Mental Health and Physical Activity 18 (2020) 100322

Contents lists available at ScienceDirect

Mental Health and Physical Activity

journal homepage: www.elsevier.com/locate/menpa

Physical activity, mental health and academic achievement: A cross-sectional study of Norwegian adolescents

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ARTICLE INFO

Keywords:
Physical activity
Accelerometer
Mental health
Academic achievement
Adolescents

ABSTRACT

Background: The purpose of this study was to describe associations between physical activity (PA), mental health and academic achievement in a Norwegian adolescent cohort.
Methods: In total, 1001 adolescents were invited to participate, of whom 599 (54.4% female, mean age ± SD 13.3 ± 0.3y) entered the study. PA was measured objectively using accelerometers, variables on mental health were assessed through an online questionnaire and academic achievement was assessed using grade point average (GPA) collected through school records. The associations between PA, mental health and academic achievement were modelled using multiple linear regression.
Results: PA was positively associated with mental wellbeing ($p \leq .05$), self-perception of athletic competence ($p \leq .001$) and self-perception of social acceptance ($p \leq .001$). It was not associated with global self-esteem or mental health complaints. No significant association between PA and GPA was found. However, results showed a significant association between PA and grade in physical education among girls ($p \leq .001$).
Conclusion: PA was associated with mental wellbeing and domain specific self-esteem although the causal significance of the association requires further investigation. The current study does not support associations between PA and mental health problems or PA and academic achievement. Further studies are necessary to investigate the longitudinal relationship between PA, variables of mental health and academic achievement amongst adolescents.

1. Background

The relationship between physical activity (PA) and various dimensions of mental health, especially among children and young people, has received increased attention in recent years (see for example, Biddle, Ciaccioni, Thomas, and Vergeer, 2018). Data from many high-income countries indicate that mental health problems among the young have increased over the last decade (Biddle et al., 2018; Reneflot et al., 2018). In Norway, for example, estimates indicate that 15–20% of 3-18-year-olds experience reduced function due to symptoms of poor mental health (Norwegian Insitute of Public Health, 2014). While the prevalence of mental disorders seems to be stable across most age groups over time, it is increasing among 14–17-year-old adolescent girls (Reneflot et al., 2018). Poor mental health is of concern in itself because it may exert a negative effect on young people's quality of life (Fox, 1999) in addition to tracking into adulthood (Rutter, Kim-Cohen, & Maughan, 2006). Furthermore, poor mental health has been associated with poor academic performance (Tempelaar et al., 2017). The putative role of PA in mental health promotion, prevention of mental health problems and academic achievement among the young has been increasingly debated both within and beyond the research field (Dale, Vanderloo, Moore, & Faulkner, 2019; Lubans et al., 2016).

A growing body of research indicates that PA may have a positive effect on some mental health outcomes in children and adolescents (Biddle et al., 2018; Dale et al., 2019). Recent research has also shown a positive relationship between PA and academic achievement (Booth et al., 2014; Kantomaa et al., 2016; Kwak et al., 2009), although the associations are usually weak and inconsistent across studies (Mountjoy et al., 2011; Poitras et al., 2016). Nevertheless, the quality of evidence in all these studies is considered to be low (Poitras et al., 2016). The limited quality of studies to date is indicative of the methodological challenges inherent in studying the relationship between PA – a

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https://doi.org/10.1016/j.mhpa.2020.100322
Received 4 October 2019; Received in revised form 24 January 2020; Accepted 4 February 2020
Available online 06 February 2020

complex multidimensional behaviour – and complex and multidimensional outcomes, such as mental health and academic achievement (Lagerberg, 2005; Marques, Santos, Hillman, & Sardinha, 2017). The limitations of a cross-sectional study design in exploring relationships have been noted as well as the heterogeneity of studies in terms of the mental health outcomes studied, the age-group targeted and the measurement of PA. In particular, one of the main outcome variables, mental health, has tended to be operationalized in terms of mental illness (such as anxiety), the presence of symptoms (such as those related to depression) and, to a lesser extent, self-esteem (Mountjoy et al., 2011). Although recent studies are starting to address these issues (see for example Van Dijk, Savelberg, Verboon, Kirschner, and De Groot, 2016 and Opdal et al., 2019), the conceptualization and measurement of mental health and consideration of the role of PA in mental health promotion require further elaboration.

There is some consensus within and beyond the research field that the construct 'mental health' has traditionally been defined as the absence of mental illness (Westerhof & Keyes, 2010). Westerhof and Keyes (2010) argue, however, that mental health can also be conceptualized as having positive dimensions, often defined as mental wellbeing, which is underpinned by social, psychological and emotional wellbeing constructs. These varying conceptualizations of mental health are important because they allow a more nuanced investigation of the relationship between PA and mental health. PA, for example, may be associated with some but not all of these mental health constructs. In part, this reflects the underpinning theoretical model of how PA might be causally related to mental health. It has been hypothesized that PA might have a positive effect on multiple aspects of brain function and cognition (Hillman, Erickson, & Kramer, 2008), and thereby influence academic achievement in a positive way. In a conceptual model from Lubans et al. (2016) it is hypothesized that the mechanisms explaining the association between PA, cognition and mental health in young people might be neurobiological, psychosocial and/or behavioural, and might be moderated by the frequency, intensity, time, type and context of PA.

