Sands, Whittington, & Sun, 2016; Lees & Hopkins, 2013; Marques, Gomez, Martins, Catunda, & Sarmento, 2017; Marques, Santos, Hillman, & Sardinha, 2017; Martin et al., 2018; Mura, Vellante, Nardi, Machado, & Carta, 2015; Poitras et al., 2016; Rasberry et al., 2011; Ruiz-Ariza, Grao-Cruces, de Loureiro, & Martinez-Lopez, 2017; Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012; J. J. Smith et al., 2014; Spruit et al., 2016; Tan, Pooley, & Speelman, 2016; Verburgh, Konigs, Scherder, & Oosterlaan, 2014). This shows a significant increase in interest in the topic of physical activity and cognitive functioning in young people (see Table 6). Regarding the quality of the reviews, 7 (28%) were rated ‘good’, 17 (68%) ‘fair’ and one (4%) as ‘poor’. Meta-analyses to be more likely to be rated as ‘good’ (60%).

Insert Table 6 about here

There were 392 primary studies included across the 25 reviews, of which 273 were featured in more than one review (70%). Overall, the reviews concluded that there are positive associations or effects for physical activity on cognitive functioning and/or academic achievement. Most meta-analyses (90%) concluded that there were meaningful effect sizes, and systematic reviews suggested largely positive associations (73%), with three reviews showing mixed findings. Two reviews of devise-based measures of physical activity concluded that little or no association could be found (Marques, Santos, et al., 2017; Poitras et al., 2016), and long-term or longitudinal evidence was also largely null across two reviews (Den Heijer et al., 2017; Marques, Gomez, et al., 2017), although positively associated with physical fitness in Donnelly et al. (2016).

The field of cognitive functioning is complex and results are best summarised across three main outcome measures: cognitive function, academic achievement, and brain structure and function. Regarding cognitive function, meta-analytic effect sizes for those without cognitive impairment were small but significant (0.20-0.43), with one small review concluding no effect for a measure of planning (e.g., organising thoughts and anticipating consequences) in pre-adolescent children (Verburgh et al., 2014). Larger effects were shown for those with ADHD from 6-10 weeks of aerobic exercise (0.58-0.84) (Cerrillo-Urbina et al., 2015). The most comprehensive systematic review was reported by Donnelly et al. (2016) and this is published as a Position Stand paper for the American College of Sports Medicine. For cognitive outcomes, they concluded that children with higher fitness showed better cognitive performance and this was across longitudinal and cross-sectional studies. They also concluded that interventions showed improvements in executive function tests from physical activity programs. In summary, review-level evidence, including meta-analytic syntheses, showed that positive cognitive effects can arise from physical activity and/or enhanced physical fitness.

Results concerning academic achievement were a little less clear. Effect sizes tended to be smaller than for cognitive function tests (e.g., Alvarez-Bueno, Pesce, Cavero-Redondo, Sanchez-Lopez, Garrido-Miguel, et al., 2017; ES 0.13-0.26). Donnelly et al. (2016) concluded positive associations between physical fitness and academic achievement but more mixed findings for physical activity interventions.

Donnelly et al. (2016) were the only researchers to systematically review the effects of physical activity and fitness on brain structure (e.g., neural architecture) and function (e.g., fMRI). They concluded that physical activity and aerobic fitness were beneficial for brain structures that support executive functioning and memory, including neural networks supportive of executive functioning.

In 2011, Biddle and Asare concluded that the “available evidence does not contribute strongly to the proposition that increasing school physical activity time to the detriment of classroom curricular time is beneficial for school children” (p. 894). However, the data from the current review, and a significantly larger literature than was available in 2011, suggests that evidence does support the view that physical activity and fitness are beneficial for the cognitive health and performance of young people. This could come in various forms of physical activity performed in different contexts and would not necessarily need to replace learning time in the classroom. Indeed, there is now evidence showing the benefits of more physical activity integrated into classroom learning time itself (Donnelly et al., 2016).

Cognitive Functioning: analysis of causality. Table 7 shows a summary of the evidence regarding the criteria for judging whether physical activity can be considered to be causally associated with cognitive functioning in young people. From the large number of reviews assessed in the current update, there appears to be cautious support for a causal relationship. Evidence for strength of association is evident for cognitive function outcome measures, as well as academic achievement and brain structure and function. There is coherence and biological plausibility through the evidence with brain measures. Consistency of findings is partial, but still somewhat limited, and there is partial evidence to support temporal sequencing. Largely null effects have been found for intensity, frequency and duration of physical activity as moderators, thus providing no support for a dose-response relationship. Experimental evidence does exist for cognitive and academic outcomes, with the former showing larger effects.

Insert Table 7 about here

Overall assessment of causality. Table 8 provides a summary of appraisals for assessing whether mental health outcomes can be considered causally associated with physical activity in young people. Anxiety was not assessed for causality, as explained earlier. In summary, the strongest evidence for causality is for cognitive functioning outcomes. A case can be made for a causal link. Four of the seven criteria are satisfied, including strength of association and experimental evidence. A dose-response association, however, is not evident. For depression, causality can only be partially supported. While there is experimental evidence and plausibility, strength of association is only partial, with little evidence across observational studies, including prospective designs. Moreover, there is no dose-response relationship. Self-esteem does not show evidence of a causal association. While there is experimental evidence, there is only partial support for strength of association and no support for consistency, temporal sequencing, or dose-response.

Insert Table 8 about here

General Discussion

Overall conclusions

The purpose of this omnibus review was to update the findings from Biddle and Asare (2011). With a significant increase in the quantity of systematic reviews addressing depression, self-esteem, and cognitive functioning, we felt this was warranted. In addition, an analysis of causality was undertaken, thus allowing a more in-depth assessment of findings in comparison to that provided in the 2011 review.

Overall, there is continued evidence of links between physical activity and mental health in children and adolescents when mental health is restricted to the outcomes of depression, anxiety, self-esteem, and cognitive functioning. Moreover, a case can be made for a causal association with cognitive functioning outcomes, a partial case for depression, but no case for self-esteem. Research on anxiety appears to have stagnated and an analysis of causality is premature.

Our conclusions since 2011 have changed somewhat. Biddle and Asare (2011) said that the effects for self-esteem seemed to be the strongest. This is no longer the case. A significant increase in the quantity and quality of evidence regarding cognitive functioning and, to a lesser extent, depression, now shows these two outcomes to be more clearly associated with physical activity than self-esteem. However, self-esteem is a particularly complex area, as we discuss later.

Across the three mental health outcomes of depression, self-esteem, and cognitive functioning where we were able to assess for causality (see Table 8 for a summary), strength of association was evident, albeit with more variability for depression and self-esteem. But the general lack of support for temporal sequencing (i.e., physical activity preceding the mental health outcome measure) is a weakness. Similarly, there is no evidence across these three mental health outcomes for a dose-response relationship. While this is also a weakness, there may be more complex associations between dose of physical activity and outcomes than are currently assessed. For example, the association may be linear, curvilinear, or contain a threshold, after which no further gains in mental health are made. At this stage, we cannot conclude on any of these due to the lack of evidence. Moreover, 'dose' can be defined in several ways, including physical activity intensity, frequency, and duration.

Finally, all three outcomes assessed for causality showed support from experimental evidence. This alone provides some confidence that physical activity has mental health effects. But, overall, the picture concerning causality remains mixed and in need of clarification and development. Given current evidence, though, we can conclude that a causal association exists for cognitive functioning. Depression is partially supported, but not self-esteem.

Depression

For adults, depression is often seen as the mental health outcome most clearly associated with physical activity (P. J. Smith & Blumenthal, 2013). While evidence exists for an association in young people from the reviews we analysed, the links seem less consistent than for adults. For example, longitudinal studies do not support temporal sequencing, and there is no evidence for a dose-response relationship (see discussion above). Reasons for these mixed findings include the diversity of sampling of young people, including being 'healthy', having mild depressive moods, with clinical levels of depression, and also including other conditions (e.g., ADHD). Where the sampling was more focused on those with depression, results clearly favoured physical activity. However, the identification of reasons for why physical activity might be beneficial for the reduction of depression in young people – so called 'mechanisms' – remains less well studied. Most commentary on this has referred to adults rather than young people. For adults, plausible psychological mechanisms include the enhancement of self-efficacy, the regulation of affect and mood, distraction from negative thoughts, and reinforcement of positive behaviours (Craft, 2013). A number of neurobiological mechanisms have also been proposed, including the monoamine and neurotrophin hypotheses (see Chen, 2013).

According to a conceptual model proposed by Lubans and colleagues (2016), possible mechanisms for young people might be neurobiological, psychosocial or behavioural, and moderators are likely to include frequency, intensity, time, type, and context of physical activity. Lubans et al. (2016) conducted a systematic review of mechanisms by synthesising studies that tested for mediation effects. Rather few studies were available concerning depression and only one tested full mediation. They found that less depression was associated with positive changes in 'physical self-concept' (Annesi, 2005).

Anxiety

The literature concerning physical activity and anxiety in children and adolescents appears not to have expanded in recent years, at least if we note the number of new reviews. It is the only mental health outcome we reviewed that showed fewer systematic reviews available from 2011 than before. It is unclear why this trend is evident. The topic of anxiety and stress is highly relevant to contemporary society and is one of the most frequently managed mental health problems for children, adolescents and young adults (Australian Institute of Health and Welfare, 2011; Lawrence et al., 2015). It is possible that the research focus has shifted towards acute bouts of exercise and how these might influence more transient affective states (Ekkekakis & Dafermos, 2012). However, for the research we reviewed, the literature appears to be small and fragmented. Nevertheless, there were indications of strength of association and experimental evidence. Clearly much more is needed concerning chronic studies of anxiety and stress reduction, particularly during periods of prolonged stress, such as for examinations. The role of acute effects of exercise is also relevant.

Self-esteem

Self-esteem results showed a somewhat mixed picture. Causality was not supported, although there was partial support for strength of association and coherence, and support from experimental evidence. However, self-esteem is a complex field and is replete with definitional and conceptual ambiguity. Key terms are often not defined consistently, such as the interchangeable use of self-esteem (concerning evaluation) and self-concept (concerning description) (Fox, 1997a). Moreover, some studies focus only on global self-esteem and ignore arguably more relevant sub-domains of self-esteem.

