Physical activity and mental health in children and adolescents: a review of reviews

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ABSTRACT

Objective To synthesise reviews investigating physical activity and depression, anxiety, self-esteem and cognitive functioning in children and adolescents and to assess the association between sedentary behaviour and mental health by performing a brief review.

Methods Searches were performed in 2010. Inclusion criteria specified review articles reporting chronic physical activity and at least one mental health outcome that included depression, anxiety/stress, self-esteem and cognitive functioning in children or adolescents.

Results Four review articles reported evidence concerning depression, four for anxiety, three for self-esteem and seven for cognitive functioning. Nine primary studies assessed associations between sedentary behaviour and mental health. Physical activity has potentially beneficial effects for reduced depression, but the evidence base is limited. Intervention designs are low in quality, and many reviews include cross-sectional studies. Physical activity interventions have been shown to have a small beneficial effect for reduced anxiety, but the evidence base is limited. Physical activity can lead to improvements in self-esteem, at least in the short term. However, there is a paucity of good quality research. Reviews on physical activity and cognitive functioning have provided evidence that routine physical activity can be associated with improved cognitive performance and academic achievement, but these associations are usually small and inconsistent. Primary studies showed consistent negative associations between mental health and sedentary behaviour.

Conclusions Association between physical activity and mental health in young people is evident, but research designs are often weak and effects are small to moderate. Evidence shows small but consistent associations between sedentary screen time and poorer mental health.

Mental illness is a serious public health issue. It is expected to account for 15% of the global burden of disease by 2020, which would make it the leading disease burden.[1] Suicide, depression, eating disorders and anxiety are some of the conditions that affect young people in disproportionate rates in comparison to many other population groups.[2] Moreover, there is widespread belief that physical activity is inherently good for young people in respect of varied psychosocial outcomes, such as self-esteem and cognitive functioning. The majority of studies in this area, however, are cross-sectional and therefore causality cannot be established because the temporal relationship between exposure (physical activity) and outcome (mental health) has not been tested or shown with any consistency. Thus, although there is evidence that physical activity can enhance psychological well-being, such an outcome may not be inevitable[3] or may be dependent on certain conditions existing.

The effect of physical activity on mental health in children and adolescents has received significantly less attention than in adult populations.[4] Where it has been investigated, the work has primarily focused on depression, anxiety and self-esteem. In addition researchers and education professionals are showing increasing interest in the effects of physical activity on cognitive functioning. For these reasons, and space restrictions, our review is delimited to the outcomes of depression, anxiety, self-esteem and cognitive functioning.

The purpose of this article, therefore, is to synthesise evidence on chronic physical activity participation and mental health in children and adolescents mainly through a review of reviews. Such a method has been adopted to optimise the ability to cover four areas of mental health and to synthesise 18 reviews. It would have been unwieldy to attempt individual systematic reviews of the literature in each of the four mental health domains. Moreover, a review of reviews is accepted practice in the medical and health behaviour literatures.[5] In addition a brief analysis will also be provided on relationships between sedentary behaviour and mental health from primary research studies.

METHOD

To find reviews of studies on chronic physical activity and mental health in young people, the following electronic databases were searched up to October2010:PubMed,SPORTDiscus,PsychINFO, Web of Science, Medline, Cochrane Library and ISI Science Citation Index. We searched using terms that reflected exposure variables of interest (eg, sport, exercise, physical activity), mental health outcome variables (eg, depression, anxiety, self-esteem, cognitive functioning) and methods (only reviews, systematic reviews, meta-analyses). Only review articles were included. Additional searches of personal files supplemented the electronic sources.

Articles were selected for detailed analysis if they met the following inclusion criteria (1) were review articles (narrative, systematic or meta-analytic); (2) reported the relationship between physical activity and at least one mental health outcome that included depression, anxiety/stress, self-esteem or physical self-worth and cognitive functioning; (3) reported chronic physical activity studies, including interventions (reviews of acute studies were excluded); (4) were on school-aged children or adolescents up to and including 18 years with no known physical health limitations. If a review contained some data on young people, but the primary emphasis was on adults, the data were scrutinised and reported where appropriate.

To balance the work on physical activity, a brief narrative review was conducted on sedentary behaviour and mental health. This is not meant to be a comprehensive systematic review but rather a commentary on recent articles.