A further overarching problem with research investigating the relationship between PA, various dimensions of mental health and academic achievement is that the majority of studies have relied on subjective self-report of PA (Biddle et al., 2018; Kantomaa et al., 2016). Such measures are prone to errors in precision (Guinhouya, Samouda, & de Beaufort, 2013), mainly because of overestimation of time spent in PA, social desirability and recall bias (Sallis & Saelens, 2000). As a consequence, the IOC consensus statement on the health and fitness of young people recommends the use of objective measures of PA whenever possible to enhance quality of data (Mountjoy et al., 2011).

The purpose of this study was, therefore, to investigate the relationship between objectively measured PA level, various dimensions of mental health and academic achievement among adolescents in Norway. The specific research questions are twofold:

1. Is PA associated with mental health among adolescents?
2. Is PA associated with academic achievement among adolescents?

2. Methods

A longitudinal cohort study of 13-16-year-olds was carried out, with data collection on an annual basis within the first semester of each academic year. This paper reports on the results from the first wave of the study.

2.1. Participants

In the spring of 2016, 12 schools located in three different counties in the Western and Eastern part of Norway were invited to participate in the study through an email and follow-up telephone call. These schools were selected because they represented differences in terms of location (urban/suburban/rural), school size, type of school and composition of pupils (ethnicity, socioeconomic status). Following the initial contact, a meeting was held at each school to inform them about the purpose and design of the study. Eleven schools decided to participate in the study.

The eligible participants were the 1001 adolescents starting in 8th grade at these schools in the autumn of 2016. Of these, five hundred and ninety nine grade eight adolescents (54.4% female, mean age ± SD 13.3 ± 0.3y) participated, generating a participation rate of 59.8%. Written informed consent from adolescents and their parent or legal guardian was obtained prior to participation in the study.

2.2. Measurements

Data collection was conducted in three steps. In the first visit, anthropometrics were measured and accelerometers were distributed. Eight days later, the accelerometers were collected and the adolescents answered an online questionnaire. At the end of the first semester (January 2017), midterm grades were obtained.

2.3. Anthropometrics

Weight and height were measured to the nearest 0.1 kg (Seca 877, SECA GmbH, Hamburg, Germany) and 0.5 cm (wall-mounted measuring tape), respectively. Participants were asked to remove shoes and sweaters. In line with standard practice, bodyweight measures were adjusted by subtracting 0.3 kg to account for clothing (Dalene et al., 2018). Body mass index (BMI) was calculated using weight and height ($kg \cdot m^{-2}$).

2.4. Physical activity

Physical activity was measured by accelerometry (ActiGraph GT3X + and GT3X-bt, LLC, Pensacola, Florida, USA). The participants were required to wear the accelerometer on their right hip in all waking hours for seven consecutive days, and only remove it during water activities and while sleeping. Because participants with only 2 and 3 days of valid measurements did not differ significantly from the participants with at least 4 days, data were included if the participants had ≥2 days of measurements with a minimum wear time of ≥480 min a day (Rich et al., 2013). Intervals of ≥20 consecutive minutes with no acceleration recorded was defined as non-wear time. Accelerometers were initialized to start recording at 06:00 on the day after the participants received them. ActiLife (ActiGraph GT3X+, LLC, Pensacola, Florida, USA) was used for initialization of the monitors, downloading of the accelerometer files and further processing of the data. Data recorded from 00:00 to 06:00 were excluded from the analysis. Because children and adolescents' PA-level can be intermittent, an epoch of 10 s was used (Bailey et al., 1995).

As a measure of total PA, average $counts \cdot min^{-1}$ (CPM) for the entire assessment period were used. In addition, minutes in sedentary behaviour (SB), light PA (LPA) and moderate to vigorous PA (MVPA) have been used for descriptive purposes. There is still no consensus in the literature regarding use of intensity-based cut-points for children and adolescents (Trost, Loprinzi, Moore, & Pfeiffer, 2011). In the current study SB, LPA and MVPA were set to < 100 CPM, 100–1999 CPM and ≥2000 CPM respectively. Similar cut-points have been used elsewhere (Dalene et al., 2018).

When returning the accelerometer, participants were asked to register the amount of time spent doing activities which are poorly measured with the accelerometer (cycling), or require removal of the device (swimming).

2.5. Mental health

The online questionnaire incorporated three validated instruments which were used to measure different dimensions of mental health: the Warwick-Edinburgh Mental Wellbeing scale (WEMWBS) (Tennant et al., 2007), Harter's Self-Perception Profile for Adolescents (SPPA) (Harter, 1988, 2012) and the Strengths and Difficulties Questionnaire (SDQ) (Goodman & Goodman, 2009).

Mental wellbeing was measured through WEMWBS, which comprises 14 positively worded statements which require a response on a 5-point Likert scale (1 = 'none of the time' to 5 = 'all of the time'). Responses were summed to create an overall score ranging from 14 to 70, with higher scores indicating higher levels of mental wellbeing (Tennant et al., 2007). The scale has been validated for use in adolescents from 13 years and over (Clarke et al., 2011). The current study used the established Norwegian translation with minor linguistic amendments. The scale was piloted before use.

