

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.

1. Introduction

Mental health has no universal definition, however key issues include those of depression and anxiety, which have been shown to have high prevalence rates among young people (see below). Furthermore, self-esteem is considered a key indicator of mental health, including emotional stability and subjective well-being (Lindwall & Acsi, 2014), and is a strong focus for educational programs for young people. Moreover, cognitive functioning is an important element of child development and has gained increasing traction in recent years, including in the context of physical activity (Davis & Lambourne, 2009).

Data from developed countries suggest that the mental health of many young people is less than optimal. Ireland, Portugal, Germany, and Finland have the highest rates of reported depression in Europe for those aged 15 years and over, all with greater than 10% prevalence rates for chronic depression (Eurostat Statistics Explained, 2018). The Mental Health Foundation reports 2014 data showing that 19.7% of

people in the UK aged 16 years and over showed symptoms of anxiety or depression. This was a 1.5% increase from the previous year, and rates appear to be higher among females (Mental Health Foundation, 2018).

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).

Based on these statistics, it is important to be able to identify potential low cost strategies for improving mental health for young people across the population. Physical activity is often suggested as one such

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approach (Ekkekakis, 2013). 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, 2018). While the field has expanded considerably over the past 30–40 years, it remains replete with simplistic statements and lacks a more nuanced approach that recognises its inherent complexity. For example, it is common to see assertions in national guidelines and educational contexts that physical activity is 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. However, the identification of underlying mechanisms explaining changes in mental health as a result of changes in physical activity levels remains imprecise. That said, a number of interacting neuro-biological, psychological, and social mechanisms are thought to be at play, including changes to the structure and function of the brain, changes to feelings of competence and confidence, and opportunities for positive social interaction and growth (Biddle, Mutrie, & Gorely, 2015).

As the research field develops better evidence, it is important to synthesise current findings to assist with optimal mental health promotion efforts. Moreover, it is important to focus on young people because of the important developmental issues faced during this life stage.

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. 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 and the number of reviews available then was limited.

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 was not done in the 2011 review. Assessing causality requires appraisal 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.

2. Methods

2.1. Searches and eligibility criteria

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 involvement in physical activity over time, or typical physical activity levels, 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:

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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.
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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 (single) 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 researchers to exclude articles out of scope. Subsequently, two researchers 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.

2.2. Assessment of study quality/risk of bias

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 Supplementary Tables 1, 3, 4, and 6). Each of the included systematic reviews was assessed independently by two researchers. Disagreements were resolved through discussion.

3. Results

Searches revealed 162 full-text papers after screening titles and abstracts (see Fig. 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

