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Ingeborg Barth Vedøy

Physical activity, mental health and academic achievement in adolescents

A longitudinal study exploring the role of physical activity on dimensions of mental health and academic achievement in Norwegian adolescents at lower secondary school

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Samandrag på norsk

Introduksjon: God psykisk helse i ungdomsåra er viktig for å unngå fråfall i skulen, seinare tilknyting til arbeidslivet, samt for evna til å meistre motgang og utfordringar i livet. Det vil også danna eit godt fundament for vaksenlivet. Vidare er det vist at å oppnå gode skuleprestasjonar gjennom utdanningsløpet er assosiert med seinare akademisk suksess, betre løn, i tillegg til betre fysisk og psykisk helse. Å inneha god psykisk helse, samt oppnå gode skuleprestasjonar er difor eit vesentleg premiss for ungdommar si framtid. Av den grunn er det viktig å få meir kunnskap om faktorar som kan fremje psykisk helse og skuleprestasjonar i denne perioden av livet. Tidlegare forsking har peikt på at fysisk aktivitet (FA) kan vera ein slik faktor. Likevel er forskinga som understøttar denne konklusjonen hefta med metodiske utfordringar knytt til målemetodane som er nytta, samt at forskinga som føreligg også primært har nytta eit tverrsnittsdesign for å studera desse samanhengane. Dette medfører usikkerheit knytt til resultata konklusjonane kviler på, og eit uttalt behov for ny forsking som kan adressera desse tilkortkommingane.

Hensikt med avhandlinga: Det overordna målet med denne avhandlinga var difor å bruka både eit tverrsnitt- og longitudinelt forskingsdesign til å utforska forholdet mellom objektivt målt FA og psykisk helse (målt som psykiske problem og psykisk well-being), og mellom objektivt målt FA og skuleprestasjonar hos ungdom.

Metode: Avhandlinga er basert på ei treårig prospektiv kohortstudie av 599 elevar frå 8. til 10. steg i ungdomsskulen (12-16 år). Elevane sokna til ulike 11 skular i Noreg på aust- og vestlandet. Mål på psykisk helse vart innhenta ved bruk av instrumenta: *Strengths and Difficulties Questionnaire*, *Warwick-Edinburgh Mental Well-Being Scale* og *Self-Perception Profile for adolescents*. Skuleprestasjonar vart målt ved bruk av gjennomsnittskarakter frå 1. termin av kvart skuleår. FA vart målt objektivt ved bruk av akselerometer over 7 samanhengande dagar. Data vart innhenta årleg frå 2016 til 2018.

Hovudresultat: Artikkel I nytta tverrsnittsdata og fann samanhengar mellom FA og psykisk well-being, samt med domenespesifikk sjølvtillit. Desse var imidlertid små. Ingen samanheng var til stade mellom FA og psykiske problem eller mellom FA og skuleprestasjonar. **Artikkel II** nytta longitudinelle data og fann ingen direkte eller indirekte samanhengar mellom endring i FA volum eller intensitet og skuleprestasjonar. **Artikkel III** nytta longitudinelle data og fann ein samanheng mellom auke i stillesitjande tid og høgare nivå av psykisk well-being hos gutar. Hos jenter var det ein liten samanheng mellom auke i FA volum og psykisk well-being. Ingen relasjon var til stade mellom endring i stillesitjande tid, FA volum eller intensitet og psykiske problem.

Konklusjon: Overordna syner resultata ingen klar samanheng mellom FA eller stillesitjande tid og psykiske problem. Sidan tydelegare samanhengar har blitt funnet gjennom forsking på utval med kliniske diagnosar, kan dette tyda på at forholdet mellom fysisk aktivitet og psykisk helse er mindre uttalt i tilsynelatande friske studieutval. Med omsyn til positive dimensjonar av psykisk helse, synte resultata ein liten samanheng mellom FA og domenespesifikk sjølvtillit, samt også med psykisk well-being, men då særskilt hos jenter. Då ein positiv samanheng mellom stillesitjande tid og psykisk well-being vart funnet hos gutar, er det eit behov for å studera om dette forholdet er ulikt for ulike stillesitjande aktivitetar. Det vart ikkje funnet noko støtte for ein samanheng mellom FA og skuleprestasjonar, noko som peiker mot at desse faktorane ikkje er relatert i det undersøkte studieutvalet. Desse resultata understøttar moglegheita for at FA kan ha ulik betydning for ulike indikatorar på psykisk helse, og at mengda og intensiteten av FA i liten grad ser ut til å ha betydning for psykiske problem og skuleprestasjonar.