Domain-specific self-esteem was measured through the revised version (Wichstrøm, 1995) of SPPA (Harter, 1988, 2012). The revised instrument consists of 35 statements divided into seven domain-specific subscales (scholastic competence, social acceptance, athletic competence, physical appearance, romantic appeal, close friends and global self-worth), each comprising five statements, of which approximately half are reversed to avoid acquiescence. Response categories are fourfold from 'describes me very poorly' to 'describes me very well'. The revised version shows better reliability, convergent and factorial validity than the original version (Wichstrøm, 1995). Based on a review of the literature, we selected the subscales that were judged to be the most relevant to PA. The current paper used the following subscales: social acceptance, athletic competence and global self-worth.

To be able to account for mental health problems, the SDQ was used. The instrument consists of 25 questions divided into five subscales (emotional symptoms, conduct problems, hyperactivity, peer problems, prosocial behavior), each consisting of five items. Each item can be answered 'not true', 'somewhat true' or 'certainly true'. A 'total difficulty score' ranging from 0 to 40 was created by summing all subscales except prosocial behavior (Goodman & Goodman, 2009). This score is a psychometrically sound measure of overall mental health problems among children and adolescents (Goodman, Lamping, & Ploubidis, 2010). The continuous score was used as the outcome variable in all analyses.

2.6. Academic achievement

Academic achievement was assessed using two indicators: the grade point average (GPA) from the midterm grades for all subjects and the grade in physical education (PE). The grade range in Norway is 1–6, where 6 represents the highest achievement possible.

2.7. Socioeconomic status

The Family Affluence Scale (FAS) measures material affluence, and was used as a proxy for socioeconomic status (SES) (Hartley, Levin, & Currie, 2016). Based on this scale, a score of *relative family affluence* was constructed by summing scores on all answers and categorising them into three broader groups (the lowest 20%, the middle 60% and the highest 20%).

2.8. Data analysis

Statistical analyses were preformed using IBM SPSS Statistics for Windows, Version 24.0 and Stata Statistical Software, version 16.0 (Copyright 1985–2019 StataCorp LLC), Texas 77845 USA. Descriptive data are presented as frequencies, mean and SD where appropriate. Multiple linear regression was used to analyse the associations between PA (exposure variable), and measures of mental health and academic achievement (outcome variables). The crude models showed the association between total PA (CPM) and the outcome variables. In the adjusted models, interaction of sex, SES, season of data collection (1: Sept-Oct, 2: Nov-Jan) and BMI were accounted for. Categorical variables that did not exhibit a linear trend were transformed into dummy variables before entering the model. To account for possible clustering in the outcomes, 'school' was included as a cluster variable to obtain robust standard errors. Imputations have been performed in the psychometric scales enabling such procedures, and have followed statistical guidelines. The results from the instruments measuring mental health outcomes (SDQ, WEMWBS and SPPA-R) were all converted to different continuous scores according to standard procedures. This enabled further processing as a continuous variable that could enter a linear regression model. This is in line with standard practise (Hallal et al., 2015; Haugen, Säfvenbom, & Ommundsen, 2011).

Adjustments for multiple comparisons were not made. This decision was based on the argument that reducing the type I error for null associations would increase the type II error for the associations that are not null (Rothman, 1990). However, the increased likelihood of false positive findings has been taken into account when interpreting the results.

In this study WEMWBS was assessed in a six-point Likert scale from *not at all* (0) to *all the time* (5). To be able to compare results with international data, the following equation was applied: WEMWBS 5-point score = 1 + 4/5*WEMWBS 6-point score.

3. Results

There were no sex differences in BMI. Total PA (CPM) was significantly higher for boys than for girls ($p \leq .001$). Furthermore, boys had a significantly higher level of mental wellbeing than girls ($p = .01$), but there were no sex differences with regard to mental health problems. Girls had a significantly higher GPA than boys ($p \leq .001$) (Table 1).

Total PA (CPM) was positively associated with both mental wellbeing ($p \leq .01$), self-perception of athletic competence ($p \leq .001$) and self-perception of social acceptance ($p \leq .001$). It was not associated with global self-esteem or mental health complaints (Table 2).

Multiple linear regression analysis showed that total PA (CPM) predicted some mental health outcomes when controlling for sex, BMI, SES and season of data collection. An increase in total PA of 100 CPM, predicted an equivalent increase in scores of mental wellbeing, self-perceived athletic competence and self-perceived social acceptance with β 0.71, 0.10 and 0.03 respectively.

Multiple linear regression analysis revealed that total PA (CPM) was not associated with academic achievement measured in overall GPA. Associations were found when analyzing total PA and grade in PE. This association was however, only significant for girls. Observed mean increase of 100 CPM shows equivalent increase of β 0.20 ($p \leq .001$) higher grade in PE for girls.

The measures of PE grade stratified by quartiles of PA are presented for girls and boys respectively in Table 3. There was a significant increase in girls' PE grades in all quartiles compared to the lowest quartile (lowest 25%). Among boys the differences between the lowest quartile was only significant compared to the third and fourth quartile.