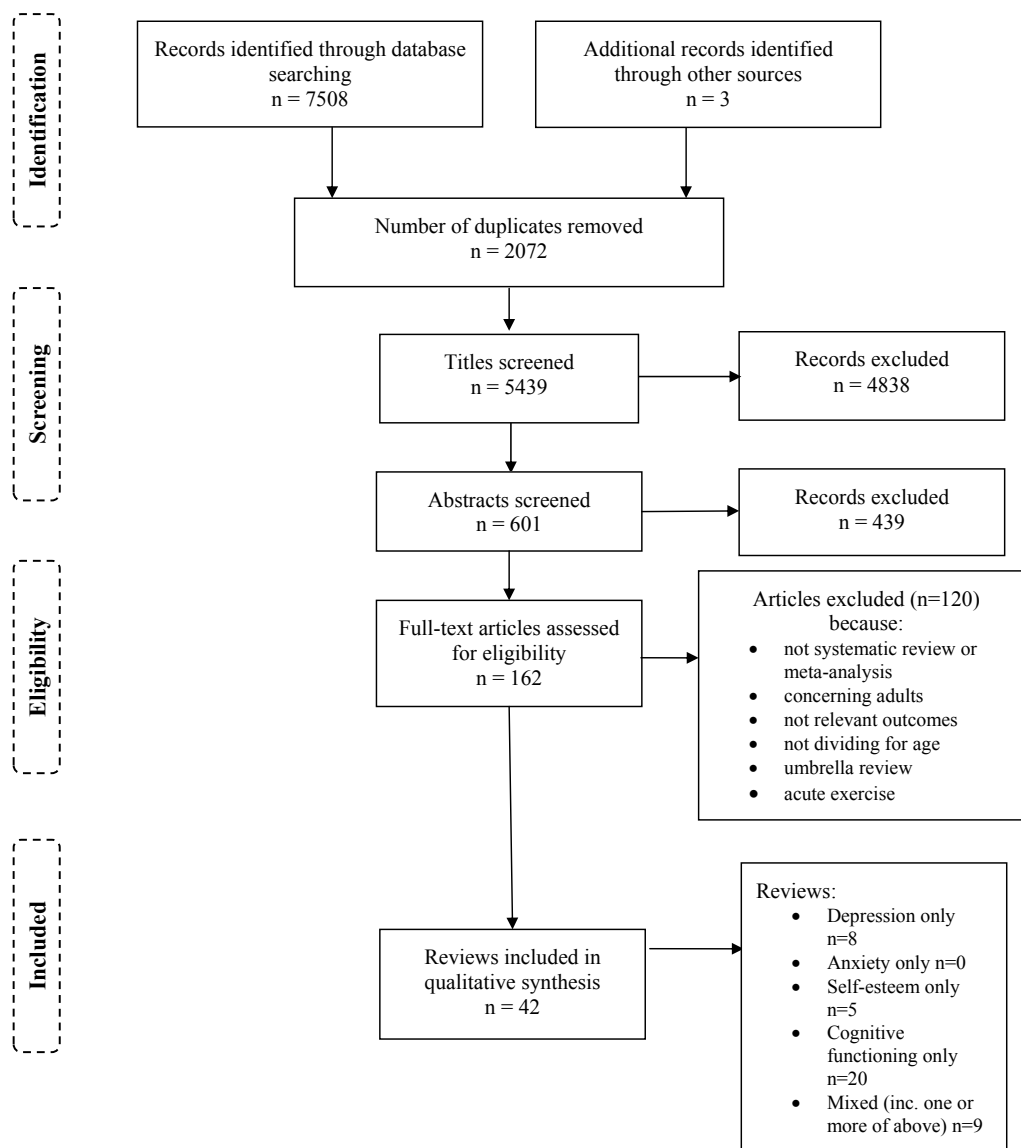


Fig. 1. Flowchart of the literature search and screening.

covered more than one mental health outcome, including depression ($k = 2$), anxiety ($k = 3$), self-esteem ($k = 5$), and cognitive functioning ($k = 5$).

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 to provide context for the results, 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 mental health outcome can be considered causally associated with physical activity for young people.

3.1. 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 to 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, 2018; 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 Supplementary Table S1). Reviews tended to analyse apparently healthy samples with only two synthesising evidence specifically for depressed youth, with another including some young people with depression. Ages ranged from pre-school to late adolescence with six reviews covering both children and adolescents, and four with adolescents only. Physical activity was broadly defined.

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 Supplementary Table S1). 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%).

For interventions, six of seven meta-analytic effect sizes (ES) varied between -0.41 and -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). Unsurprisingly, intervention effects tended to be greater over shorter time periods ([Brown et al., 2013](#)). Typical duration of trials was around three months, but this is poorly reported and analysed across reviews.

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.

3.1.1. Depression: analysis of causality

[Supplementary Table S2](#) 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., 2018](#); [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. \(2018\)](#) 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.

Overall, the field is still rather immature, at least in comparison to the literature concerning adults ([Catalan-Matamoros, Gomez-Conesa, Stubbs, & Vancampfort, 2016](#); [P. J.; Smith & Blumenthal, 2013](#)). 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., 2018](#); [Carter et al., 2016](#)).

3.2. 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 to 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 [Supplementary Table S3](#)). Two reviews tended to analyse apparently healthy samples and one synthesised evidence specifically for youth with attention deficit hyperactivity disorder (ADHD). Ages ranged from pre-school to late adolescence and physical activity modalities also included physical education programs and yoga. 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.

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.

3.2.1. 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.