RESULTS

Five review articles were retrieved that reviewed evidence concerning physical activity and depression, four for anxiety, three for self-esteem and seven for cognitive functioning. Two articles covered more than one mental health outcome variable, with Larun *et al*[6] addressing anxiety and depression, and Calfas and Taylor[7] reviewing depression, anxiety and self-esteem.

Depression

Evidence from adult studies demonstrates that physical activity is inversely associated with symptoms of depression,[8 9] and there is some evidence that this relationship is causal.[10] There is, however, much less evidence for this relationship in children and adolescents. We found five reviews that synthesised data for young people,[6–9 11] although the article by Dunn and Weintraub primarily provides a methodological critique of articles used in the review by Larun *et al*. Reviews of depression are summarised in table 1, excluding the critique by Dunn and Weintraub, leaving four reviews.

The study by North *et al*[9] was the first meta-analysis investigating associations between physical activity and depression and included all research designs. An overall effect size (ES) of −0.53 was reported, with five studies involving only young people reflecting a similar value (ES = −0.49). However, acute and chronic studies were included as well as non-intervention designs.

The first systematic review concerning physical activity and mental health in adolescents was published as part of the American physical activity guidelines process,[7] although the authors used a wide age range of 11–21 years. All research designs were eligible for analysis but ES was calculated only for experimental designs. From only four intervention studies, ES = −0.38 favouring physical activity over a control group. By using all research designs, Calfas and Taylor reported that 9 of 11 studies showed a negative association between physical activity and depression.

Craft and Landers[8] conducted a meta-analysis on exercise and depression for those with clinical depression. Only three studies provided data for those aged 12–18 years, showing a small non-significant ES of −0.15, much smaller than that for adults and in all studies (−0.72).

Larun *et al*[6] conducted a systematic review of exercise interventions on depression in young people up to the age of

Table 1 Reviews of physical activity and depression in young people

Author, date and years covered	Type of review; number of studies (K)	Sample for current analyses	Exposure variables	Types of research design	Main findings	Comments
Larun *et al*[6] 1965–2005	Meta-analysis K=5	11–19 years	Vigorous exercise	RCTs	The review assessed vigorous exercise (VIG) vrs no intervention in a general population. VIG had a significant negative effect on depression; ES= −0.66. VIG v. no exercise for children in treatment: no difference. VIG v. low intensity exercise for depressed children in treatment: no difference. Exercise v. psychosocial intervention for depressed children in treatment: no difference.	Few studies included.
Craft and Landers[8] Up to 1996	Meta-analysis and systematic review K=3	12–18 years	PA: aerobic and anaerobic	Quasi-experimental	Exercise significantly reduced depression among participants with clinical depression and depression resulting from mental illness (including adults). Effect size for young people was small (ES= −0.15).	The review is one of the few that examined the effects of chronic exercise on clinically diagnosed depression. Review includes varied age groups. Only 3 studies were on young people.
Calfas and Taylor[7] Up to 1982	Meta-analysis K=11	11–21 years	PA: flexibility training; running; vigorous activity	Quasi-experimental and cross-sectional observational	34trials available for meta-analysis. Significant negative relationship between PA and depression (ES= −0.38). 9 of 11 studies showed negative association.	Only 4 effect sizes available for calculation of overall ES.
North, *et al*[9] Up to 1989	Meta-analysis K=5	<18 years	PA: aerobic; and muscular strength endurance	Various	Higher levels of exercise significantly associated with lower depression (ES= −0.49) among young people.	Only 5 studies involved young people. It was not possible to identify research designs used, intensity or duration of exercise, or type of depression assessed.

ES, effect size; PA, physical activity; RCT, randomised controlled trial.

20 years. Five trials were found that investigated whether vigorous exercise (fitness training and weight training) conferred benefits over no intervention. They found a significant moderate effect (ES = −0.66; CI, −1.25 to −0.08) but noted that the trials were of low quality and highly varied in respect of methodological characteristics, such as sampling and measurement. When comparing vigorous with low-intensity exercise, only two trials were found, and these showed no significant effect, a result repeated for two trials investigating children receiving psychological treatment. This might suggest that lower levels of physical activity intensity may also be effective for anxiety reduction.