4. Discussion

The main aim of this study was to examine the associations between PA and measures of mental health and academic achievement. Our cross-sectional analyses suggest that PA levels are associated with mental wellbeing and specific sub-domains of self-esteem. They also

Table 1
Descriptive characteristics of the study sample by sex (mean ± SD unless otherwise specified).

	All (N = 599)	Girls (n = 326; 54.4%)	Boys (n = 273; 45.6%)
Age (years)	13.33 (0.3)	13.32 (0.3)	13.35 (0.3)
Anthropometrics			
Height (cm)	162.7 (7.8)	161.7 (6.9)	163.9 (8.6)
Weight (kg)	52.9 (10.8)	52.8 (9.9)	53 (11.8)
BMI ($kg{\cdot}m^{-2}$)	19.8 (3.2)	20.1 (3.1)	19.6 (3.3)
SES (n)			
Lowest N (%)	136 (23.7)	76 (24.5)	60 (22.7)
Middle N (%)	346 (60.3)	188 (60.6%)	158 (59.9)
Highest N (%)	92 (16.0)	46 (14.8)	46 (17.4)
Physical Activity			
SB (min)	558.0 (65.1)	565.7 (55.3)	548.4 (74.6)
LPA (min)	166.2 (33.5)	161.4 (32.3)	172.3 (34.2)
MVPA (min)	58.4 (21.2)	54.1 (18.5)	63.9 (22.9)
CPM	434.4 (152.6)	402.4 (118.4)	474.5 (179.1)
Meeting national PA recommendations N (%)	251 (43.9)	116 (36.5)	135 (53.1)
Total included valid days	5.8 (1.4)	5.9 (1.3)	5.7 (1.4)
Mental health			
Mental wellbeing (WEMWBS)	56.0 (9.0)	55.1 (8.9)	57.1 (9.1)
Mental health problems (SDQ)	9.8 (5.2)	10.0 (5.1)	9.7 (5.4)
Self-perception of social acceptance (SPPA-R)	2.9 (0.4)	2.9 (0.4)	3.0 (0.3)
Self-perception of athletic competence (SPPA-R)	2.7 (0.6)	2.5 (0.6)	2.8 (0.6)
Self-perception of global self-worth (SPPA-R)	3.3 (0.6)	3.1 (0.7)	3.5 (0.5)
Academic achievement			
GPA	4.0 (0.7)	4.1 (0.7)	3.8 (0.6)
PE	4.4 (0.7)	4.4 (0.7)	4.5 (0.7)

Note. BMI = body mass index, SES = socioeconomic status, SB = average daily sedentary behaviour, LPA = average daily light physical activity, MVPA = average daily moderate-to-vigorous physical activity, CPM = average daily counts per minute, WEMWBS = Warwick-Edinburgh mental wellbeing scale, SDQ = Strengths and Difficulties Questionnaire, SPPA-R = Self-perception profile for adolescents, GPA = grade point average, PE = Physical Education.

suggest that PA levels are associated with grade in PE. In contrast, PA was not associated with mental health problems, GPA or global self-esteem. To our knowledge, this is the first study that looks at associations between objectively measured PA and mental wellbeing measured by WEMWBS in an adolescent population.

4.1. Associations between physical activity and mental wellbeing

Although small, the results add support to the hypothesis that higher levels of PA are associated with higher levels of mental wellbeing. This finding is consistent with the conclusion of an earlier review (Whitelaw, Teuton, Swift, & Scobie, 2010) that PA and mental wellbeing are associated in adolescents. More specifically, this is also in keeping with findings using the same wellbeing scale in an adult population (Cooper & Barton, 2016). Whitelaw et al. (2010) discuss the different effects from PA that might explain this association. Physiological changes that occur with PA, psychological effects emerging from 'mastery' of PA, as well as serving as a 'distraction' from other stressors, and the social aspect of interacting with others in PA are put forward as possible explanatory mechanisms. These might serve as underlying factors to the association found between total PA (CPM) and mental wellbeing.

4.2. Associations between physical activity and self-esteem

In their review of reviews, Biddle et al. (2018) underscore the complexity of the field, especially in relation to ambiguity in definitions of self-esteem, and broad definitions of PA. Nonetheless, six of the 10 studies reported positive associations between PA and self-esteem. The remaining four were inconclusive, showing mixed or null findings. The same pattern was reported by Dale et al. (2019) in their umbrella systematic review, where seven of 14 included studies showed positive findings. In the review of Poitras et al. (2016), no consistent evidence for a relationship between objectively assessed PA and self-esteem was

Table 2
Associations between physical activity and measures of mental health and academic achievement analysed with a multiple linear regression model (n = 474–570).

	Crude[a]				Adjusted[b]			
	n	β	95% CI	p	n	β	95% CI	p
Mental wellbeing	504	0.78	0.36, 1.21	≤.001	474	0.71	0.14, 1.28	.014
Self-perception of athletic competence	544	0.12	0.09, 0.15	≤.001	511	0.10	0.06, 0.14	≤.001
Self-perception of social acceptance	538	0.04	0.02, 0.06	≤.001	505	0.03	0.01, 0.05	≤.001
Self-perception of global Self-worth	542	0.01	−0.02, 0.06	.414	509	−0.006	−0.05, 0.04	.793
Mental health problems	550	−0.01	−0.20, 0,25	.908	517	0.06	−0.23, 0,36	.677
Academic achievement	570	−0.01	−0.05, 0.03	.565	518	0.003	−0.05, 0.05	.989

Note. Mental wellbeing is measured by WEMWBS score, Self-perception domains are measured by SPPA-R score, Mental health problems are measured by SDQ score. Academic achievement is measured by GPA in all subjects, β = standardized regression coefficient.