One approach to understanding this complexity is the multidimensional and hierarchical model, with global self-esteem at the apex of a structure underpinned by more context-specific domains of self-perceptions, such as an academic self, social self, and physical self (Fox & Corbin, 1989; Shavelson, Hubner, & Stanton, 1976). In turn, each of these domains comprises more specific self-perceptions. For example, perhaps the most relevant sub-domain of global self-esteem in the context of physical activity is the physical self, or ‘physical self-worth’ (Fox, 1997b). This might comprise perceptions about the body, as well as physical capabilities and skills. If physical activity is to impact on global self-esteem, it seems logical that the domain of physical self-worth is an important route through which this will happen. Of course, logically, the connection from such physical self-perceptions through to global self-esteem will only be positive if the experience and context of physical activity are also positive. Experiences in physical activity (e.g., ridicule, embarrassment, perceived failure) could equally damage self-esteem. In addition, some self-perceptions will be subject to discounting. This is where personal qualities might be seen as irrelevant or less important, particularly if negative. On the other hand, some personal qualities, such as physical appearance, might be difficult to discount due to societal norms and pressures.

These arguments show that self-esteem is highly complex. It could be argued that it would be naïve to expect simple associations between physical activity and self-esteem, or its constituent parts, without knowing the wider context and felt experience of physical activity. This may explain the difficulty in being able to find evidence for a causal association.

In their review of mechanisms research concerning physical activity and mental health in youth, Lubans et al. (2016) identified studies where it was possible to test whether physical activity changed potential mechanisms for self-esteem. Changes in appearance and self-esteem were evident in five of six studies. Physical self-worth (two of three studies) and perceived competence (three of four studies) also showed associations with self-esteem. Based on this, Lubans et al. concluded that a causal link between physical activity and self-esteem is evident. This may be true from their review of mechanisms, although we were unable to conclude a causal association when using a more diverse set of criteria. However, the work of Lubans et al. does point to the potential importance of studying changes in aspects of physical self-perceptions rather than just global self-esteem.

Cognitive functioning

Results from the reviews addressing physical activity and cognitive functioning showed the strongest evidence for causality. This field has expanded greatly only the past five years or so and also appears to have increased in quality. However, cognitive functioning is complex and reviews have addressed physical activity in the context of cognitive function, academic achievement, and brain structure/function. It is still early days in determining the effects of physical activity on brain structure and function, and the understanding of mechanisms explaining cognitive effects from physical activity is still developing. Nevertheless, there is a longstanding belief that physical movement is an essential part of the child's overall physical and cognitive development (Blakemore, 2003; Williams, 1986).

One possible explanation for cognitive effects of physical activity is through the effect on executive functioning (EF) which de Greef et al. (2018) define as "higher order cognitive functions that are responsible for initiating, adapting, regulating, monitoring, and controlling information processes and behaviour" (p. 501). The effect of physical activity on EF in older adults is strong (Colcombe & Kramer, 2003), but still developing for young people. Effective executive functioning is known to be important for goal-directed behaviours, memory, and attention, and can affect academic achievement through inhibition and memory, as well as writing and reading skills (Davis & Lambourne, 2009). Donnelly et al. (2016) provided review-level evidence that physical activity interventions do show improvements in EF for young people. Confidence in these conclusions is enhanced by further evidence showing changes in brain structure and function. For example, Donnelly et al. (2016) showed the effects of physical activity and fitness on brain structures such as neural architecture, as well as brain function through fMRI measures. Such mechanisms seem consistent with enhanced executive functioning.

The changes in cognitive and neuro-biological measures from physical activity might logically lead to enhanced academic performance. However, research on physical activity and academic performance is a complex field replete with biases and poor measures. For example, studies using teacher assessments can be non-blinded and biased, and some measures may not be appropriate and open to biases from the social and cultural context. This probably accounts for the less clear effects of physical activity reported in our current omnibus review. That said, if stronger effects can be shown, this will have major implications for the important role of physical activity in schools. For example, emerging evidence is available on the role of more active classrooms, but more is needed on whether physical activity breaks can be effective for learning and performance (Donnelly et al., 2016).

There is now stronger evidence for the effects of physical activity on cognitive functioning in young people than reviewed in our 2011 paper. Moreover, our appraisal of causality is positive, with evidence for strength of association, biological plausibility, and experimental effects. The lack of evidence concerning dose-response may not be a flaw in this argument as it is still unclear whether we should expect a linear relationship for, say, exercise intensity. A lower threshold may be a possibility, after which further gains may not be forthcoming. But more work is needed on this. Given that physical fitness is also associated with cognitive functioning, it remains plausible that some kind of dose-response curve will exist. But this has yet to be identified.

Strengths and Limitations

When placed in the wider context of scientific knowledge generation, this review of reviews has strengths and limitations. Van Strien (1986) has argued that a systematic and comprehensive body of knowledge consists of a network of theories generated at different levels of generalizability (including highly generalizable, mid-range, and highly specific), and via both nomothetic (generally quantitative) and hermeneutic (generally qualitative) methodological approaches (see Vergeer, 2000). The main strength of the current review of reviews is its contribution towards highly generalizable nomothetic theory. At the same time, this is a limitation. It does not address the hermeneutic pathway of the model, nor theories at lower levels of generalisability, such as mid-range theories focusing on particular problems occurring in situations with comparable characteristics.

According to Dixon-Woods et al. (2004), syntheses of qualitative research can play a useful role in explaining the findings of quantitative syntheses and vice versa. In particular, qualitative approaches can inform and enhance intervention studies by examining feasibility and acceptability of trial designs, illuminate participant experiences, evaluate intervention processes, and help understand the links between evidence and practice. Furthermore, qualitative syntheses could contribute to mid-range theoretical knowledge by outlining contextual and cultural differentiations, and providing more context-specific insights that can guide local level policy and interventions. In an effort to update the review of reviews by Biddle and Asare (2011), and appraise criteria for causality, we searched for reviews that focussed on associations (usually quantitative) between physical activity and mental health. We did not integrate qualitative reviews, and this is a limitation.

Nevertheless, the review of reviews we conducted, even allowing for an update over only 7 years, was extensive, covering 42 reviews synthesising evidence from over 700 primary studies. That said, several limitations exist in our ability to conclude with precision. First, studies inevitably assess both physical activity and mental health outcomes in a variety of ways and in different sub-populations. Regarding physical activity, some reviews focus only on assessments from wearable devices, while others utilise self-report measures. Both have limitations and specific purposes. Moreover, the distinction between the behaviour of physical activity and the outcome of physical fitness was not always made clear. We are still uncertain about the role of physical exertion. While acute studies suggest that more positive feelings are elicited by light and moderate intensity physical activity (Ekkekakis, 2003), the evidence is still in need of development for chronic studies.

The assessment of mental health outcomes has also been inconsistent. For example, the operational definition of 'self-esteem' has been variable, and the concept itself is diffuse. In addition, cognitive functioning has been assessed in diverse ways and that field, too, is complex.

Finally, while a number of mechanisms have been proposed to explain why physical activity might impact mental health, there has been rather slow progress on disentangling effects within the physical activity environment for social influences and activity preferences. To put it simply, we would expect stronger effects for physical activity when the social context is positive and reinforcing, and less so for activities that individuals find dull or aversive.

Conclusion

In updating the Biddle and Asare (2011) review of reviews, we have shown, through an extensive analysis of a large number of systematic reviews, that physical activity is associated with mental health in young people. A causal association can be claimed for cognitive functioning, in part for depression, but not currently for self-esteem. The field of anxiety research in physical activity is in need of further development. Overall, we concur with a recent call for greater policy emphasis on physical activity for young people, based on the assertion that “the scientific evidence suggests that regular physical activity protects against deficits in mental health and supports cognitive function” (Beauchamp, Puterman, & Lubans, 2018).

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References

Ahn, S., & Fedewa, A. L. (2011). A meta-analysis of the relationship between children's physical activity and mental health. *Journal of Pediatric Psychology, 36*(4), 385-397. doi:10.1093/jpepsy/jsq107

Alvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sanchez-Lopez, M., Garrido-Miguel, M., & Martinez-Vizcaino, V. (2017). Academic achievement and physical activity: a meta-analysis. *Pediatrics, 140*(6). doi:10.1542/peds.2017-1498

Alvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sanchez-Lopez, M., Martinez-Hortelano, J. A., & Martinez-Vizcaino, V. (2017). The effect of physical activity interventions on children's cognition and metacognition: a systematic review and meta-analysis. *Journal of the American Academy of Child and Adolescent Psychiatry, 56*(9), 729-738. doi:10.1016/j.jaac.2017.06.012

Annesi, J. J. (2005). Improvements in self-concept associated with reductions in negative mood in preadolescents enrolled in an after-school physical activity program *Psychological Reports, 97*(2), 400-404.

Australian Institute of Health and Welfare. (2011). *Young Australians: their health and wellbeing 2011* (Vol. Cat. no. PHE 140). Canberra: Australian Institute of Health and Welfare.

Babic, M. J., Morgan, P. J., Plotnikoff, R. C., Lonsdale, C., White, R. L., & Lubans, D. R. (2014). Physical activity and physical self-concept in youth: systematic review and meta-analysis. *Sports Medicine, 44*(11), 1589-1601. doi:10.1007/s40279-014-0229-z

Bailey, A. P., Hetrick, S. E., Rosenbaum, S., Purcell, R., & Parker, A. G. (2017). Treating depression with physical activity in adolescents and young adults: a systematic review and meta-analysis of randomised controlled trials. *Psychological Medicine*, 1-20. doi:10.1017/S0033291717002653

Bassett-Gunter, R., McEwan, D., & Kamarhie, A. (2017). Physical activity and body image among men and boys: A meta-analysis. *Body Image, 22*, 114-128. doi:10.1016/j.bodyim.2017.06.007

Beauchamp, M. R., Puterman, E., & Lubans, D. R. (2018). Physical inactivity and mental health in late adolescence. *JAMA Psychiatry, Published online April 18, 2018*, E1-E2.

Biddle, S. J. H., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine, 45*, 886-895 doi:10.1136/bjsports-2011-090185

Biddle, S. J. H., & Vergeer, I. (in press). A brief history of exercise psychology. In M. Anshell & S. Petruzzello (Eds.), *Handbook of sport and exercise psychology: Vol 2 - Exercise psychology*. Washington, DC: American Psychological Association.

Blakemore, C. L. (2003). Movement is essential to learning. *Journal of Physical Education, Recreation and Dance, 74*(41), 22-24.