Nøkkelord: Ungdom, psykisk helse, psykisk well-being, psykiske problem, skuleprestasjonar, fysisk aktivitet, stillesitjande tid, akselerometer, midjemål, søvnlengde, tverrsnitt, longitudinell, prospektiv, epidemiologi, folkehelse

Summary

Introduction: Good mental health during adolescence is seen as important for positive social and educational outcomes, as well as a healthy transition to adulthood. Similarly, achieving academic success at school is associated with later educational success, higher income and better physical and mental health. Mental health and academic achievement during adolescence thus serve as important determinants of future health and wellbeing. Consequently, it is important to explore factors that may promote mental health and academic achievement during adolescence. Physical activity (PA) has been identified as a factor that may promote both mental health and academic achievement among young people. Nevertheless, research in this field to date has been replete with methodological issues related to measurement of PA, mental health and academic achievement as well as primarily reliant on cross-sectional study designs.

Purpose: The overall purpose of this thesis was to explore the cross-sectional and longitudinal relationships between objectively measured PA and mental health (both in terms of mental health problems and mental well-being) and objectively measured PA and academic achievement among Norwegian adolescents.

Methods: This thesis is based on a three-year prospective cohort study of 599 lower secondary school students (aged 12 to 16 years) recruited from 11 schools in the east and west side of Norway. Mental health was assessed by the *Strengths and Difficulties Questionnaire*, the *Warwick-Edinburgh Mental Well-Being Scale* and the *Self-Perception Profile for adolescents*. Academic achievement was measured by grade point average from midterm grades and PA was measured objectively using accelerometers over a period of 7 days. Data were collected annually from 2016 to 2018.

Main results: Paper I found small cross-sectional associations between PA and mental wellbeing, as well as with domain-specific self-esteem. There was no association between PA and mental health problems or academic achievement. **Paper II** found no longitudinal relationship between change in volume or intensity of PA and academic achievement, neither through direct nor indirect associations. **Paper III** found a longitudinal relationship between increase in sedentary time and higher levels of mental wellbeing among boys, as well as a small relationship between increase in PA volume and mental wellbeing in girls. No relationships were present for change in sedentary time, volume or intensity of PA and mental health problems.

Conclusion: Overall, the results point towards no clear relationship between either PA or sedentary behaviour and mental health problems. As stronger associations between PA and indicators of mental health is found in clinical samples, these results may suggest that the relationship is less clear among an apparently healthy study sample. With regard to the positive dimensions of mental health,

results showed small associations between PA and domain-specific self-esteem, as well as with mental wellbeing, especially for girls. Based on the positive relationship between sedentary behaviour and mental wellbeing among boys, there is a need to further explore whether this relationship varies with different activities when sedentary. No evidence of a relationship between PA and academic achievement was found, and thus suggest them to be largely unrelated in the current study sample. These results provide some weight to the possibility that PA may relate differently to diverse indicators of mental health, and that the determinants of mental health problems and how well adolescents do at school may lie beyond the amount and intensity of PA.