[a] Adjusted for cluster sampling.

[b] Adjusted for cluster sampling, sex, BMI, SES and season of data collection. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.

Table 3
The grade in PE within quartiles of PA (n boys = 252, n girls = 282)[a].

	Quartile 1	Quartile 2			Quartile 3			Quartile 4		
		β	95% CI	p	β	95% CI	p	β	95% CI	P
Boys	ref.	0.14	−0.12, 0.40	.291	0.34	0.09, 0.59	.008	0.32	0.08, 0.56	.008
Girls	ref.	0.24	0.03, 0.45	.027	0.43	0.22, 0.65	≤.001	0.71	0.46, 0.95	≤.001

Note. Ref. = Reference value (equals PE grade 4.88 for boys and 4.64 for girls).
[a] Adjusted for BMI, SES and season of data collection.

found. However, the review only included one study exploring associations between MVPA and self-esteem, among adolescent girls. The same conclusion was drawn in a recent study using objective measures to assess PA (Van Dijk et al., 2016). The authors discuss whether this might be explained by the use of global self-esteem as an overall measure of self-esteem, which might be too distant from specific behaviours such as PA. This view is consistent with Biddle et al. (2018): they argue that some studies only focus on global self-esteem, excluding more relevant sub-domains. No evidence of an association between PA and global self-esteem was found in the current study, but support for associations with domain specific self-esteem were identified. The foundation for the Self-perception Profile is that one evaluates oneself based on perceived competence in a domain and one's aspiration within that domain (Harter, 1988, 2012; Wichstrøm, 1995). Thus, athletic competence taps into perceptions of one's ability to do well in sports (Harter, 1988, 2012). Results from the current study showed an increase in self-perception of athletic competence with higher total PA-levels. At a theoretical level, being more physically active might generate a greater belief in one's ability in different sporting activities. Social acceptance refers to having the skills to get others to like oneself and understanding what it takes to become popular (Harter, 1988, 2012). In Norwegian culture where being physically active is considered to be a valuable trait (Green, Thurston, Vaage, & Roberts, 2015), this might offer one explanation for why physical activity is positively associated with self-perception of social acceptance in the current study.

4.3. Associations between physical activity and mental health problems

Even though the majority of existing studies have reported an association between (self-reported) PA and lower levels of mental health problems (for example, depressive symptoms) among adolescents (Biddle et al., 2018), existing research has not yet shown either a clear direction, or strength, of the potential association. While results from studies specifically sampling those with depression clearly show favourable associations with PA, the same conclusion cannot be drawn in healthy samples (Biddle et al., 2018). The lack of association found in this and other (Van Dijk et al., 2016) studies using objective measures of PA, provides no support for the hypothesis that PA can prevent mental health problems (that is to say, that higher levels of PA protect against mental health problems). However, as Van Dijk et al. (2016) argue, the pathways between PA and mental health problems may take longer to develop, and therefore not occur until later in adolescence. This theory could explain the lack of association found in the current study. Another explanation proposed is that such a relationship might not exist in particular subgroups, and that changes in mental health problems might be explained by variables other than PA (Van Dijk et al., 2016). Results from the current study may also support such an explanation. Wiles, Haase, Lawlor, Ness, and Lewis (2012) found an inverse association between objectively measured PA and depressive symptoms, but no association between MVPA and depressive symptoms in a cohort of 14-year-old English adolescents. They argue that it might be the amount of PA, rather than the intensity, which is associated with depressive symptoms. The current study found no evidence of such an association through analysis of total PA and mental health problems.

4.4. Associations between physical activity and academic achievement

Our results corroborate previous studies using objective measures of PA suggesting no association between PA and academic achievement (Oliveira et al., 2017; van Dijk, de Groot, Savelberg, van Acker, & Kirschner, 2014). van Dijk et al. (2014) discuss whether PA and academic achievement might be positively associated up to a particular threshold where additional time spent being physically active could come at the expense of academic pursuits, such as time devoted to homework. However, in the current study, analysis of PA quartiles (data not shown) showed no such pattern, and thus is not likely to be the explanation for the results.

Our findings differ from those of Esteban-Cornejo, Tejero-Gonzalez, Sallis, and Veiga (2015) whose systematic review supported a positive relationship between PA and academic achievement. However a study by Esteban-Cornejo et al. (2014) found a weak negative association between objectively measured PA and academic achievement. The inconsistency in findings among these and other studies, including our own, might be explained by several factors. First, there is no consensus as to the method of assessing academic achievement, which makes it arbitrarily assessed in different studies (Esteban-Cornejo et al., 2015). According to Marques et al. (2017) school grades might not only relate to academic skills, but could also reflect other factors, such as teacher perception. In studies where grades have been self-reported, inaccuracy might have influenced the level of precision (Marques et al., 2017). Comparison of results using different measures of academic achievement might therefore offer one explanation for the different results seen in these studies.