When comparing exercise with psychosocial interventions, Larun *et al* found only two trials, and no significant effect was evident. This was also the case for one trial involving children receiving psychological treatment, suggesting that physical activity may be equally effective as psychosocial interventions. There was no evidence for intervention effectiveness after 8 weeks.

Limitations of findings include the use of broad inclusion criteria that allows participants in some interventions to have rather mild depression over a short time frame (ie, they may not be particularly depressed at all). Studies also fail to specify the exact nature of the physical activity interventions in respect of frequency, intensity, duration and type of activity. Group-based physical activity interventions often fail to control for the effects of social interaction.

In summary, physical activity over no intervention seems to be potentially beneficial for reduced depression, but the evidence base is limited. Intervention designs are low in quality, and many reviews include cross-sectional studies that may distort associations or fail to rule out reverse causality.

Anxiety

Active adults report fewer symptoms of anxiety than inactive adults.[12 13] However, the amount of evidence for young people is considerably less. Our search revealed four reviews (see table 2). The meta-analysis of exercise and anxiety reduction conducted by Petruzzello *et al*[14] also reported ESs for those younger than 18 years. Results showed a small-to-moderate effect for physical activity programmes when assessing trait anxiety (ES = −0.47), although only three studies were available for review. The review by Calfas and Taylor[7] found only three intervention studies on anxiety and reported an ES of −0.15. This review does not completely map onto the studies reviewed by Petruzzello *et al* and lacks methodological detail.

Larun *et al*[6] conducted a systematic review of exercise interventions on anxiety in young people up to the age of 20 years. Six trials were found that investigated whether vigorous exercise conferred benefits over no intervention. They found a non-significant, although small to moderate, trend (ES = −0.48). Studies were of low quality and highly varied in respect of methodological characteristics. When comparing vigorous with low-intensity exercise, only three trials were found, and these showed no significant effect. When comparing exercise with psychosocial interventions, Larun *et al* found only two trials, and no significant difference was evident.

Wipfli *et al*[15] claimed to address the methodological weaknesses of previous reviews by conducting a meta-analysis of just randomised controlled trials, although this was also performed by Larun *et al*.[6] Three trials were reviewed for those younger than 18 years, revealing a non-significant effect (ES = −0.18). It is not clear why Wipfli *et al* only found three interventions 2 years after Larun *et al* analysed six.

In summary, physical activity interventions for young people have been shown to have a small beneficial effect for

Table 2 Reviews of physical activity and anxiety in young people

Author, date and years covered	Type of review; number of studies (K)	Sample for current analyses	Exposure variables	Types of research design	Main findings	Comments
Larun *et al*[6] 1965–2005	Meta-analysis K=6	11–19 years	VIG	RCTs	VIG had a small-to-moderate effect on anxiety (ES=−0.48). There was no statistically significant difference between VIG and low intensity exercise on anxiety. There was no statistically significant difference between exercise and psychosocial interventions on anxiety.	Few studies and many with methodological weaknesses.
Wipfli *et al*[15] Up to Jan 2006	Meta-analysis K=3	<18 years	PA: aerobic; anaerobic; combined	RCTs	Exercise group showed small reductions in anxiety v. other forms of anxiety treatment (ES = −0.19).	8 studies were included in the full meta-analysis (all ages) that were acute studies. It was not possible to tell if the 3 studies on those <18 years included those in acute exercise RCTs. Unclear why only three interventions were found two years after Larun *et al* analysed six.
Calfas and Taylor[7] Up to 1982	Meta-analysis and systematic review K=20	11–21 years	PA: (Fitness training): flexibility training; running; vigorous activity	Quasi-experimental and cross-sectional observational	3 trials available for meta-analysis. Small relationship between PA and anxiety (ES=−0.15).	Duration of PA was not mentioned; moderate PA was not adequately explained.
Petruzzello, *et al*[14] 1960–1989	Meta-analysis K=3	< 18 years	PA: programmes (aerobic, anaerobic)	Longitudinal design	Chronic exercise significantly associated with less trait anxiety (ES= −0.47).	Not clear on methods for studies with young people.

ES, effect size; PA, physical activity; RCT, randomised controlled trial; VIG, vigorous exercise.