3.3. 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 to 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 [Supplementary Table S4](#)). This suggests that the field has expanded quite considerably over this time. Reviews largely analysed apparently healthy samples. Ages ranged from pre-school to late adolescence with three reviews covering adolescents only. Physical activity was broadly defined and included reviews of leisure-time physical activity, yoga, recreational dance, and muscle strengthening exercise. 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%).

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 and 0.78, while observational studies reported lower effects of between 0.04 and 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).

3.3.1. Self-esteem: analysis of causality

Supplementary Table S5 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.

3.4. 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 to 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, Caverro-Redondo, Sanchez-Lopez, Garrido-Miguel et al., 2017; Alvarez-Bueno, Pesce, Caverro-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, & Sarmiento, 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 Supplementary Table S6). 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%). Reviews tended to analyse apparently healthy samples with only two synthesising evidence specifically for those overweight and obese, with another four focusing on young people with learning disabilities, cognitive impairment, autism or ADHD. Ages ranged from pre-school to late adolescence and physical activity was broadly defined, including reviews on yoga, structured physical activity, school-based activity, muscle strengthening exercise, and device-based-measured physical activity.

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 device-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 to 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, Caverro-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).

3.4.1. Cognitive functioning: analysis of causality

Supplementary Table S7 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

Table 1
Summary assessments for whether physical activity is causality associated with mental health in young people.

Causality criterion	Definition	Mental Health Outcome: Evidence for Causality ^a		
		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
Overall appraisal for support for causality		Partial	No	Yes

^a Insufficient evidence for anxiety.

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.

3.5. Overall assessment of causality

Table 1 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.

4. General discussion

4.1. 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 not a 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 1 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. Consistency of findings is evident across mental health outcomes in so far as effects or associations were seen across age, sex, and other potential moderators. Reporting of effects for those with different conditions (e.g., ADHD or clinical depression), tended to be favourable towards such groups but differences with apparently healthy cohorts were not reported consistently or clearly. This needs addressing in the future.

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.

4.2. 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, continuing to support prior work, 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 et al. (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).

4.3. 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 here.

4.4. 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 multi-dimensional 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. Moreover, a recent large meta-analysis showed that average levels of self-esteem increased from 4 to 11 years of age but remained stable from 11 to 15 years (Orth, Erol, & Luciano, 2018). These issues may explain the difficulty in being able to find evidence for a causal association with physical activity.

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.

4.5. 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 (see Blakemore, 2003; Williams, 1986), and the current review supports and extends this.

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; Riley, Lubans, Morgan, & Young, 2015; Routen et al., 2017).

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.

4.6. 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 generalisability (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, Agarwal, Young, Jones, and Sutton (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.

4.7. Directions for future research

1. Physical activity effects between genders and ages (e.g., children and adolescents) requires further development and testing.
2. The testing and reporting of effects for those with different mental health conditions needs strengthening. Studies need to better differentiate effects of physical activity for those with conditions that might be expected to be particularly relevant for intervention. These could include those with depression, heightening anxiety, low self-esteem, or impaired cognitive functioning.
3. The context of physical activity for mental health outcomes is poorly understood. More is needed on different types of physical activity, individual preferences, as well as social and physical contexts.
4. Prospective studies need to test for different time periods between physical activity and future effects on mental health.
5. A more diverse approach is required for testing dose-response effects. Currently, the focus tends to be on physical activity intensity, but more needs to be known on duration of sessions and programs, as well as overall physical activity load.
6. Research is required that allows for better tests of mediation effects of any association between physical activity and mental health.
7. Stress reduction effects of physical activity could be a fruitful area for future research, and studies need to test both acute and chronic effects in ecologically valid settings.
8. Progress needs to be made in identifying the mechanisms underpinning any changes in mental health from physical activity, including separate and combined effects of neurobiological, psychosocial, and behavioural factors.

5. 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).

Declarations of interest

Stuart Biddle conducted consultancy work on physical activity for Halpern PR Ltd in 2016. Simone Ciacconi, George Thomas and Ineke Vergeer have no declarations of interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.psychsport.2018.08.011>.

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