Another explanation is that PA could be associated with single subjects without being associated with overall GPA. For example, van Dijk et al. (2014) found that PA was significantly associated with mathematics in Grade 9 students. Sub-analysis of the current data revealed that there was a significant association between total PA and PE. This association was stronger for girls than for boys. Esteban-Cornejo et al. (2015) suggest that associations between time spent in PA and academic achievement tend to be found more frequently among adolescent girls than in boys. They discuss whether these findings could be explained by a dose-response relationship where boys are more active than girls, and therefore need higher levels of PA to produce the same effect. Even though our results show that boys had a higher PA level than girls, it might not have been sufficiently higher to produce the same effect size as for girls.

4.5. Strengths and limitations

The main strength of this study is the use of an objective measure of PA. This minimizes the risk of bias from self-report. Nevertheless, the accelerometer has some limitations. First, because the adolescents were instructed to remove the monitor during water activities these were not recorded. Consequently, the activity level of pupils who are active swimmers was underestimated. In addition, the accelerometers have known limitations in the measurements of upper body activities, load-carrying activities and biking (Shephard & Aoyagi, 2012). The amount of time spent cycling or swimming were recorded in the questionnaire and the majority of participants reported zero hours of both activities.

Thus, this limitation seems unlikely to have led to an underestimation of the true activity level, at least to a large degree. Average CPM has been used as the primary measure of PA thereby avoiding problems related to the lack of consensus in the generation of cut-points for different intensity levels. An additional strength is that the study includes a relatively large sample size and several important covariates have been addressed. Nonetheless, all models are simplifications of complex mechanisms, and it cannot be ruled out that there are additional covariates that were not controlled for in the current study.

A limitation of the study is its cross-sectional methodology, which constrains the possibility of addressing cause and effect between PA and the dependent variables. In this regard, the explanations discussed remain speculative and theoretical and require further exploration using different study designs. In addition, because the schools were strategically selected, generalizability was not feasible. The participation rate was close to 60%. It was not possible to perform an analysis of those not giving their consent to participate. It is, therefore, possible that the moderate participation rate, together with the strategic selection of schools, introduced some selection bias into our findings.

5. Conclusion

Although the effect sizes were small, this study provides some support for the hypothesis that physical activity is associated with both mental wellbeing and domain-specific measures of self-esteem. The study shows some advantages to using different outcome measures for mental health and for conceptualizing mental health as a multi-dimensional construct. Our findings contribute to an expanding evidence-base that links physical activity and mental health.

No association with academic achievement was found, supporting the notion that the evidence is still insufficient for reaching robust conclusions. Previous research has shown a relationship between mental health and academic achievement (Gustafsson et al., 2010), which might confound the relationship between PA and academic achievement. This needs further exploration in future studies.

Questions remain in terms of the most beneficial kinds of PA (including frequency and intensity but also form and context) for mental health and academic achievement, which might differ from the current recommendations for physical health.

Funding

This work was supported by the Research Council of Norway (238212/F60).

Availability of data

Please contact author for data requests.

Ethical approval and consent to participate

The study was approved by the Norwegian Centre for Research Data (project no. 48192). Written informed consent from adolescents and their parent or legal guardian was obtained prior to participation in the study.

Declaration of competing interest

None.

Acknowledgements

The authors wish to thank all the schools involved in the study, especially the pupils who participated, as well as all those who helped with data collection. The authors would also like to thank the Research Council of Norway for funding this project.

References

Bailey, R. C., Olson, J., Pepper, S. L., Porszasz, J., Barstow, T. J., & Cooper, D. M. (1995). The level and tempo of children's physical activities: An observational study. *Medicine & Science in Sports & Exercise, 27*(7), 1033–1041.

Biddle, S. J. H., Ciaccioni, S., Thomas, G., & Vergeer, I. (2018). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise*. https://doi.org/10.1016/j.psychsport.2018.08.011.

Booth, J. N., Leary, S. D., Joinson, C., Ness, A. R., Tomporowski, P. D., Boyle, J. M., et al. (2014). Associations between objectively measured physical activity and academic attainment in adolescents from a UK cohort. *British Journal of Sports Medicine, 48*(3), 265. https://doi.org/10.1136/bjsports-2013-092334.

Clarke, A., Friede, T., Putz, R., Ashdown, J., Martin, S., Blake, A., ... Stewart-Brown, S. (2011). Warwick-edinburgh mental well-being scale (WEMWBS): Validated for teenage school students in England and Scotland. A mixed methods assessment. *BMC Public Health, 11*. https://doi.org/10.1186/1471-2458-11-487 487-487.

Cooper, K., & Barton, G. C. (2016). An exploration of physical activity and wellbeing in university employees. *Perspectives in Public Health, 136*(3), 152–160. https://doi.org/10.1177/1757913915593103.

Dalene, K. E., Anderssen, S. A., Andersen, L. B., Steene-Johannessen, J., Ekelund, U., Hansen, B. H., et al. (2018). Secular and longitudinal physical activity changes in population-based samples of children and adolescents. *Scandinavian Journal of Medicine & Science in Sports, 28*(1), 161–171. https://doi.org/10.1111/sms.12876.