Table 3 Reviews of physical activity and self-esteem in young people

Author, date and years covered	Type of review; number of studies (K)	Sample for current analyses	Exposure Variables	Types ofresearch design	Main findings	Comments
Ekeland *et al*[18] 1965–2002	Meta-analysis K=25	3–20 years	PA > 4 weeks	RCTs	8 trials available for meta-analysis. Exercise alone intervention versus a no-intervention control showed small-to-moderate effect in favour of the intervention group (SMD = 0.49).	25 trials found but only 8 subjected to meta-analysis.
Calfas and Taylor[7] Up to 1982	Meta-analysis and systematic review K=20	11–21 years	PA: flexibility training; running; vigorous activity	Quasi-experimental and cross-sectional observation	3 trials available for meta-analysis. There was a significant positive relationship between PA and psychological outcomes - ie, increased self-esteem; effect size was 0.12.	Only 3 trials subjected to meta-analysis. Unclear distinction between self-esteem and self-concept as outcome variables.
Gruber[19] Dates covered not stated	Meta-analysis K=27	<18 years	PA: aerobic; PE activities; perceptual motor; dance	Experimental and quasi-experimental	Exercise significantly associated with higher self-esteem among children (ES=0.41). Exercise had larger effects for children with a disability (ES=0.57) and for aerobic fitness activities (ES=0.89).	Report lacked detail on search strategies and methods.

ES, effect size; PA, physical activity; PE, physical education.

reduced anxiety. However, the evidence base is limited and in need of development.

Self-esteem

Self-esteem reflects the degree to which an individual values himself or herself and is widely viewed as a key indicator of positive mental health and well-being.[16] The belief that physical activity, including sport, is associated with the development of self-esteem in young people is a commonly held view. Typically, global self-esteem is seen as the apex of a hierarchical and multidimensional framework, underpinned by different domains of the self, including the perceptions of physical self-worth.[17]

We found three systematic reviews addressing physical activity and self-esteem in young people[7 18 19] (see table 3). One of the first meta-analyses in exercise psychology was that by Gruber (1986). He meta-analysed 27 experimental designs, mainly on children, but gave limited detail on methodology.

Gruber[19] reported an overall effect for physical activity on self-esteem of 0.41, representing a small effect. Larger effects were found for children with perceptual, emotional and learning disabilities (ES = 0.57), for better controlled experiments assessing only one dependent variable (ES = 0.65) and for aerobic fitness activities (ES = 0.89). Three studies analysed by Calfas and Taylor[7] showed a small effect (ES = 0.12).

A recent Cochrane meta-analysis by Ekeland *et al*[18] examined whether exercise interventions improved global self-esteem among children and young people aged 3–20 years. This was later published as a journal article.[20] The results showed that in the eight trials available for meta-analysis and testing an exercise-alone intervention versus a no-intervention control, there was a small-to-moderate effect in favour of the intervention group (ES = 0.49).

Most of the trials analysed by Ekeland *et al*[18] were small scale and of short duration. No follow-up results were given so the sustainability of changes could not be assessed. Only one of the trials was considered to be of high methodological quality and demonstrated the strongest effects. A further four trials compared the effects of exercise as part of a comprehensive intervention package against no-intervention control groups and showed a moderate positive effect on self-esteem in favour of the intervention (ES = 0.51).

In summary, physical activity can lead to improvements in self-esteem, at least in the short term. However, there is a paucity of good quality research. Moreover, global measures of self-esteem can be affected by many factors beyond physical activity. Hence, measures of physical aspects of the self, such as body image or physical self-worth, important indices of psychological health in their own right, might be better targets for intervention.

Cognitive functioning

A link between physical activity and cognitive functioning has been believed to exist for many years. Blakemore[21] reported that the brain is activated during physical activity by increasing blood flow to essential areas that may stimulate learning.[22] Moreover, research has suggested that integrating physical activity in the classroom will enhance student learning.[23] However, further studies are needed to make school authorities confident that encouraging school physical activity will improve learning rather than disrupt academic time. Cognitive functioning is best defined as a) intelligence, which is the ability to reason quickly and abstractly; b) cognitive skills of concentration and attention; c) academic achievement, usually assessed by overall school grades and performance.