Brown, H. E., Pearson, N., Braithwaite, R. E., Brown, W. J., & Biddle, S. J. (2013). Physical activity interventions and depression in children and adolescents : a systematic review and meta-analysis. *Sports Medicine, 43*(3), 195-206. doi:10.1007/s40279-012-0015-8

Burkhardt, J., & Brennan, C. (2012). The effects of recreational dance interventions on the health and well-being of children and young people: A systematic review. *Arts & Health, 4*(2), 148-161. doi:10.1080/17533015.2012.665810

Bursnall, P. (2014). The relationship between physical activity and depressive symptoms in adolescents: a systematic review. *Worldviews of Evidence Based Nursing, 11*(6), 376-382. doi:10.1111/wvn.12064

Busch, V., Loyen, A., Lodder, M., Schrijvers, A. J. P., van Yperen, T. A., & de Leeuw, J. R. J. (2014). The effects of adolescent health-related behavior on academic performance: a systematic review of the longitudinal evidence. *Review of Educational Research, 84*(2), 245-274. doi:10.3102/0034654313518441

Bustamante, E. E., Williams, C. F., & Davis, C. L. (2016). Physical activity interventions for neurocognitive and academic performance in overweight and obese youth: a systematic review. *Pediatric Clinics of North America, 63*(3), 459-480. doi:10.1016/j.pcl.2016.02.004

Carter, T., Morres, I. D., Meade, O., & Callaghan, P. (2016). The effect of exercise on depressive symptoms in adolescents: a systematic review and meta-Analysis. *Journal of the American Academy of Child and Adolescent Psychiatry, 55*(7), 580-590. doi:10.1016/j.jaac.2016.04.016

Cerrillo-Urbina, A. J., Garcia-Hermoso, A., Sanchez-Lopez, M., Pardo-Guijarro, M. J., Santos Gomez, J. L., & Martinez-Vizcaino, V. (2015). The effects of physical exercise in children with attention deficit hyperactivity disorder: a systematic review and meta-analysis of randomized control trials. *Child: Care, Health, and Development, 41*(6), 779-788. doi:10.1111/cch.12255

Chen, M. J. (2013). The neurobiology of depression and physical exercise. In P. Ekkekakis (Ed.), *Routledge handbook of physical activity and mental health* (pp. 169-183). London: Routledge.

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14*(2), 125-130.

Cooney, G. M., Dwan, K., Greig, C. A., Lawlor, D. A., Rimer, J., Waugh, F. R., . . . Mead, G. E. (2013). Exercise for depression. *Cochrane Database of Systematic Reviews, Issue 9*, Art. No.: CD004366. doi:10.1002/14651858.CD004366.pub6

Craft, L. L. (2013). Potental psychological mechanisms underlying the exercise and depression relationship In P. Ekkekakis (Ed.), *Routledge handbook of physical activity and mental health* (pp. 161-168). London: Routledge.

Davis, C. L., & Lambourne, K. (2009). Exercise and cognition in children. In T. McMorris, P. D. Tomporowski, & M. Audiffren (Eds.), *Exercise and cognitive function* (pp. 249-267). Chichester, UK: Wiley-Blackwell.

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *Journal of Science and Medicine in Sport, 21*(5), 501-507. doi:10.1016/j.jsams.2017.09.595

Den Heijer, A. E., Groen, Y., Tucha, L., Fuermaier, A. B., Koerts, J., Lange, K. W., . . . Tucha, O. (2017). Sweat it out? The effects of physical exercise on cognition and behavior in children and adults with ADHD: a systematic literature review. *Journal of Neural Transmission, 124*(Suppl 1), 3-26. doi:10.1007/s00702-016-1593-7

Dishman, R. K., Heath, G. W., & Lee, I.-M. (2013). *Physical activity epidemiology (2nd Edn)*. Champaign, IL: Human Kinetics.

Dixon-Woods, M., Agarwal, S., Young, B., Jones, D., & Sutton, A. (2004). *Integrative approaches to qualitative and quantitative evidence*. London: Health Development Agency [https://www.webarchive.org.uk/wayback/archive/20140616160402/http://nice.org.uk/aboutnice/whoweare/aboutthehda/hdapublications/hda_publications.jsp?o=551].

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., . . . Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Medicine and Science in Sports and Exercise, 48*(6), 1197-1222. doi:10.1249/MSS.0000000000000901

Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspectives from exercise. *Cognition and Emotion, 17*, 213-239. doi:10.1080/02699930244000282

Ekkekakis, P., & Dafermos, M. (2012). Exercise is a many-splendored thing, but for some it does not feel so splendid: staging a resurgence of hedonistic ideas in the quest to understand exercise behavior. In E. O. Acevedo (Ed.), *The Oxford handbook of exercise psychology* (pp. 295-333). New York: Oxford University Press.

Esteban-Cornejo, I., Tejero-Gonzalez, C. M., Sallis, J. F., & Veiga, O. L. (2015). Physical activity and cognition in adolescents: A systematic review. *Journal of Science and Medicine in Sport, 18*(5), 534-539. doi:10.1016/j.jsams.2014.07.007

Fedewa, A. L., & Ahn, S. (2011). The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis. *Research Quarterly for Exercise and Sport, 82*(3), 521-535. doi:10.1080/02701367.2011.10599785

Ferreira-Vorkapic, C., Feitoza, J. M., Marchioro, M., Simoes, J., Kozasa, E., & Telles, S. (2015). Are there benefits from teaching yoga at schools? a systematic review of randomized control trials of yoga-based interventions. *Evidence Based Complementary and Alternative Medicine, 2015*, 345835. doi:10.1155/2015/345835

Fox, K. R. (1997a). Let's get physical. In K. R. Fox (Ed.), *The physical self: From motivation to well-being* (pp. vii-xiii). Champaign, IL: Human Kinetics.

Fox, K. R. (1997b). The physical self and processes in self-esteem development. In K. R. Fox (Ed.), *The physical self: From motivation to well-being* (pp. 111-139). Champaign, IL: Human Kinetics.

Fox, K. R., & Corbin, C. B. (1989). The Physical Self Perception Profile: Development and preliminary validation. *Journal of Sport and Exercise Psychology, 11*, 408-430.

Hill, A. B. (1965). The environment and disease: Association or causation? *Proceedings of the Royal Society of Medicine, 58*(5), 295-300.

Hoare, E., Milton, K., Foster, C., & Allender, S. (2016). The associations between sedentary behaviour and mental health among adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 108. doi:10.1186/s12966-016-0432-4

Jackson, W. M., Davis, N., Sands, S. A., Whittington, R. A., & Sun, L. S. (2016). Physical activity and cognitive development: a meta-analysis. *Journal of neurosurgical anesthesiology, 28*(4), 373-380. doi:10.1097/ANA.0000000000000349

Janssen, I., & Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*, 40. doi:10.1186/1479-5868-7-40

Johnson, K. E., & Taliaferro, L. A. (2011). Relationships between physical activity and depressive symptoms among middle and older adolescents: a review of the research literature. *Journal for Specialists in Pediatric Nursing, 16*(4), 235-251. doi:10.1111/j.1744-6155.2011.00301.x

Korczak, D. J., Madigan, S., & Colasanto, M. (2017). Children's physical activity and depression: a meta-analysis. *Pediatrics, 139*(4), e 20162266. doi:10.1542/peds.2016-2266

Lawrence, D., Johnson, S., Hafekost, J., Boterhoven De Haan, K., Sawyer, M., Ainley, J., & Zubrick, S. R. (2015). *The mental health of children and adolescents: report on the second Australian Child and Adolescent Survey of Mental Health and Wellbeing*. Canberra: Department of Health.

Layman, E. M. (1974). Psychological effects of physical activity. *Exercise and Sport Sciences Reviews, 2*, 33-70.

Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: a systematic review of randomized control trials. *Preventing Chronic Disease, 10*, E174. doi:10.5888/pcd10.130010

Liu, M., Wu, L., & Ming, Q. (2015). How does physical activity intervention improve self-esteem and self-concept in children and adolescents? evidence from a meta-analysis. *PLoS ONE, 10*(8), e0134804. doi:10.1371/journal.pone.0134804

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Medicine, 40*(12), 1019-1035. doi:10.2165/11536850-000000000-00000

Lubans, D. R., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., . . . Biddle, S. J. H. (2016). Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics, 138*(3), e20161642. doi:10.1542/peds.2016-1642

Marques, A., Gomez, F., Martins, J., Catunda, R., & Sarmento, H. (2017). Association between physical education, school-based physical activity, and academic performance: a systematic review. *Retos - Nuevas Tendencias En Educacion Fisica Deporte Y Recreacion, 31*, 316-320.

Marques, A., Santos, D. A., Hillman, C. H., & Sardinha, L. B. (2017). How does academic achievement relate to cardiorespiratory fitness, self-reported physical activity and objectively reported physical activity: a systematic review in children and adolescents aged 6-18 years. *British Journal of Sports Medicine, Published Online First: 14 October 2017*. doi:10.1136/bjsports-2016-097361

Martin, A., Booth, J. N., Laird, Y., Sproule, J., Reilly, J. J., & Saunders, D. H. (2018). Physical activity, diet and other behavioural interventions for improving cognition and school achievement in children and adolescents with obesity or overweight. *Cochrane Database of Systematic Reviews, Issue 1*(Art. No.: CD009728). doi:10.1002/14651858.CD009728.pub3

Mountjoy, M., Andersen, L. B., Armstrong, N., Biddle, S., Boreham, C., Bedenbeck, H.-P. B., . . . van Mechelen, W. (2011). International Olympic Committee consensus statement on the health and fitness of young people through physical activity and sport. *British Journal of Sports Medicine, 45*(11), 839-848. doi:10.1136/bjsports-2011-090228

Mura, G., Vellante, M., Nardi, A. E., Machado, S., & Carta, M. G. (2015). Effects of school-based physical activity interventions on cognition and academic achievement: a systematic review. *CNS & Neurological Disorders - Drug Targets, 14*(9), 1194-1208. doi:10.2174/1871527315666151111121536

Mutrie, N. (2000). The relationship between physical activity and clinically defined depression. In S. J. H. Biddle, K. R. Fox, & S. H. Boutcher (Eds.), *Physical activity and psychological well-being* (pp. 46-62). London: Routledge.