Dale, L. P., Vanderloo, L., Moore, S., & Faulkner, G. (2019). Physical activity and depression, anxiety, and self-esteem in children and youth: An umbrella systematic review. *Mental Health and Physical Activity, 16*, 66–79. https://doi.org/10.1016/j.mhpa.2018.12.001.

van Dijk, M. L., de Groot, R. H. M., Savelberg, H. H. C. M., van Acker, F., & Kirschner, P. A. (2014). The association between objectively measured physical activity and academic achievement in Dutch adolescents: Findings from the GOALS study. *Journal of Sport & Exercise Psychology, 36*(5), 460–473. https://doi.org/10.1123/jsep.2014-0014.

Esteban-Cornejo, I., Tejero-González, C. M., Martinez-Gomez, D., Cabanas-Sánchez, V., Fernández-Santos, J. R., Conde-Caveda, J., ... Veiga, O. L. (2014). Objectively measured physical activity has a negative but weak association with academic performance in children and adolescents. *Acta Paediatrica, 103*(11), e501–e506. https://doi.org/10.1111/apa.12757.

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

Fox, K. R. (1999). The influence of physical activity on mental well-being. *Public Health Nutrition, 2*(3a), 411–418. https://doi.org/10.1017/S1368980099000567.

Goodman, A., & Goodman, R. (2009). Strengths and difficulties questionnaire as a dimensional measure of child mental health. *Journal of the American Academy of Child & Adolescent Psychiatry, 48*(4), 400–403. https://doi.org/10.1097/CHI.0b013e3181985068.

Goodman, A., Lamping, D. L., & Ploubidis, G. B. (2010). When to use broader internalising and externalising subscales instead of the hypothesised five subscales on the strengths and difficulties questionnaire (SDQ): Data from British parents, teachers and children. *Journal of Abnormal Child Psychology, 38*(8), 1179–1191. https://doi.org/10.1007/s10802-010-9434-x.

Green, K., Thurston, M., Vaage, O., & Roberts, K. (2015). 'We're on the right track, baby, we were born this way'! Exploring sports participation in Norway. *Sport, Education and Society, 20*(3), 285–303. https://doi.org/10.1080/13573322.2013.769947.

Guinhouya, B. C., Samouda, H., & de Beaufort, C. (2013). Level of physical activity among children and adolescents in europe: A review of physical activity assessed objectively by accelerometry. *Public Health, 127*(4), 301. https://doi.org/10.1016/j.puhe.2013.01.020.

Gustafsson, J.-E., Allodi Westling, M., Alin Åkerman, B., et al. (2010). *School, learning and mental health: A systematic review*. Stockholm: The Royal Academy of Sciences 978-991-7190-138-5.

Hallal, P. C., Martínez-Mesa, J., Coll, C. V., Mielke, G. I., Mendes, M. A., Peixoto, M. B., ... Menezes, A. M. (2015). Physical activity at 11 Years of age and incidence of mental health problems in adolescence: Prospective study. *Journal of Physical Activity & Health, 12*(4), 535. https://doi.org/10.1123/jpah.2013-0029.

Harter, S. (1988, 2012). *Selv-perception profile for adolescents: Manual and questionnaires*. Retrieved from https://portfolio.du.edu/SusanHarter/page/44210.

Hartley, J. E. K., Levin, K., & Currie, C. (2016). A new version of the HBSC family affluence scale - FAS III: Scottish qualitative findings from the international FAS development study. *Child Indicators Research, 9*(1), 233–245. https://doi.org/10.1007/s12187-015-9325-3.

Haugen, T., Säfvenbom, R., & Ommundsen, Y. (2011). Physical activity and global self-worth: The role of physical self-esteem indices and gender. *Mental Health and Physical Activity, 4*(2), 49–56. https://doi.org/10.1016/j.mhpa.2011.07.001.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*(1), 58–65. https://doi.org/10.1038/nrn2298.

Kantomaa, M. T., Stamatakis, E., Kankaanpää, A., Kajantie, E., Taanila, A., & Tammelin, T. (2016). Associations of physical activity and sedentary behavior with adolescent academic achievement. *Journal of Research on Adolescence, 26*(3), 432–442. https://doi.org/10.1111/jora.12203.

Kwak, L., Kremers, S. P., Bergman, P., Ruiz, J. R., Rizzo, N. S., Sjostrom, M., ... Syndrome, R. N. R. M. (2009). Associations between physical activity, fitness, and academic achievement. *The Journal of Pediatrics, 155*(6), 914–918. https://doi.org/10.1016/j.