Seven review articles were found (see table 4). More than a decade ago, Shephard[24] reported a systematic review to investigate links between physical activity and cognitive functioning using cross-sectional and longitudinal studies. It was found that increasing physical education (PE) time in schools by 14–26% did not have a significant negative effect on academic performance. However, only three studies on routine physical activity were involved, and evidence was not established concerning additional time for physical activity and intellectual enhancement; students who had extra PE time performed

Table 4 Reviews of physical activity and cognitive functioning in young people

Author, date and years covered	Type of review; number of studies (K)	Sample for current analyses	Exposure variables	Types of research design	Main findings	Comments
Best[30] Dates covered not stated	Systematic review K=3	7–11 years	PA (aerobic): running; walking	Experimental	Exercise (specifically aerobic) had significant positive relationship with creativity- specifically flexible and divergent thinking but not with perceptual-motor skills or visual-motor coordination.	
Centres for Disease Control and Prevention[29] Dates covered not stated	Systematic review K=50	Children; exact ages not stated	School PE; Recess (break); classroom physical activity breaks; extra-curricular physical activity	All	School-based PE (k=14): weak or no association between increased PE time and academic achievement. Recess studies (k=8): weak or no association between recess activity and cognitive outcomes. Classroom physical activity studies (k=9): Consistent association between classroom activity breaks and cognitive outcomes. Extra-curricular physical activity studies (k=19): Consistent association between extra-curricular physical activity and cognitive outcomes.	Some studies analysed included 'attitude' and 'mood' outcomes, not cognitive functioning.
Keeley and Fox[28] Up to Feb 2009	Systematic review N=18	4–18 years	PA (break-time play; active travel; sport and physical education; informal play and sports; and dance clubs outside school)	RCTs; quasi experimental; longitudinal; cross sectional	A weak positive relationship was found between increased school physical activity and cognitive functioning. Cross-sectional studies indicated that more physical activity was associated with better performance in some subjects (eg, mathematics) but not in others (eg, English). Intervention Studies indicated that introduction of more curricular time to PE did not have a detrimental effects on children's academic performance. A weak but positive association was found between physical fitness and cognitive functioning in young people with the strongest correlations being with cardiovascular fitness.	
Tomporowski *et al*[27] Dates covered not stated	Systematic review K=15	8–16 years	PA (chronic exercise): Strength training; aerobic; running	Cross-sectional, prospective and experimental	Prospective and experimental designs: 2 of 4 studies showed improvements in intelligence 3 of 6 for cognition 1 of 6 for academic achievement. Cross-sectional designs: 3 of 4 studies showed association with academic achievement.	Executive functioning tasks seem most positively affected.
Trudeau and Shephard[26] 1966–2007	Systematic review K=17	5–16 years	PA: PE activities; school sport	Quasi experimental; longitudinal; cross-sectional	PA and academic achievement: Allocating up to an additional hour per day of curricular time to PA programmes did not affect academic performance of primary school students. Children, in the experimental group, whose academic tuition was reduced achieved equally as the control group. PA and classroom behaviour: PA significantly improved concentration and classroom behaviour. Fitness and academic achievement: A positive but weak relationship.	The context of PA was not clearly defined. Limited studies were used to assess the effect of fitness on academic achievement.

Continued

Table 4 Continued

Author, date and years covered	Type of review; number of studies (K)	Sample for current analyses	Exposure variables	Types of research design	Main findings	Comments
Sibley and Etnier[25] Up to 2001	Meta-analysis K=16	4–18 years	PA: aerobic; resistance training; perceptual motor; PE programs	True experiment; quasi experiment; cross- sectional	PA significantly associated with better cognitive functioning (ES=0.32). No effect for memory tests and only a small effect for verbal tests. Results were similar for healthy subjects, subjects with mental impairments and subjects with physical disabilities. The influence of PA on cognitive functioning was not moderated by the type of research design, participant health and PA type.	
Shephard[24] Dates covered not stated	Narrative review K=3 long-itudinal studies highlighted	<20 years	PA: PE activities	Cross-sectional; longitudinal	Academic performance is maintained or even enhanced by an increased level of PA.	Narrative review only.