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J. P., Janssen, I., . . . Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology Nutrition and Metabolism, 41*(6 Suppl 3), S197-239. doi:10.1139/apnm-2015-0663

Radovic, S., Gordon, M. S., & Melvin, G. A. (2017). Should we recommend exercise to adolescents with depressive symptoms? A meta-analysis. *Journal of Paediatrics and Child Health, 53*(3), 214-220. doi:10.1111/jpc.13426

Rasberry, C. N., Lee, S. M., Robin, L., Laris, B. A., Russell, L. A., Coyle, K. K., & Nihiser, A. J. (2011). The association between school-based physical activity, including physical education, and academic performance: a systematic review of the literature. *Preventive Medicine, 52 Suppl 1*, S10-20. doi:10.1016/j.ypmed.2011.01.027

Ruiz-Ariza, A., Grao-Cruces, A., de Loureiro, N. E. M., & Martinez-Lopez, E. J. (2017). Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005-2015. *International Review of Sport and Exercise Psychology, 10*(1), 108-133. doi:10.1080/1750984x.2016.1184699

Ruotsalainen, H., Kyngas, H., Tammelin, T., & Kaariainen, M. (2015). Systematic review of physical activity and exercise interventions on body mass indices, subsequent physical activity and psychological symptoms in overweight and obese adolescents. *Journal of Advanced Nursing, 71*(11), 2461-2477. doi:10.1111/jan.12696

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research, 46*, 407-441.

Singh, A., Uijtdewilligen, L., Twisk, J. W., van Mechelen, W., & Chinapaw, M. J. (2012). Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment. *Archives of Pediatric & Adolescent Medicine, 166*(1), 49-55. doi:10.1001/archpediatrics.2011.716

Smith, J. J., Eather, N., Morgan, P. J., Plotnikoff, R. C., Faigenbaum, A. D., & Lubans, D. R. (2014). The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. *Sports Medicine, 44*(9), 1209-1223. doi:10.1007/s40279-014-0196-4

Smith, P. J., & Blumenthal, J. A. (2013). Exercise and physical activity in the prevention and treatment of depression. In P. Ekkekakis (Ed.), *Routledge handbook of physical activity and mental health* (pp. 145-160). London: Routledge.

Spruit, A., Assink, M., van Vugt, E., van der Put, C., & Stams, G. J. (2016). The effects of physical activity interventions on psychosocial outcomes in adolescents: A meta-analytic review. *Clinical Psychology Review, 45*, 56-71. doi:10.1016/j.cpr.2016.03.006

Suchert, V., Hanewinkel, R., & Isensee, B. (2015). Sedentary behavior and indicators of mental health in school-aged children and adolescents: A systematic review. *Preventive Medicine, 76*(0), 48-57. doi:10.1016/j.ypmed.2015.03.026

Tan, B. W., Pooley, J. A., & Speelman, C. P. (2016). A meta-analytic review of the efficacy of physical exercise interventions on cognition in individuals with Autism Spectrum Disorder and ADHD. *Journal of Autism and Developmental Disorders, 46*(9), 3126-3143. doi:10.1007/s10803-016-2854-x

Van Strien, P. J. (1986). *Praktijk als wetenschap: Methodologie van het sociaal-wetenschappelijk handelen [Practice as science: Methodology of social-scientific actions]*. Assen, The Netherlands: van Gorcum.

Verburgh, L., Konigs, M., Scherder, E. J., & Oosterlaan, J. (2014). Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. *Br J Sports Med, 48*(12), 973-979. doi:10.1136/bjsports-2012-091441

Vergeer, I. (2000). Interpersonal relationships in sport: From nomology to idiography. *International Journal of Sport Psychology, 31*, 578-583.

Williams, H. G. (1986). The development of sensory-motor function in young children. In V. Seefeldt (Ed.), *Physical activity and well-being* (pp. 106-122). Reston, VA: American Alliance for Health, Physical Education, Recreation, and Dance.

Table 1. Reviews of physical activity and depression in young people, 2011-2017

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	**Type of review; types of research design and number of studies (k) on depression**	**Sample for current analyses**	**Exposure variables**	**Main findings**	**Comments and conclusions**
Ahn & Fedewa (2011) 1960-2010 NIHQ: 5 (fair)	Meta-analysis RCT, k=14, non-RCT (between-subject posttest-only-control group design or within-subject pretest–posttest design), k=16. Observational (CS): k=12	Aged 3-18 years; all young people eligible regardless of health status.	Aerobic, strength, flexibility, PE, sports, motor skill training, yoga.	Interventions: RCT: ES (d) = -0.41; non-RCT: ES (d) = -1.14 Observational: ES (r) = -0.14	Conclusions “increased levels of physical activity had significant effects in reducing depression …” Effect sizes “consistent with meta-analytic reviews in adults”
Bailey et al. (2017) 1980-2016 NIHQ: 7 (good)	Meta-analysis RCT(k=5)	Aged 12-25 years. Only adolescents analysed here. Depression (a) meeting diagnostic criteria or (b) minimum threshold (defined by trial authors).	PA	ES (SMD) = -0.59 (95%CI = −1.08 to −0.11)	Conclusions: “physical activity is a promising primary intervention for adolescents … experiencing a diagnosis or threshold symptoms of depression, however concerns surrounding methodological quality of included trials limit our ability to conclude on its effectiveness.”
Brown et al. (2013) Up to 2011 NIHQ: 6 (fair)	Meta-analysis RCT (k=5), controlled trials (k=2), cluster RCT	Aged 8-19 years; all young people eligible regardless of health status.	PA	ES (g) = -0.26 (95% CI =-0.43, -0.08).	Conclusions: “study quality was higher than in previous reviews, and the small but significant treatment effect suggests that PA may

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on depression	Sample for current analyses	Exposure variables	Main findings	Comments and conclusions
	(k=1), quasi-experimental (k=1)				play a role in the prevention and treatment of depression in young people"; "largest effects … were for higher quality, short (less than 3 months in duration), RCTs that included both education and PA".
Bursnall (2014) 2008-2013 NIHQ: 3 (poor)	Systematic review RCT (k=1), non-RCT intervention (k=1), cohort studies (k=8)	Aged 11-17 years	PA	Cohort studies: significant, consistent inverse relationship between PA and depression. Interventions: positive effects for PA on reduced depression	Comment: One intervention study was included with mean age = 9 (range = 7–11) years. Conclusion: "evidence cannot establish a causal link, but does show promise as it consistently found a strong inverse correlation between PA and depressive symptoms"
Carter et al. (2016) Up to April, 2014 NIHQ: 8 (good)	Systematic review (k=11) and meta-analysis (k=8) RCT	Aged 13-17 years. General population (5 trials); participants with moderate depression ("at risk" population in a juvenile delinquent institution) (1 trial); clinical samples (5 trials).	Exercise and PA with specified duration and overall time	Trials with clinical samples: ES (SMD) = -0.43 (95% CI -0.84, -0.02). General population: ES (SMD) = -0.52 (95% CI -1.30, 0.26).	Conclusion: "exercise appears to be a promising antidepressant strategy for adolescents"

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on depression	Sample for current analyses	Exposure variables	Main findings	Comments and conclusions
Janssen & LeBlanc (2010) Up to January, 2008 NIHQ: 5 (fair)	Systematic review Observational CS (k=3); RCT (k=3)	Aged 5-17 years	PA, inc. aerobic exercise	CS: small (non-significant) to modest associations RCT: small to modest ESs in favour of PA (significant)	Comments: Part of a wide-ranging review of health outcomes of PA. RCTs reviewed had a small volume of PA (60-90 mins/wk) Conclusions: none provided
Johnson & Taliaferro (2011) Dates of search not specified. Searched for papers published 1997-2010. NIHQ: 4 (fair)	Systematic review Observational CS (k=12); LONG (k=5); RCT (k=1)	Aged 14-19 years (middle and older adolescents)	MVPA and team sports	Inverse relationships between PA, including sports participation, and depression. One null study.	Comment: 19 studies reported, but one was a review of literature. Conclusions: “PA serves as a protective factor against depression among middle and older adolescents. However, the strength of this relationship remained small to moderate and may not generalize to high-risk groups of older adolescents”.
Korczak et al. (2017) Up to 2015, for papers published 2005-2015 NIHQ: 6 (fair)	Meta-analysis CS k=36; LONG k=14	Aged < 18 years	PA	ES (r) = –0.14 (95% CI = –0.19, –0.10) (adjusted r=-0.06). Cross-sectional: r = –0.17 (95% CI = –0.23 to –0.10)	Conclusions: “PA in childhood and adolescence is associated with improved concurrent symptoms of depression … and has weak but significant effects on future depressive symptoms

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on depression	Sample for current analyses	Exposure variables	Main findings	Comments and conclusions
				Longitudinal: r = –0.07 (95% CI = –0.10 to –0.04)	
Poitras et al. (2016) Up to January, 2015 NIHQ: 4 (fair)	Systematic review CS k=4; LONG k=1	Aged 5-17 years. Healthy, inc. obese.	PA assessed with 'objective' (wearable technology) devices.	Null or mixed CS findings; no longitudinal association for depressed mood or major depression.	Comments: Part of a wide-ranging review of health outcomes of PA. Conclusions (below) seem optimistic given evidence summarised. Conclusions: "some support for favourable relationships between total PA and … psychological distress"
Radovic et al. (2017) Up to January, 2015 NIHQ: 6 (fair)	Meta-analysis RCT (k=8)	Aged 12-18 years. Adolescents diagnosed with depression.	All forms of exercise engaged in at least twice a week for a minimum of 20 min	ES (g) = −0.61 (p = .007)	Conclusion: "moderate significant effect of exercise in the reduction of depressive symptoms"

<u>Notes</u>:

k: number of studies

NIHQ: NIH (National Institutes of Health) Quality Assessment of Systematic Reviews and Meta-Analyses. Scores for systematic reviews out of 7 (Good: 6-7; Fair: 4-5; Poor 0-3). Scores for meta-analyses out of 8 (Good: 7-8; Fair: 4-6; Poor 0-3).

Exposure. PE: physical education; PA: physical activity; MVPA: moderate-to-vigorous physical activity;

Design (as described in reviews). CS: cross-sectional; LONG: longitudinal or prospective; RCT: randomised controlled trial

Results. ES: effect size; d: Cohen's d; SMD: standardised mean difference; g: Hedges' g; r: Pearson's r; CI: confidence interval

Table 2. Assessments for whether physical activity is causality associated with depression.