jpeds.2009.06.019 e911.
Lagerberg, D. (2005). Physical activity and mental health in schoolchildren: A complicated relationship. *Acta Paediatrica, International Journal of Paediatrics, 94*(12), 1699–1701. https://doi.org/10.1080/08035250500369627.
Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., ... Biddle, S. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics, 138*(3), https://doi.org/10.1542/peds.2016-1642.
Marques, A., Santos, D. A., Hillman, C. H., & Sardinha, L. B. (2017). How does academic achievement relate to cardiorespiratory fitness, self-reported physical activity and objectively reported physical activity: A systematic review in children and adolescents aged 6-18 years. *British Journal of Sports Medicine*. https://doi.org/10.1136/bjsports-2016-097361.
Mountjoy, M., Andersen, L. B., Armstrong, N., Biddle, S., Boreham, C., Bedenbeck, H.-P. B., & van Mechelen, W. (2011). International Olympic Committee consensus statement on the health and fitness of young people through physical activity and sport. *British Journal of Sports Medicine, 45*(11), 839. https://doi.org/10.1136/bjsports-2011-090228.
Norwegian Insitute of Public Health (2014). *Folkehelserapporten 2014 : Helsetilstanden i norge [public health report 2014: The state of health in Norway], 2014:4*. Oslo: Norwegian Insitute of Public Health.
Oliveira, T., Pizarro, A., Costa, M., Fernandes, L., Silva, G., Mota, J., et al. (2017). Cardiorespiratory fitness, but not physical activity, is associated with academic achievement in children and adolescents. *Annals of Human Biology, 44*(4), 309–315.
Opdal, I. M., Morseth, B., Handegård, B. H., Lillevoll, K., Ask, H., Nielsen, C. S., ... Rognmo, K. (2019). Change in physical activity is not associated with change in mental distress among adolescents: The Tromsø study: Fit Futures. *BMC Public Health, 19*(1), https://doi.org/10.1186/s12889-019-7271-6.
Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J.-P., Janssen, I., ... Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology Nutrition and Metabolism, 41*(6), S197–S239. https://doi.org/10.1139/apnm-2015-0663.
Reneflot, A., Aarø, L., Aase, H., Reichborn-Kjennerud, T., Tambs, K., & Øverland, S. (2018). *Psykisk helse i norge, folkehelseinstituttet. Rapport 2018. [Mental health in Norway, Norwegian institute of public health. Report 2018]*elektronic. Oslo: Norwegian Institute of Public Health978-82-8082-878-1.
Rich, C., Geraci, M., Griffiths, L., Sera, F., Dezateux, C., & Cortina-Borja, M. (2013). Quality control methods in accelerometer data processing: Defining minimum wear time. *PloS One, 8*(6), e67206. https://doi.org/10.1371/journal.pone.0067206.
Rothman, K. J. (1990). No adjustments are needed for multiple comparisons. *Epidemiology, 1*(1), 43–46.
Rutter, M., Kim-Cohen, J., & Maughan, B. (2006). Continuities and discontinuities in psychopathology between childhood and adult life. *Journal of Child Psychology and Psychiatry, 47*(3–4), 276–295. https://doi.org/10.1111/j.1469-7610.2006.01614.x 276-274.
Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: Status, limitations, and future directions. *Research Quarterly for Exercise & Sport, 71*(2), 1.
Shephard, R. J., & Aoyagi, Y. (2012). Measurement of human energy expenditure, with particular reference to field studies: An historical perspective. *European Journal of Applied Physiology, 112*(8), 2785–2815. https://doi.org/10.1007/s00421-011-2268-6.
Tempelaar, W. M., de Vos, N., Plevier, C. M., van Gastel, W. A., Termorshuizen, F., MacCabe, J. H., et al. (2017). Educational level, underachievement, and general mental health problems in 10,866 adolescents. *Academic Pediatrics, 17*(6), 642–2859. https://doi.org/10.1016/j.acap.2017.04.016.
Tennant, R., Hiller, L., Fishwick, R., Platt, S., Joseph, S., Weich, S., ... Stewart-Brown, S. (2007). The Warwick-Edinburgh mental well-being scale (WEMWBS): Development and UK validation. *Health and Quality of Life Outcomes, 5*, 63. https://doi.org/10.1186/1477-7525-5-63.
Trost, S. G., Loprinzi, P. D., Moore, R., & Pfeiffer, K. A. (2011). Comparison of accelerometer cut points for predicting activity intensity in youth. *Medicine & Science in Sports & Exercise, 43*(7), 1360. https://doi.org/10.1249/MSS.0b013e318206476e.
Van Dijk, M. L., Savelberg, H. H. C. M., Verboon, P., Kirschner, P. A., & De Groot, R. H. M. (2016). Decline in physical activity during adolescence is not associated with changes in mental health. *BMC Public Health, 16*, 300. https://doi.org/10.1186/s12889-016-2983-3.
Westerhof, G., & Keyes, C. (2010). Mental illness and mental health: The two continua model across the lifespan. *Journal of Adult Development, 17*(2), 110–119. https://doi.org/10.1007/s10804-009-9082-y.
Whitelaw, S., Teuton, J., Swift, J., & Scobie, G. (2010). The physical activity – mental wellbeing association in young people: A case study in dealing with a complex public health topic using a 'realistic evaluation' framework. *Mental Health and Physical Activity, 3*(2), 61–66. https://doi.org/10.1016/j.mhpa.2010.06.001.
Wichstrøm, L. (1995). Harter's self-perception profile for adolescents: Reliability, validity, and evaluation of the question format. *Journal of Personality Assessment, 65*(1), 100.
Wiles, N. J., Haase, A. M., Lawlor, D. A., Ness, A., & Lewis, G. (2012). Physical activity and depression in adolescents: Cross-sectional findings from the ALSPAC cohort. *Social Psychiatry and Psychiatric Epidemiology, 47*(7), 1023–1033. https://doi.org/10.1007/s00127-011-0422-4.