ES, effect size; PA, physical activit; PE, physical education.

equally well as students who had intact classroom curricular time.

Sibley and Etnier[25] conducted a meta-analysis to investigate the effects of different types of physical activity on cognitive functioning across varied age groups of young people. All research designs were included. The findings revealed that physical activity was associated with better cognitive functioning across all age groups. A small effect for chronic studies was found (ES = 0.29).

Trudeau and Shephard[26] conducted a systematic review on physical activity, physical fitness and academic performance. Seventeen studies of varied research designs were involved. Findings indicated that allocating up to an additional hour per day of curricular time to physical activity programmes in school does not affect academic performance of primary school students. Furthermore, physical activity improved classroom behaviour, attention and concentration. A positive but weak relationship was established between physical fitness and academic achievement. However, for experimental studies, the authors did not find strong evidence for an effect of school physical activity on academic performance because children in the experimental group, whose academic tuition was reduced, did not perform better than the control group; that is, children exposed to additional school physical activity achieved equally well as those students who had regular academic tuition.

Tomporowski *et al*,[27] in a systematic review of 15 studies, examined the relationship between physical activity and cognitive functioning among children aged 6–16 years. For prospective and experimental designs, two of four studies showed improvements in intelligence, three of six for cognition and one of six for academic achievement. In contrast, three of four cross-sectional studies on academic achievement showed positive associations. They concluded that children's cognitive functioning can be enhanced through physical activity, but this is mainly in respect of executive functioning tasks (ie, "goal-directed actions in complex stimulus environments, especially novel ones, in which elements are constantly changing"; p. 126).

To update previous reviews, Keeley and Fox[28] conducted a systematic review to investigate the relationship between physical activity, physical fitness and cognitive functioning among 4- to 18-year-old students. Eighteen studies with varied research designs were included. Generally studies involved exposing experimental participants to increased school-based physical activities at the expense of academic work time. A weak positive relationship was found between increased school physical activity and cognitive functioning. Specifically, cross-sectional studies indicated that more physical activity was associated with better performance in some subjects (eg, mathematics) but not in others (eg, English). One intervention study reported that increased physical activity significantly improved cognitive functioning; two intervention studies found no association between increased physical activity and academic performance. A weak but positive association was found between physical fitness and cognitive functioning in young people, with the strongest correlations being with cardiovascular fitness.

Although a strong association has not been established between increased school physical activity and cognitive functioning, Keeley and Fox (2009) found that the introduction of more physical activity, at the expense of academic subject time, did not have a detrimental effect on children's academic performance. This reflects conclusions from other reviews.

The Centres for Disease Control and Prevention[29] in the United States has also examined the effect of routine physical activity on the cognitive functioning of young people. The review involved 50 studies with cross-sectional ($K = 11$) and longitudinal ($K = 38$) research designs, with 32 classified as interventions. It was found that increased PE time in schools had a positive but weak relationship with academic achievement in 11 of 14 studies. Time spent in increased break (recess) play had a small positive relationship with classroom behaviour, including children's attention and concentration (all eight studies found one or more positive associations between recess and indicators of cognitive skills). In addition classroom-based physical activity (5-20 min break during lessons) improved children's academic behaviour and achievement (eight of the nine studies found positive associations). Extracurricular physical activities (participation in school sports) also had a positive association with academic performance (all 19 studies examining after-school sport found one or more positive associations with cognitive performance). Finally the review

Table 5 Primary studies investigating sedentary behaviour and mental health in young people