Causality criterion	Definition	Current updated review assessment	
		Evidence for causality?	Summary
Strength of association	How strong is the association between physical activity and depression?	Partial	Interventions show moderate effect sizes (ES) usually in the 0.4-0.5 range (see Experimental Evidence below). Observational studies show small to very small associations.
Consistency	How consistent is the evidence across different populations and in different settings?	Partial	Where tested (e.g., age, sex), little indication of inconsistent findings, but some populations not studied.
Temporal sequencing	Does physical (in)activity precede the development of depression?	No	Longitudinal studies do not support temporal sequencing, with null to small associations or effects. Reverse causality not tested but plausible.
Coherence and biological plausibility	Any interpretation of the data should not seriously conflict with what is known about depression. Biological plausibility provides further support for causation.	Yes	Plausible but studies lacking on definitive tests of mechanisms.
Dose-response relationship	Do higher levels of physical activity show	No	Largely null effects for intensity, frequency and duration as moderators.

Causality criterion	**Definition**	**Current updated review assessment**	
	lower levels of depression?		
Experimental evidence	Is there evidence from interventions using experimental methods for changes in depression to result from changes in physical activity?	Yes	Evidence for intervention trials, for both clinical and non-clinical samples show moderate effect sizes (see Strength of Association above).

Table 3. Reviews of physical activity and anxiety in young people, 2011-2017

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	**Type of review; types of research design and number of studies (k) on anxiety**	**Sample for current analyses**	**Exposure variables**	**Main findings**	**Comments and conclusions**
Ahn & Fedewa (2011) 1960-2010 NIHQ: 5 (fair)	Meta-analysis RCT, k=16, non-RCT (between-subject posttest-only-control group design or within-subject pretest–posttest design), k=9, Observational (CS): k=7	Aged 3-18 years; all young people eligible regardless of health status	Aerobic, strength, flexibility, PE, sports, motor skill training, yoga	Interventions: RCT: ES (d) = -0.35; non-RCT: ES (d) = -1.51 Observational: ES (r) = -0.09	Conclusions: “increased levels of physical activity had significant effects in reducing anxiety …” Effect sizes “consistent with meta-analytic reviews in adults”
Cerrillo-Urbina et al. (2015) Up to 2014 NIHQ: 7 (good)	Systematic review & Meta-analysis RCT (k=3; 2 reported for meta-analysis)	Aged 6-18 years; young people diagnosed with ADHD	PE programmes (motor driven & multi-sports aerobic activity, yoga)	ES (SMD) = -0.66 (95% CI =-0.13, -1.18).	Conclusions: “short-term aerobic exercises (6-10 weeks), based on several intervention formats, reported a moderate to large effect on…anxiety”
Ferreira-Vorkapic et al. (2015) 1980-2014 NIHQ: 6 (fair)	Systematic review & Meta-analysis RCT (k=2)	Aged 12-17 years; young people with learning disabilities or any diagnosed mental disorder were not eligible	Yoga	ES (SMD) = -0.036 (95% CI=-0.71, -0.01)	Conclusions: “… significant effect for the sub-items tension and anxiety”. Comment: Overall, very small significant effect from only 2 reviews with one review (weighted 30%) showing large effect size. Yoga includes relaxation.

Notes:

k: number of studies

NIHQ: NIH (National Institutes of Health) Quality Assessment of Systematic Reviews and Meta-Analyses. Scores for systematic reviews out of 7 (Good: 6-7; Fair: 4-5; Poor 0-3). Scores for meta-analyses out of 8 (Good: 7-8; Fair: 4-6; Poor 0-3).

Exposure. PE: physical education; PA: physical activity; MVPA: moderate-to-vigorous physical activity

Design (as described in reviews). CS: cross-sectional; LONG: longitudinal or prospective; RCT: randomised controlled trial

Results. ES: effect size; SMD: standardised mean difference; d: Cohen’s d; r: Pearson’s r; CI: confidence interval

952 Table 4. Reviews of physical activity and self-esteem in young people, 2011-2017

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Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	**Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)**	**Sample for current analyses**	**Exposure variables**	**Self-esteem related outcome variables**	**Main findings**	**Comments and conclusions**
Ahn & Fedewa (2011) 1960-2010 NIHQ: 5 (fair)	Meta-analysis SE, RCT: k=26, non-RCT, k=16. CS: k=14 SC, RCT, k=9, non-RCT, k=6. CS: k=8	Aged 3-18 years; all young people eligible regardless of health status	Aerobic, strength, flexibility training, PE, sports, motor skill training, yoga, combined (e.g., aerobic and strength)	SC	SE: Interventions: RCT: ES (d) = 0.29; non-RCT: ES (d) = 0.78. Observational: ES (r) = 0.04 SC: Interventions: RCT: ES (d) = 0.16; non-RCT: ES (d) = 0.12. Observational: ES (r) = 0.14	Conclusions: SE: “both RCT and non-RCT studies showed that PA increased children’s levels of SE”. SC: “correlational studies found a significant relationship between increased levels of PA and an enhanced SC”. Effect sizes “consistent with meta-analytic reviews in adults”. “These findings can be interpreted as robust”.
Babic (2014) Up to August 2013, for papers	Systematic review and meta-analysis	Aged 5–20 years	Leisure-time PA	SC; general physical SC; perceived competence; perceived fitness;	ES (r) = 0.25 for general physical SC; ES (r) = 0.33 for perceived competence;	Conclusions: “young people with stronger beliefs about their physical characteristics

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)	Sample for current analyses	Exposure variables	Self-esteem related outcome variables	Main findings	Comments and conclusions
published 1991-2013 NIHQ: 8 (good)	SC, CS: k=76, LONG: k=22, EXP: k=13			perceived appearance	ES (r) = 0.30 for perceived fitness; ES (r) = 0.14 for perceived appearance. Findings not Included in meta-analysis: consistent positive associations between PA and general physical SC (22 studies reporting statistically significant association from 26 studies), perceived competence (24/29), perceived fitness (11/13), perceived appearance (19/28)	are more likely to engage in PA than those who report lower levels of physical SC", but "it is not clear if participation in PA leads to improvements in physical SC or those with high levels of physical SC are attracted to PA". "There is sufficient evidence to conclude that there is a bi-directional association between PA and physical SC". Effect sizes "similar, but slightly smaller, than those of reviews on the effects of exercise on SE in young adults and adults".

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)	Sample for current analyses	Exposure variables	Self-esteem related outcome variables	Main findings	Comments and conclusions
Bassett-Gunter (2017) Up to January 2015, for papers published 1983-2014 NIHQ: 7 (good)	Meta-analysis BI, correlational studies: k=9. Intervention studies: k=3	Adolescents (age range not clear)	Leisure-time PA, exercise, weight training	BI	Correlational studies, ES (g) = 0.47 Intervention studies, ES (g) = 0.04	Conclusions: "The limited number of studies examining adolescents preclude any conclusive understanding of the PA-BI relationship" in this group.
Burkhardt (2012) 1947-2009 NIHQ: 5 (fair)	Systematic review RCT: k=1; non-RCT: k=2	Aged 13-16 years. Female.	Recreational dance	Attractiveness; physical SW; BI; SC	RCT: significant improvements in attractiveness and physical SW. Positive effects on BI and SW, but not sustained longer-term. Non-RCT: small but non-significant improvements in SC; significant improvements in physical SW and body attractiveness	Conclusions: "There is limited evidence that suggests that dance participation may improve SC and BI".

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)	Sample for current analyses	Exposure variables	Self-esteem related outcome variables	Main findings	Comments and conclusions
Ferreira-Vorkapic (2015) 1980-2014 NIHQ: 6 (fair)	Systematic review and meta-analysis SE, RCT: k=3	Aged 5-18 years	Yoga	SE	2 RCT, ES (SMD): −0.37 (95% CI −0.66 to −0.07). 1 RCT, no differences.	Conclusions: "Although the number of RCT studies is very limited, the results seem promising".
Liu (2015) Up to July 2014, for papers published 1981-2014 NIHQ: 6 (fair)	Systematic review and meta-analysis RCT: k=25. Non-RCT: k=13 (SE, k=19; SC: k=7; SW: k=12)	Aged 3-20 years	PA, exercise, sport	SC; SW	PA alone on self-outcomes: RCT, ES (SMD): 0.29 (95% CI 0.14 to 0.45). Non-RCT, ES (SMD): 0.33 (95% CI -0.35 to 1.01) PA combined with other interventions: RCT, ES (SMD): 0.24 (95% CI -0.09 to 0.58). Non-RCT, ES (SMD): 0.08 (95% CI -0.12 to 0.29). RCT, PA alone on SC ES (g) = 0.49; SW ES (g) = 0.31; No significant ES on SE. Non-RCT, no	Conclusions: "PA alone is an effective method to improve SW and SC in juveniles". "Setting of PA intervention is potentially important", "school-based and gymnasium-based PA interventions may exert stronger effects on developing SE and SC."

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	**Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)**	**Sample for current analyses**	**Exposure variables**	**Self-esteem related outcome variables**	**Main findings**	**Comments and conclusions**
					significant ES on SE. Limited number of studies for analyses on SC and SW	
Lubans (2012) Up to December 2010 NIHQ: 6 (good)	Systematic review RCT: k=3; PRE-POST: k=3; QEXP: k=2	Aged 4–18 years Disaffected or at risk youth.	Outdoor activities, sport, physical fitness programmes	SC; SW	Outdoor activities: significant improvements in SW and SC in 2 studies, no improvement in SC in 1 study. Sport: no significant changes in SW and SE in 2 studies; significant effects in SE in 1 study. Fitness: significant improvement in SC in 1 study, no improvement in 1 study	Comments: “encouraging at-risk youth to engage in PA programmes is justified”, but “these findings should be treated with caution due to the high risk of bias in all of the studies reviewed”.
Ruotslainen (2015) 2002–2013 NIHQ: 7 (good)	Systematic review RCT: k=2	Aged 12-18 years. Overweight and obese adolescents	PA, exercise	Physical self-perception; body satisfaction	Positive effects for physical self-perception or body satisfaction. Self-perception or SE, no significant changes	Conclusions: “exercise may improve adolescents’ physical self-perception even if the effect on subsequent PA is marginal”.

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on self-esteem (SE)/ self-concept (SC)/ self-worth (SW)/ body image (BI)	Sample for current analyses	Exposure variables	Self-esteem related outcome variables	Main findings	Comments and conclusions
Smith (2014) Up to May, 2013 NIHQ: 8 (good)	Systematic review CS: k=5; EXP: k=1.	Aged 4-19 years. School-aged youth in the general population	Muscular fitness-related PA (e.g., resistance or weight training)		5/6 (83%) of reported studies showed strong evidence of a positive association between MF and SE	Conclusions: “there is strong evidence for a positive association between MF and SE, although the associations are low to moderate”.
Spruit (2016) Up to August 2015, for papers published 1977-2016 NIHQ: 4 (fair)	Systematic review and meta-analysis RCT: k=20; QEXP: k=13	Aged 10-21 years	PA, sport, exercise	SC	PA increased positive SC: ES (d): 0.297	Conclusions: “PA was effective in improving SC”. “In line with previous literature, larger effects were found for (aerobic) exercise compared to sports.”