Keywords: Adolescents, mental health, mental wellbeing, mental health problems, academic achievement, physical activity, sedentary behaviour, accelerometer, waist circumference, sleep duration, cross-sectional, longitudinal, prospective, epidemiology, public health

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Elverum, May 2021

Ingeborg Barth Vedøy

List of papers

This PhD thesis is based on the following three research papers:

Paper I:

Barth Vedøy, I., Anderssen, S. A., Tjomsland, H. E., Skulberg, K. R., & Thurston, M. (2020). Physical activity, mental health and academic achievement: a cross-sectional study of Norwegian adolescents. *Mental Health and Physical Activity, 18*, 100322. doi:10.1016/j.mhpa.2020.100322

Paper II:

Barth Vedøy, I., Skulberg, K. R., Anderssen, S. A., Tjomsland, H. E., & Thurston, M. (2021). Physical activity and academic achievement among Norwegian adolescents: Findings from a longitudinal study. *Prev Med Rep, 21*, 101312-101312. doi:10.1016/j.pmedr.2021.101312

Paper III:

Barth Vedøy, I., Skulberg, K. R., Anderssen, S. A., Fagerland, M. W., Tjomsland, H. E., & Thurston, M. (2021). The longitudinal association between objectively measured physical activity and mental health among Norwegian adolescents. Status: Currently being revised after reviewers' feedback with *Int J Behav Nutr Phys Act*.

Abbreviations

BMI: Body mass index

CI: Confidence interval

CPM: Counts per minute

FAS: Family affluence scale

GPA: Grade-point average

HBSC: Health Behaviour in School-aged Children Study

ICAD: International children's accelerometer database

LPA: Light physical activity

MET: Metabolic equivalent

MHP: Mental health problems

MWB: Mental wellbeing

MPA: Moderate physical activity

MVPA: moderate-to-vigorous physical activity

NSD: Norwegian Centre for research data PA: Physical activity

PAEE: Physical activity energy expenditure

PANCS: Physical activity among Norwegian children study

PISA: Programme for International Student Assessment

SD: Standard deviation

SDQ: Strengths and Difficulties Questionnaire

SED: Sedentary behaviour

SES: Socio-economic status

SPPA-R: Self-perception profile for adolescents

T1: First wave of data collection

T2: Second wave of data collection

T3: Third wave of data collection

VPA: Vigorous physical activity

WC: Waist circumference

WEMWBS: Warwick-Edinburgh Mental Well-Being Scale

WHO: World health Organization

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1. Introduction and background

Public health has been defined as "the science and art of preventing disease, prolonging life and promoting health through the organized efforts of society" (1, p4). In order to promote health and prevent disease and disability in the population the field of public health draws on many disciplines, such as biology, psychology, sociology, education, medicine and public policy (2, 3). The foundation for public health is that the causes of health and illness go beyond individual biology and behaviour (4) and, in particular, draws on evidence that a good start in life has lifelong effects on many aspects of health and wellbeing (5). Thus, there is a need to give particular attention to the formative period of the early years and adolescence. Adolescence is defined as the period spanning from 10-19 years of age (6). In this period of life, the physical, cognitive, emotional, social and economic resources that lay the foundations for later life in terms of health and wellbeing are developed (7, 8). On this basis, there is a profound need to explore factors that might promote good health among adolescents in order to build good health for the future as well as 'prevent' rather than 'repair'. As the major determinants of health lie outside the health care sector, other sectors potentially have an important role in addressing the health and wellbeing of young people (7).

Education serves as a powerful determinant of adolescent health (7). More years of education as well as greater academic success are associated with broad and enduring advantages for later educational success, income and better physical and mental health (5, 9). Those who accumulate more years in education also live longer lives and have less ill health compared with those who have fewer years. This trend is apparent in both high-income and low-income countries (7). The possibility to participate in education and achieve educational success is thus of major importance for young people and serves as an essential factor for public health.

Good mental health is considered critical for a healthy transition to adulthood, and has implications for growth and development, as well as for social and educational outcomes (8). Promoting good mental health throughout the life course and ensuring that mental health is an equal part of public health work is amongst the goals of both global (10) and national (11) policy plans. The Norwegian policy plan further underscores the importance of a healthy lifestyle in terms of a healthy diet, sufficient amounts of physical activity (PA) and sleep, reduction in use of alcohol and drugs and smoke cessation for obtaining good mental health in the population (11).