Study	Sample characteristics	Design/method	Sedentary behaviour exposure variables	Mental health outcome variables	Results	Comments
Murdey *et al*[37]	N= 119 UK youth. 64 boys and 55 girls across three school year cohorts: Year 6 (10.0–10.9 years); Year 8 (12.0–12.9 years); Year 10 (14.0–14.9 years).	Cross-sectional phase of longitudinal study.	Free-time sedentary behaviour assessed by momentary time sampling paper diary.	Body image (body attractiveness subscale of Physical Self-Perception Profile for Children; PSPP-C)	Small negative association only for girls between sedentary behaviour and body image: r=-0.23, p=0.05	PA not accounted for in analyses. Only study to assess and aggregate multiple sedentary behaviours.
Mathers *et al*[38]	N= 925 Australian adolescents (mean age = 16.1 years)	Cross-sectional data from the third (2005) wave of the longitudinal Health of Young Victorians Study.	Electronic media use (EMU) assessed with MARCA – Multimedia Activity Recall for Children and Adolescents, a computerised time-use diary.	Health-related quality of life (HRQoL; KIDSCREEN); health status (Pediatric Quality of Life Inventory 4.0; PedsQL); depression/ anxiety (Kessler-10); behaviour problems (Strengths and Difficulties Questionnaire - SDQ).	Higher EMU associated with poorer HRQoL and more behaviour problems. High video game use associated with worse HRQoL.	PA not accounted for in analyses.
Iannotti, Janssen, *et al*[39]	N= 49 124 Young people aged 11, 13 and 15 years from countries participating in the Health Behaviour in School-Aged Children (HBSC). 10 countries selected to represent 5 regions: North America, North Europe, South Europe, West Europe, East Europe.	Cross-sectional self-report survey of health behaviours, including physical activity and screen time.	Screen-based media sedentary behaviour (SBM) in h/day.	Physical Self-Image: Perception (of body size); Life Satisfaction; Quality of Family Relationships; Quality of Peer Relationships.	Higher levels of SBM associated with poorer self-image. More frequent SBM associated with poorer Life Satisfaction in four regions and poorer perceived health status and family relationships in three regions.	PA accounted for as a confounder.
Iannotti, Kogan, *et al*[40]	N=22 084 American and Canadian youth aged ~11–15 years as part of Health Behaviour in School-Aged Children (HBSC) study.	Cross-sectional self-report survey of health behaviours, including physical activity and screen time.	Screen-based media sedentary behaviour (SBM) in h/day.	Physical Self-Image: Perception (of body size); Life Satisfaction; Quality of Family Relationships; Quality of Peer Relationships.	More frequent SBM associated with poorer Life Satisfaction and family relationships. Poorer self-image only significant for Canadian youth. Higher SBM associated with higher ratings of peer relationships.	PA accounted for as a confounder. May include some participants from Iannotti, Janssen *et al* (2009). Not possible to tell.

Continued

Table 5 Continued

Study	Sample characteristics	Design/method	Sedentary behaviour exposure variables	Mental health outcome variables	Results	Comments
Hamer *et al*[41]	N=1486 Scottish children aged 4–12 years (mean age=8.5 years)	Cross sectional assessment of psychological well-being, sedentary behaviour and physical activity	Parent reported TV and screen entertainment (TVSE).	Psychological well-being (Strengths and Difficulties Questionnaire)	Higher SDQ scores associated with greater TVSE time independently of PA and after controlling for confounders.	PA accounted for as a confounder.
					TVSE and PA interact to be associated with higher levels of psychological distress.	Parental proxy reports likely to have poor validity.
Russ *et al*[42]	N=54 863 American youth aged 6–17 years.	Cross-sectional assessment of media use and parent reported child psycho-social well-being	Parent reported media use (TV, computers, screen time)	Parent reported social-emotional problems of the child, concerns about child's self-esteem, and social competence	Significant association between TV viewing and psycho-social well-being: Each additional hour of TV increased concerns about social/emotional health by 8%; for self-esteem concerns by 8%; a decrease for social competence by 10%. No effects for computer use or screen time.	Parental proxy reports likely to have poor validity. PA not accounted for in analyses.
Holder *et al*[43]	N=514 Canadian children aged ~9–11 years.	Cross-sectional assessment of screen time and phone used, self-concept and happiness	Self and parent reported sedentary behaviour (TV, computer, computer games, phone)	Piers-Harris Children's Self-Concept Scale 2 Happiness/satisfaction (from Piers-Harris) Self-reported happiness using a faces scale	Screen time (but not phone) had small but significant association with both child and parent reported happiness (faces scale) No associations with self-concept.	Markers of PA assessed but not used as covariates.
Primack *et al*[36]	N=4142 American adolescents (Grades 7-12; aged ~12–17 years at baseline)	Longitudinal cohort study with 7 year follow-up. Analyses included only those not depressed at baseline.	Self-report of 'last week' exposure to 4 types of electronic media: TV, video, computer games, radio	Centers for Epidemiologic Studies – Depression Scale (CES-D)	Significantly increased odds of depression at follow up for each additional hour of TV viewing (OR=1.08). No effect for other media.	PA not accounted for in analyses.
Page *et al*[44]	N=1013 UK youth (mean age=10.95 years)	Cross sectional assessment of psychological well-being, sedentary behaviour and physical activity	Self-reported daily TV hours and computer use. Total sedentary time also assessed with accelerometer.	Psychological well-being (Strengths and Difficulties Questionnaire)	Children who spent more than 2 h/day watching TV or using a computer were at increased risk of high levels of psychological difficulties.	PA accounted for as a confounder.