<u>Notes</u>:

k: number of studies

NIHQ: NIH (National Institutes of Health) Quality Assessment of Systematic Reviews and Meta-Analyses. Scores for systematic reviews out of 7 (Good: 6-7; Fair: 4-5; Poor 0-3). Scores for meta-analyses out of 8 (Good: 7-8; Fair: 4-6; Poor 0-3).

Exposure. PE: physical education; PA: physical activity; MVPA: moderate-to-vigorous physical activity; MF: muscle fitness activity

Outcome: SE: self-esteem; SC: self-concept; SW: self-worth; BI: body image.

Design (as described in reviews). CS: cross-sectional; LONG: longitudinal or prospective; RCT: randomised controlled trial; EXP: experimental; QEXP: quasi-experimental

Results. ES: effect size; d: Cohen’s d effect size; SMD: standardised mean difference; g: Hedges’ g; CI: confidence interval.

Table 5. Assessment of whether physical activity is causally associated with self-esteem.

Causality criterion	**Definition**	**Current updated review assessment**	
		Evidence for causality?	Summary
Strength of association	How strong is the association between physical activity and self-esteem?	Partial	Intervention effects range from small to large but observational studies show only small effect sizes.
Consistency	How consistent is the evidence across different populations and in different settings?	No	Inconsistent findings across general youth studies as well as with at-risk youth.
Temporal sequencing	Does physical (in)activity precede any changes in self-esteem?	No	Insufficient evidence but bi-directionality remains plausible.
Coherence and biological plausibility	Any interpretation of the data should not seriously conflict with what is known about self-esteem. Biological plausibility provides further support for causation.	Partial	It is logical to expect positive changes in physical and general self-esteem from positive physical activity experiences. But the reverse could also be true. It is unlikely that biological plausibility is relevant.
Dose-response relationship	Do higher levels of physical activity show higher levels of self-esteem?	No	Insufficient evidence.

Causality criterion	**Definition**	**Current updated review assessment**	
Experimental evidence	Is there evidence from interventions using experimental methods for changes in self-esteem to result from changes in physical activity?	Yes	Effect sizes range from small to large. This may be a function of the experience rather than physical activity per se.

Table 6. Reviews of physical activity and cognitive functioning in young people, 2011-2017

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Alvarez-Bueno, Garrido-Miguel et al. (2017a) To October, 2016 NIHQ: 8 (good)	Meta-analysis (k=11) and systematic review (total k=26) RCT k=18 QEXP k=8	Aged 4-13 years Healthy children and adolescents	Exercise programs aimed at enhancing or enriching PA sessions	Language, mathematics, reading and time on-task	Language ES (d) = 0.16 (−0.06, 0.37); mathematics ES = 0.21 (0.09, 0.33); reading ES = 0.13 (0.02, 0.24); composite scores ES = 0.26 (0.07, 0.45)	Conclusions: “PA programs significantly benefit multiple facets of academic achievement”
Alvarez-Bueno, Martinez-Hortelano et al. (2017b) To October, 2016 NIHQ: 8 (good)	Systematic review and meta-analysis (total k=36) RCT k=31 Non-RCT k=5	Aged 4-14 years Healthy children and adolescents	Exercise programs aimed at enhancing or enriching PA sessions	Non-executive functions, core executive functions, working memory, selective attention-inhibition, cognitive flexibility, metacognition, cognitive life skills	Non-executive functions ES (d) = 0.23; core executive functions ES = 0.20 (inc. working memory ES = 0.14); selective attention-inhibition ES = 0.26; cognitive flexibility ES = 0.11; metacognition ES = 0.23 (inc. higher level executive functions ES = 0.19); cognitive life skills ES = 0.30.	Conclusions: “PA programs benefit multiple facets of non-executive, executive and metacognitive functions and skills in children and adolescents”

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Busch et al. (2014) 1992-2012 NIHQ: 5 (fair)	Systematic review (k=9) All LONG	Aged 11-18 years Healthy adolescents	PA and sports	Academic performance	Mainly positive associations for PA/sports	Conclusions: “Most studies concluded that sports participation had a positive impact on students’ school grades”; “most researchers concluded that the observed effects were not explained by the physical activity component of sports but instead by the team component” Comment: not all sports were ‘team’ sports; the one study comparing team vs. individual sports showed similar results.
Bustamante et al. (2016) To Dec, 2015 NIHQ: 2 (poor)	Systematic review (k=13) RCT k=9 QEXP k=4	Aged 7-17 years Overweight and obese children and adolescents	At least several weeks of regular exercise, physical activity, or sport	Neurologic, cognitive, and academic outcomes	Narrative descriptive synthesis of each study showing some positive findings.	“High-quality RCTs with overweight and obese children have shown benefits of regular physical activity for different executive function and neurologic outcomes”

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Cerrillo-Urbina et al. (2015) Up to 2014 NIHQ: 7 (good)	Systematic review and meta-analysis RCT (k=5)	Aged 6-18 years Young people diagnosed with ADHD	Aerobic exercise	Cognitive function	Positive effect for attention: ES (SMD) = 0.84 (0.48, 1.20) and executive function: ES (SMD) = 0.58 (0.15, 1.00).	Conclusions: “short-term aerobic exercises (6-10 weeks) reported a moderate-to-large effect”.
De Greef et al. (2017) 2000 - April, 2017 NIHQ: 7 (good)	Meta-analysis k=15 intervention studies	Aged 6-12 years	PA	Multiple domains of executive functions, attention and academic performance	Overall small to moderate improvement of (a). cognitive functions, ES (g) = 0.37 (0.20, 0.55) and (b). academic performance, ES (g) = 0.26 (0.02, 0.49). ES (g) for domains (>3 studies): Inhibition = 0.19, working memory = 0.36, cognitive flexibility = 0.18, planning = 0.12. Larger effects for cognitively engaging PA (0.53) vs. aerobic PA (0.29).	Conclusions: “positive effects were found for physical activity programs on cognitive functions in preadolescent children. … the positive effects of physical activity programs were consistent for all domains”

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Den Heijer et al. (2017) To April, 2016 NIHQ: 5 (fair)	Systematic review (k=25)	Aged 5-18 years Children and adolescents with ADHD	Exercise (‘cardio’ and ‘non-cardio’)	Cognitive outcome measures, inc. intelligence test scores for attention, planning, inhibition and memory.	Positive effects for cardio exercise on attention (inc. auditory sustained attention and selective attention/information processing), executive functioning (inc. set shifting, response inhibition and planning), verbal working memory, and cognitive speed. No beneficial long-term effects in the areas of inhibition, processing speed, planning, memory span, and continuous motor timing.	Conclusions: “cardio exercise appears to be a more promising treatment method for children with ADHD than non-cardio exercise with regard to both acute and chronic cognitive and behavioral effects, but more well-designed studies are needed”; “information about the chronic effects of non-cardio exercise is scarce”.
Donnelly, et al. (2016) 1990 – Jan, 2014 NIHQ: 5 (fair)	Systematic review k=48 (cognition, learning, brain structure/function): CS k=24 RCT k=16 LONG k=4	Aged 5-13 years	PA, PE, sports, fitness	a). Cognitive performance, learning b). Brain structure, brain function	a). LONG studies show higher fitness associated with better cognitive performance; RCTs show significant improvements, particularly for	Comment: An extensive Position Stand of the American College of Sports Medicine. Conclusions: “there are associations among PA, fitness, cognition, and

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
	COH k=3 k=61 (academic achievement): CS k=37 'Intervention' k=20 LONG k=4			c). Academic achievement	executive function tasks. b). CS and experimental evidence support PA and fitness being associated with brain structure and function indicative of better cognitive functioning (e.g. EF) and brain activation (e.g. ERP). c). Higher physical fitness associated with better academic performance, but with some critical methodological shortcomings; PA and PE show mixed or null findings, with some evidence for benefits of physically active classroom lessons.	academic achievement. Delivery of physically active lessons generally results in improvements in academic achievement, whereas attempts to increase activity in PE do not". "PA has a positive influence on cognitive function as well as brain structure and function; however, more research is necessary to establish causality, to determine mechanisms, and to investigate long-term effects".

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Esteban-Cornejo et al. (2015) 2000 - 2013 NIHQ: 4 (fair)	Systematic review (k=20) CS k=15 LONG k=3 QEXP k=2	Aged 13-18 years	PA, PE, Sports	Cognitive performance measures; academic achievement measures (school grades)	5/6 studies showed positive associations between PA and cognitive performance. Some evidence for intervention effects, though somewhat mixed. 11/15 studies showed positive associations between PA and academic performance.	Conclusions: "evidence of a positive relationship of physical activity with both cognitive and academic performance. Cognitive performance … associated with vigorous physical activity while academic performance … related to general physical activity, mainly in adolescent girls".
Fedewa & Ahn (2011) 1940 - 2009 NIHQ: 4 (fair)	Meta-analysis (k=59) CS k=20 RCT & QEXP k=39	Aged 6-16 years Most were average in their cognitive and physical capabilities; some were cognitively impaired (k = 9), children with learning disabilities (k = 14), hyperactive (k = 2), physically disabled (k = 2),	PA	Cognitive outcomes, academic achievement	Overall ES (d) for PA = 0.28 (0.20, 0.37). ES (d) for interventions = 0.35 (0.27, 0.43) Largest effects for mathematics achievement ES = 0.44 and for cognitively impaired ES = 0.66.	Conclusions: "physical activity has a significantly positive impact on children's cognitive outcomes and academic achievement. Its magnitude … small to medium effect."

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
		or elite athletes (k = 3).				
Ferreira-Vorkapic et al. (2015) 1980-2014 NIHQ: 6 (fair)	Systematic review RCT (k=3)	Aged 12-17 years Young people with learning disabilities or any diagnosed mental disorder were not eligible	Yoga	Memory	Memory: ES (g) = -0.85 (-1.14, -0.55) (better memory performance)	Conclusions: “This review suggests important effects of yoga-based interventions at school on… cognitive function in some studies”
Jackson et al. (2016) No search dates specified NIHQ: 4 (fair)	Meta-analysis (k=8) RCTs	Aged 7-12 years	Structured PA intervention (aerobic exercise) at least once per week for a period of at least 1 month.	Executive function (inhibitory control)	ES (d) = 0.20 (0.03, 0.37)	Conclusion: “Increased regular physical activity is associated with a small and measurable improvement in neuropsychological tests of executive functions, specifically inhibitory control”.