The belief that PA could promote both physical and mental health is not new and can be found (in different versions) in many ancient cultures. Concepts of health and prevention have been found in writings from India and China since 3000 B.C. In ancient Greece, the father of preventive medicine, Hippocrates, advocated extensively for the benefits of exercise for different complaints, including

mental illnesses (12). However, it was not until *The London Transport Workers Study* by Morris et al. in 1953 (13), that systematic research on PA and health emerged. Since then, the field of study has increased considerably and PA is now widely accepted as beneficial for a diverse number of health outcomes for all age groups (14, 15). In 1994, Morris deemed PA to be the "best buy" for public health (16). In what follows, PA, mental health and academic achievement among adolescents is explored, specifically with regard to the putative relationships between PA and mental health and PA and academic achievement.

1.1 Clarifying the construct of mental health

The purpose of this section is to clarify the concepts of the different indicators of mental health for the thesis to build on.

Mental wellbeing

In the literature, the term "mental wellbeing (MWB)" is widely applied as an overall measure of positive mental health. Although there is a conceptual overlap of the most common indicators of MWB (17), there are still substantial differences between which aspect of MWB they are measuring. To simplify matters throughout this thesis, the terms will be used in accordance with the literature cited and a discussion of semantics will be provided under the methodological discussion.

Self-esteem

One dimension of mental health used in this thesis is self-esteem. This is considered to be a complex field which is filled with definitional and conceptual ambiguity (18). In the current study, the instrument used to measure this concept is the revised version of the Self-perception profile for adolescents (SPPA-R) (19, 20). One of the items captured by this instrument is global self-worth, which is an overall sense of worth as a person and is considered to be analogous to overall self-esteem (20). These concepts will therefore be used synonymously when addressing results from SPPA-R. Once again, the thesis will refer to the term of use in the cited literature and provide a discussion of semantics under the methodological discussion.

Mental health problems

Terminology for symptom-based conditions of mental health varies considerably across studies. For the purpose of the current thesis, "mental health problems (MHP)" will be used to represent preclinical psychological states, whereas "mental disorders" represent clinically diagnosed psychological disorders (e.g. depression and anxiety) (17, 21). Where a mental disorder is a diagnosis according to specified criteria (22), MHP refer to conditions or states that are perceived as stressful, but not to the extent that they are characterised as a diagnosis (23). The term used to describe

preclinical psychological states is often dependent on the terminology of the instrument of use and will therefore vary across studies. Despite differences across instruments, their aim is to assess levels of mental health in a population or identify high risk groups, not to set a diagnosis. To simplify matters in this thesis, the terms will be used in accordance with the literature cited and again a discussion of semantics will be provided under the methodological discussion.

1.2 Physical activity and sedentary behaviour

PA is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (24, p126). Sedentary behaviour (SED) on the other hand, is defined as "any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture" (25, p9). This is not to be confused with physical inactivity, which is defined as a level that is insufficient to meet present physical activity recommendations (25). SED includes use of electronic devices, reading/writing/drawing while sitting, reclining or lying, or sitting at school or during transportation (25). Contrarily, PA is a multidimensional behaviour which can be carried out through basic human movement, occupational activities, sports, conditioning, household, or other activities (24). Total volume of PA is made up of intensity (how strenuous an activity is), duration (how long the activity lasts) and frequency (how often the activity is conducted) (26). Energy expenditure from PA is often expressed in METS, where 1 MET is equivalent to 3.5 ml O_2/kg/min (27). As PA usually is separated into SED, or PA with light, moderate or vigorous intensity, the equivalent energy costs are calculated to be 1.0-1.5 METs, 1.6-2.9 METs, 3.0-5.9 METs or ≥6 METs respectively (28). To quantify energy cost of different physical activities and enhance comparability across studies using subjective measures of PA, a compendium of physical activities with MET values showing energy costs for 821 different activities have been created (28). However, as this is based on studies of adults, it has been argued that these MET values are inappropriate for children and adolescents and might overestimate their PA level (27). Recently youth MET values have been created where the intensity of different activities was calculated by dividing basal metabolic rate on the measured oxygen consumption, creating a youth MET (MET_y) which is used to characterise 196 activities across four age-groups of children and adolescents (29). Although large differences exist, PA roughly accounts for 20-30 % of the total daily energy expenditure of an individual (2).