concluded that school physical activity programmes have a positive impact on academic performance. However, effects are inconsistent and often small.

In a recent systematic review, Best[30] examined the relationship between aerobic physical activity and cognitive functioning in young people. Studies used experimental designs; however, only three studies assessed the effects of chronic aerobic exercise on cognitive functioning. Aerobic exercise did not influence children's tasks requiring visual-motor coordination, but it did improve tasks requiring flexible and divergent thinking.

In summary, systematic reviews on physical activity and cognitive functioning have provided evidence 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.

The major implication arising from these reviews is that integrating physical activity in the school system may help young people to learn better and reduce the likelihood of negative classroom behaviours. However, strong evidence has not yet been established between chronic physical activity and students' cognitive functioning, and this could be due to methodological shortcomings of studies. These include expectancy effects and unblinded intervention designs. Thus, 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. Studies with more rigorous designs are needed on physical activity, including non-aerobic exercise, and its effect on cognitive functioning.

Sedentary behaviour and mental health

Sedentary behaviour in young people and adults is a rapidly developing area of research. Operationally defined as "sitting time", sedentary behaviour can be high in the contexts of leisure time (eg, screen time), school and travel (ie, car use). Most of the evidence with young people has centred on screen time, and TV viewing in particular. Although TV viewing remains the most prevalent sedentary behaviour for youth, it is only one behaviour and may not reflect wider patterns of excessive sitting.[31] However, the development of attractive home-based or even mobile electronic entertainment has led to concerns about excessive sitting time in young people.

Most of the evidence linking sedentary behaviour to health outcomes has focused on TV viewing and weight status,[32] with more recent studies looking at screen time (ie, TV and computers) and aspects of metabolic health more broadly.[33 34] Less has been written about sedentary behaviour and mental health in young people. For this brief section of the article, we review recent articles addressing links between sedentary behaviour and mental health, with a summary shown in table 5.

Results from the nine primary studies show consistent negative mental health associations with sedentary behaviour, primarily screen viewing. This mirrors a growing literature showing adverse physical health outcomes of high sitting time.[35] The one longitudinal study did show that TV viewing, but not computer games, was associated with increased odds of depression after 7-year follow-up.[36]

The associations across the studies, however, are small and, all but one, are derived from cross-sectional designs. It is plausible that those with poorer mental health choose to be more sedentary at screens—a reverse causality hypothesis. Only half the cross-sectional studies controlled for physical activity in their analyses. Most of the studies are large, with some being very large, and one assessing across multiple countries. Sedentary behaviour needs to be considered alongside physical activity in the study of mental health.

OVERALL CONCLUSIONS

In summarising physical activity and mental health in young people, physical activity is likely to have positive psychosocial outcomes. The review of reviews method adopted allows us to see the wider field of several mental health outcomes associated with physical activity in young people. It also allows a view of the gaps and inconsistencies across different outcomes.

The effects seem strongest for self-esteem (at least in the short term), and those who are physically active seem less likely to suffer from mental health problems and may have enhanced cognitive functioning. Evidence on depression is also promising but remains an underdeveloped area of enquiry. Although all participants are likely to gain significant benefits, such effects are likely to be greater in those who have poorer mental health at baseline; however, the evidence is not extensive. Studies are largely cross-sectional (thus unable to rule out reverse causality) and small scale and lack measurement consistency. In addition although physical activity may enhance psychological well-being, it is possible that the prevailing psychological climate and social interactions inherent in such settings will also be crucial. Unfortunately, such factors are rarely accounted for. Higher levels of sedentary (sitting) behaviour are associated with worse mental health.

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