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Lees & Hopkins (2013) Up to April, 2013 NIHQ: 4 (fair)	Systematic review (k=7) RCTs	Aged 5-16 years	Aerobic PA	Academic achievement; cognitive functioning	Enhanced academic achievement or cognitive performance in the (PA) intervention group	Conclusion: "PA is positively associated with cognition, academic achievement, behavior, and psychosocial functioning outcomes".
Marques, Gomez et al. (2017) 2000- 2016 NIHQ: 4 (fair)	Systematic review (k=12) CS k=4 LONG k=2 QEXP k=2 RCT k=4	Aged 6-18 years	PE; school-based PA	Academic performance	Support from CS studies for beneficial relationships between PE or school-based PA and academic performance. LONG evidence inconclusive. Some support from QExp and RCT designs.	Conclusion: "results support … a positive relationship of physical education or school-based physical activity with academic performance".
Marques, Santos et al. (2017) 2000- 2016 NIHQ: 5 (fair)	Systematic review (k=51) CS k=41 LONG k=8 Intervention k=2	Aged 6-18 years	Devise-based ('objective') PA assessment, fitness, self-reported PA	Academic performance	a). inconsistent association between device-measured PA and academic achievement; b). 12/18 observational studies showed support for association; c). support for association between fitness and academic performance	Conclusion: "cardiorespiratory fitness … consistently and positively associated with academic achievement. Objectively measured PA was inconsistently related to academic achievement".

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Martin et al. (2018) Up to February, 2017 NIHQ: 8 (good)	Systematic review and meta-analysis (k=8) RCT Quasi-RCT	Aged 3-18 years Overweight and obese children and adolescents	Group aerobic exercise; group co-ordination skills exercises; physically active academic lessons; extra-curricular individual or small-group PA	School achievement, cognitive function	Executive function scores higher in PA intervention condition (K=1; ES = 0.42); higher in non-verbal memory (K=2; ES = 0.43); higher in mathematics (ES = 0.49, but marginally not significant). No effects for reading or inhibition control.	Comment: Results combining PA and lifestyle interventions not included in this summary. Conclusions: “some evidence that interventions which promote PA may be effective in producing small improvements in composite executive functions and non-verbal memory in primary/ elementary school-aged children with obesity or overweight specifically. However, this evidence is based on a small number of studies.”
Mura et al. (2015) January, 1980 to June, 2014 NIHQ: 4 (fair)	Systematic review (k=31) QEXP k=8 RCT k=23	Aged 3-19 years	School-based PA	Academic achievement and cognitive outcomes	Interventions did not worsen outcomes in 6 studies, and improved mathematics in 4, reading in 1, and in overall academic achievement. Global cognitive performance increased in 7 out of 9 studies.	Comment: figures on PRISMA flow chart not consistent with text. Conclusions: Review “unequivocally demonstrated the effectiveness of school-based PA interventions on academic achievement

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
						and … cognitive performance”
Poitras et al. (2016) Up to January, 2015 NIHQ: 5 (fair)	Systematic review (k=8 studies but data from: QEXP k=1 CS k=6 LONG k=3)	Aged 5-17 years Healthy, including obese.	PA assessed with ‘objective’ (wearable technology) devices.	Academic achievement; cognitive function	Largely null or mixed findings across all study designs and outcomes.	Conclusions: ‘there was a paucity of data regarding the relationships between objectively measured PA and … relevant health indicators (inc. cognition/academic achievement); this is an important research gap, and further research using high-quality study designs will be required’
Rasberry et al. (2011) 1985- October, 2008 NIHQ: 4 (fair)	Systematic review (k=50)	Aged 5-18 years.	School-based PA (inc. PE)	Academic performance (inc. cognitive skills and attitudes, academic behaviors, and academic achievement)	50.5% of all associations examined were positive between PA and cognitive outcomes, 48% were not significant, and 1.5% were negative. Positive associations shown across different exposures and	Conclusions: “adding physical activity to the school day may enhance and does not detract from academic performance”

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
					outcomes, with different research designs; range of positive outcomes across studies = 17-100%.	
Ruiz-Ariza et al. (2017) January 2005 to January 2015 NIHQ: 5 (fair)	Systematic review (k=21) CS k=10 LONG k=4 Mixed CS and LONG k=1 Intervention k=6	Aged 13-18 years	PA and physical fitness	Academic performance; cognitive performance	Description by individual studies or small groups of studies only. No overall results presented.	Conclusions: “physical fitness can be a factor with potential for cognitive and academic development during adolescence”; ‘cardiorespiratory fitness is the most studied component and has the greatest influence on cognitive and academic performance’
Singh et al. (2012) 1990 - 2010 NIHQ: 4 (fair)	Systematic review (k=14) Prospective (observational k=10; intervention k=4)	Aged 5-18 years	PA	Academic performance	1 high-quality intervention study and 1 high quality observational study suggest that being more physically active is positively related to improved academic performance in children	Conclusions: “More high-quality studies are needed on the dose-response relationship between physical activity and academic performance and on the explanatory mechanisms”

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	Type of review; types of research design and number of studies (k) on cognitive function	Sample for current analyses	Exposure variables	Cognitive outcome variables	Main findings	Comments and conclusions
Smith et al. (2014) Up to May, 2013 NIHQ: 8 (good)	Systematic review CS: k=5; EXP: k=1.	Aged 4-19 years School-aged youth in the general population	Muscular fitness-related PA (e.g., resistance or weight training)	Cognitive variables unspecified, but inclusive of academic performance.	50% of CS studies reported a significant association between MF and academic performance.	Conclusions: "Only one of the low-risk-of-bias studies reported a significant association, suggesting inconsistent/ uncertain evidence of an association between MF and cognitive benefits".
Spruit et al. (2016) Up to August 2015, for papers published 1977-2016 NIHQ: 5 (fair)	Systematic review and meta-analysis (k=10) RCT k=7 QEXP k=3	Aged 10-21 years	PA, sport, exercise	Academic achievement	PA interventions significantly increased academic achievement in adolescents: ES (d) = 0.367 (0.038, 0.697). Larger effects for grades compared to standardised achievement tests.	Conclusions: "PA interventions appear to be effective in … improving … academic achievement … the main results … provide justifications for the increasing use of physical activity interventions in adolescent mental health care practice".
Tan et al. (2016) 1968 - 2015 NIHQ: 5 (fair)	Meta-analysis (k=22) Interventions	Aged 3-25 years Individuals with Autism Spectrum Disorder (ASD) and ADHD	PA, exercise	Cognitive function	Overall ES (r) = 0.235 (0.131, 0.335)	Comment: 2 studies included with mean age 21y (18-24) and 22y (18-25). Conclusions: "findings from this meta-analysis support the efficacy of using exercise interventions in improving some aspects of cognitive

Author(s), date, years covered in searches/ review, NIH quality assessment (NIHQ)	**Type of review; types of research design and number of studies (k) on cognitive function**	**Sample for current analyses**	**Exposure variables**	**Cognitive outcome variables**	**Main findings**	**Comments and conclusions**
						functions in individuals with ASD and/or ADHD between the ages of 3–25 years old.”
Verburgh et al. (2014) Up to April, 2013 NIHQ: 7 (good)	Meta-analysis (k=3) Interventions	Aged 6-15 years Pre-adolescents and adolescents.	PA	Executive function	No effect for the EF of planning in pre-adolescents. ES (d) = 0.16 (−0.07, 0.39).	Comment: Analysis included acute PA and adults. Only data from young people extracted for this table. Conclusions: “although the current meta-analysis suggests that there are no age-related differences in the effects of physical exercise on executive functioning, more research on preadolescent children and adolescents is needed to draw firm conclusions”.

<u>Notes</u>:

k: number of studies

NIHQ: NIH (National Institutes of Health) Quality Assessment of Systematic Reviews and Meta-Analyses. Scores for systematic reviews out of 7 (Good: 6-7; Fair: 4-5; Poor 0-3). Scores for meta-analyses out of 8 (Good: 7-8; Fair: 4-6; Poor 0-3).

ADHD: attention–deficit/hyperactivity disorder

EF: executive functioning; ERP: event-related potential

Exposure. PE: physical education; PA: physical activity; MVPA: moderate-to-vigorous physical activity; MF: muscle fitness activity

Design (as described in reviews). CS: cross-sectional; LONG: longitudinal; RCT: randomised controlled trial; EXP: experimental; QEXP: quasi-experimental

Results. ES: effect size; SMD: standardised mean difference; d: Cohen's d; g: Hedges' g; r: Pearson's r

981 Table 7. Assessment of whether physical activity is causally associated with cognitive function.

Causality criterion	**Definition**	**Current updated review assessment**	
		Evidence for causality?	Summary
Strength of association	How strong is the association between physical activity and cognitive function?	Yes	Interventions show small to moderate effect sizes (ES) for academic achievement; small to large ESs for cognitive function; 'robust associations' for brain function outcomes (see Experimental Evidence below).
Consistency	How consistent is the evidence across different populations and in different settings?	Partial	Where tested (e.g., age, sex), little indication of inconsistent findings, but some populations not studied. Measures of PA using wearable devices show null findings, but are limited.
Temporal sequencing	Does physical (in)activity precede the development of cognitive function?	Partial	Longitudinal studies show mixed support for temporal sequencing.
Coherence and biological plausibility	Any interpretation of the data should not seriously conflict with what is known about cognitive function. Biological plausibility provides further support for causation.	Yes	Plausible. Experimental evidence supports PA and fitness being associated with brain structure and function indicative of better cognitive functioning.
Dose-response relationship	Do higher levels of physical activity show higher levels of cognitive function?	No	Largely null effects for intensity, frequency and duration as moderators.

Causality criterion	**Definition**	**Current updated review assessment**	
Experimental evidence	Is there evidence from interventions using experimental methods for changes in cognitive function to result from changes in physical activity?	Yes	Evidence from intervention trials show effect sizes ranging from small to large for cognitive function and small to moderate for academic achievement (see Strength of Association above). Experimental evidence supports PA/fitness affecting brain function outcomes.

984 Table 8. Summary assessments for whether physical activity is causality associated with mental health in young people.

Causality criterion	**Definition**	**Mental Health Outcome: Evidence for Causality[1]**		
		Depression	**Self-Esteem**	**Cognitive Function**
Strength of association	How strong is the association between physical activity and the specified mental health outcome?	Partial	Partial	Yes
Consistency	How consistent is the evidence across different populations and in different settings?	Partial	No	Partial
Temporal sequencing	Does physical (in)activity precede the measure or change in mental health?	No	No	Partial
Coherence and biological plausibility	Any interpretation of the data should not seriously conflict with what is known about mental health. Biological plausibility provides further support for causation.	Yes	Partial	Yes
Dose-response relationship	Do higher levels of physical activity show better levels of mental health?	No	No	No
Experimental evidence	Is there evidence from interventions using experimental methods for changes in mental health to result from changes in physical activity?	Yes	Yes	Yes

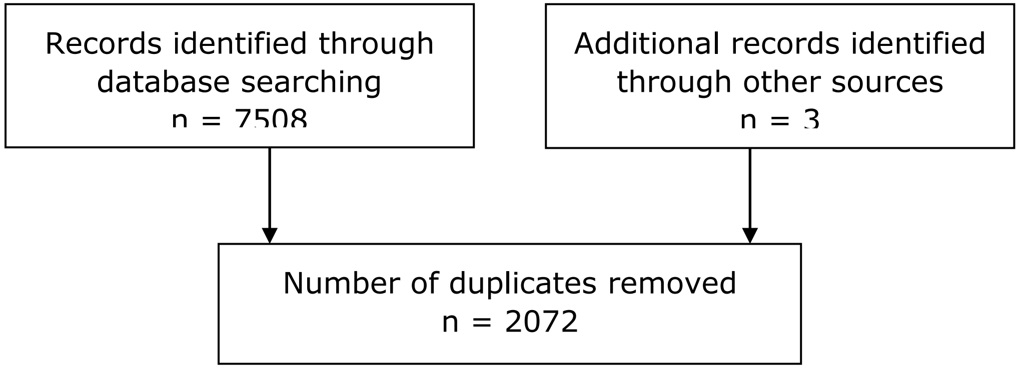
Causality criterion	Definition	Mental Health Outcome: Evidence for Causality[1]		
		Depression	**Self-Esteem**	**Cognitive Function**
Overall appraisal for support for causality		Partial	No	Yes

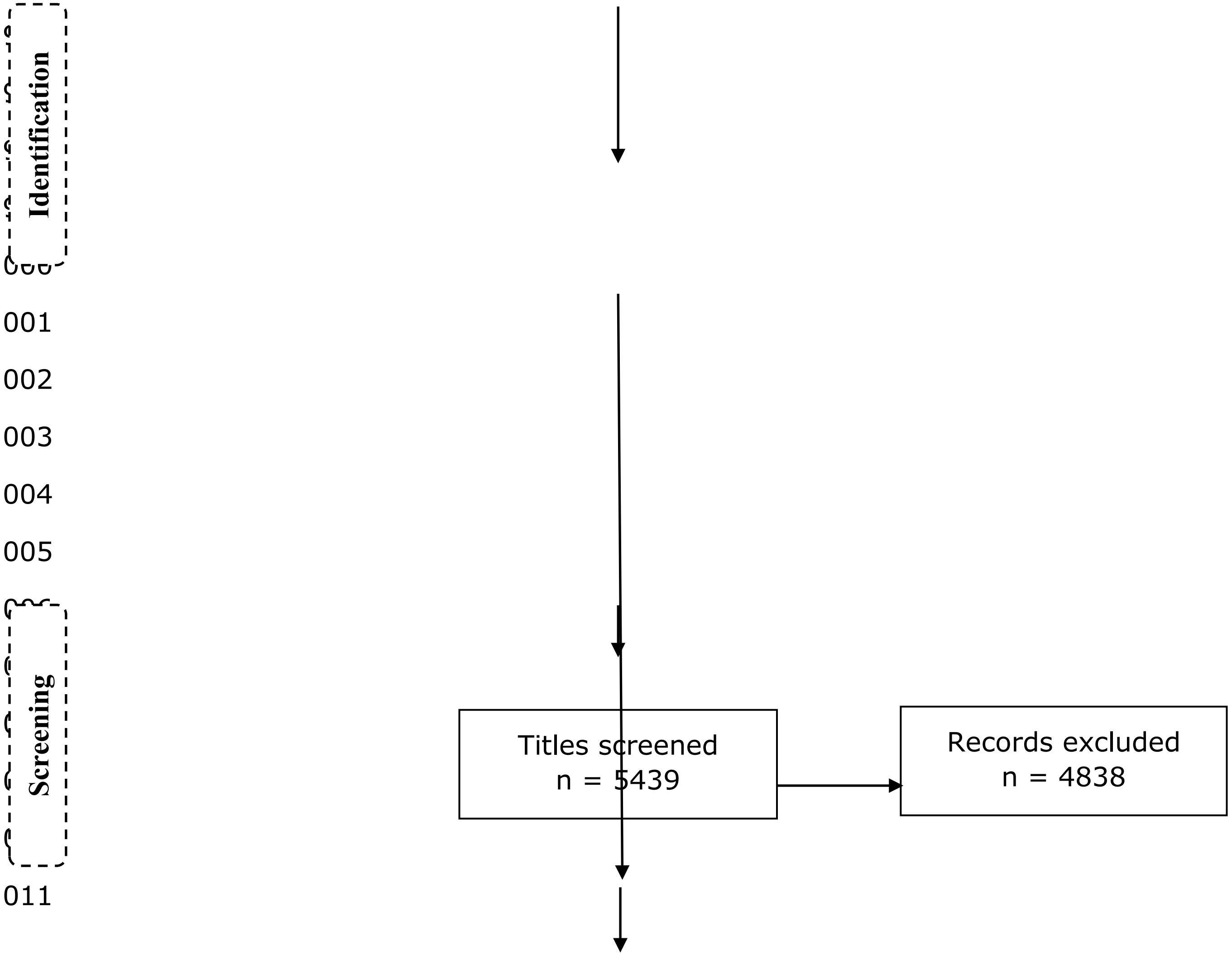
Note:

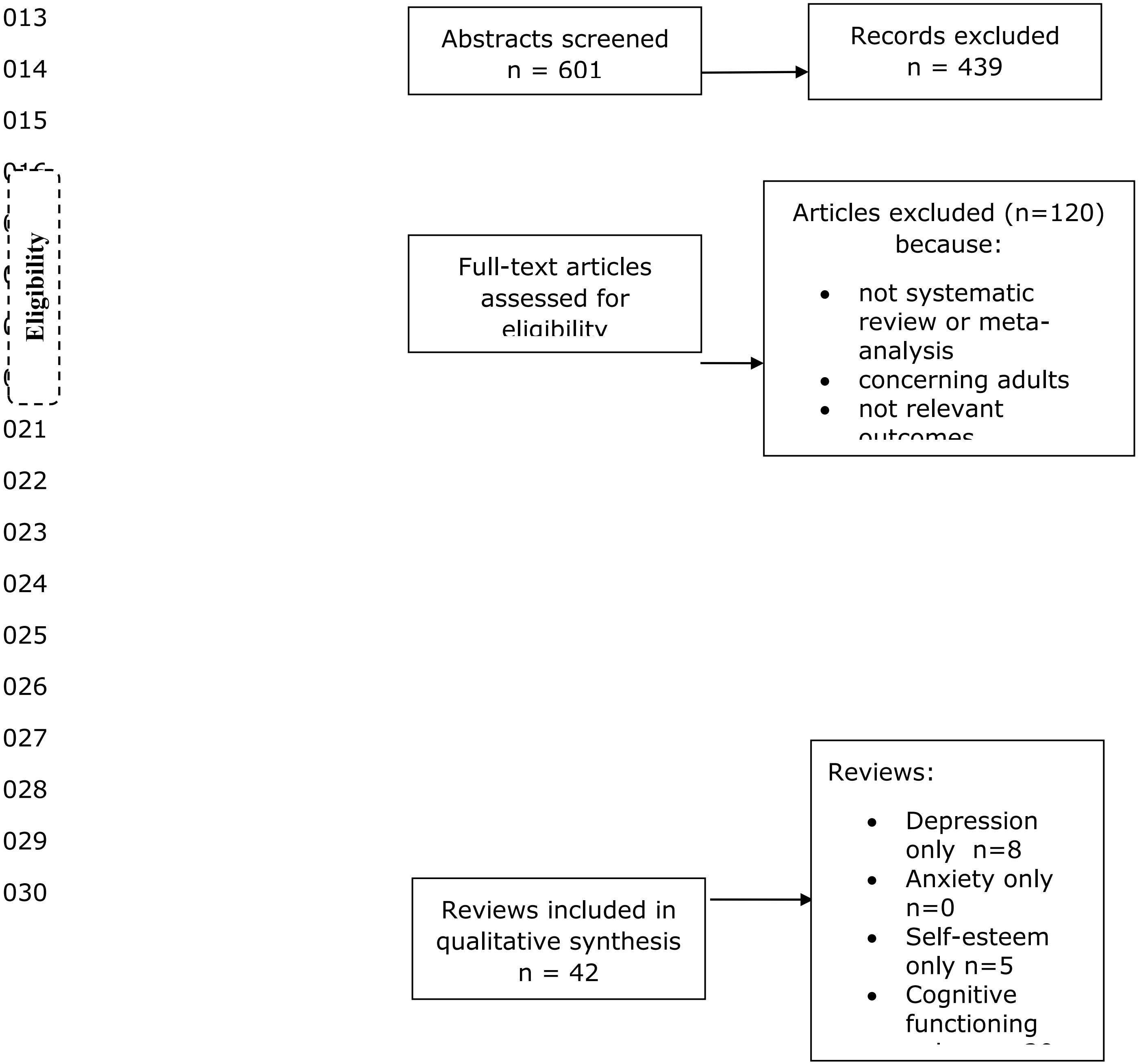
1. Insufficient evidence for anxiety.

Figure caption

Figure 1. Flowchart of the literature search and screening




Identification
Screening
Titles screened
n = 5439
Records excluded
n = 4838


Eligibility
Abstracts screened
n = 601
Records excluded
n = 439
Full-text articles
assessed for
eligibility
Articles excluded (n=120)
because:
not systematic review or meta-analysis
concerning adults
not relevant
Reviews included in
qualitative synthesis
n = 42
Reviews:
Depression only n=8
Anxiety only n=0
Self-esteem only n=5
Cognitive functioning