1.2.1 Assessment of physical activity

Given that a goal of PA research is to better understand its relationship with health outcomes, the validity and reliability of the instruments used to measure PA is of major importance (27). To be able to draw meaningful conclusions about PA, compare PA levels between different cohorts in time and make cross-national comparisons, there is a need to critically review the varying ways in which PA is measured in studies. Accurate measurement of PA is especially challenging in children and

adolescents because of their complex and multidimensional activity patterns (27). Currently, no single method can capture all dimensions of free-living PA (30). A lot of different methods exit with varying benefits and disadvantages. Since no single gold-standard exists, the measurement of use will mainly depend on the characteristics of the study (e.g. type of study, age of participants, size of study sample, budget, etc.) (27). A combination of different methods will often provide the most precise estimate of PA undertaken. However, this may not always be feasible and the increased accuracy of using multiple instruments must be weighed against the extra burden and cost it generates (30).

Broadly, measurements of PA can be categorised as subjective (e.g. questionnaires, interviews, PA diaries and direct observation) or objective/device-based measures (e.g. pedometers, accelerometers, heart rate monitors) (30). Using these instruments, habitual energy expenditure from PA (PAEE) can be estimated with a varying degree of uncertainty (30). A more precise way to estimate PAEE is to assess it by doubly labelled water. This method are sometimes characterised as a criterion measure for PA (31) and other times referred to as "laboratory measures of energy expenditure", and can estimate the amount of energy spent for a person to be physically active (2). The method uses the elimination rate of radioactive isotopes from the body to assess energy expenditure (2). Although the method is shown to be very precise, it is fairly expensive, cannot say anything about PAEE unless the basal metabolic energy expenditure of the individual is known, and is unable to provide other details about the PA that has been conducted than energy expenditure (2, 31). However, as a criterion measure, it serves as a gold standard where other measures of PAEE is being compared (31). In epidemiological research, self-report instruments and different types of movement sensors are the most used instruments for assessing PA (30).

Subjective measure: Self-report

Among the self-reported measures of PA, questionnaires have been used most frequently in large populations. Their advantages are that they are relatively inexpensive and enable assessment of PA from a large number of participants (32). In addition, they can collect information about the type of activity that has been conducted, where, and with whom (33). However, they are limited by the inherent subjectivity when individuals respond to questions about their PA behaviours (31). Their use is especially challenging among young people because of recall bias, question misinterpretation, socially desirability bias and reactivity (27, 31). In addition, they risk over- or underestimation of true PA level because of particular difficulties with estimating intensity levels of PA, especially with regards to MPA and VPA (27, 34). A previous validation study found self-reported PA to be associated with total energy expenditure when compared with doubly labelled water, but not with PAEE (32).

Objective measure: Movement sensors

Objective measures are considered to produce more robust estimates of PA by removing the problems related to recall- and response bias. However, they are often more time-consuming, expensive, intrusive and burdensome than self-report measures (27). Due to technological improvements of the movement sensors in recent years, in particular with regard to the accelerometer, the inconvenience for use have been lessened (35). In addition, reducing their cost has made them increasingly feasible for use in larger populations (35). Accelerometry is found to be a significant predictor of both total energy expenditure and PAEE among adolescents (32). Several reviews thus conclude that the accelerometer provides an accurate, reliable, and practical objective measure of PA among children and adolescents (30, 36).

An accelerometer can quantify one or more dimensions of movement from the body part to which it is attached (30). As the name suggests, the accelerometer measures accelerations (35). Acceleration is a change in velocity with respect to time (m/s^2), and the accelerometer is thus able to quantify the intensity of movement for that body part (30). The accelerometer generates "counts" based on the number of accelerations it is exposed to in a pre-defined time interval (epoch). The frequency of counts within the epoch assesses the time spent in different intensities of PA (37). Among accelerometers, the ActiGraph (LLC, Pensacola, Florida, USA) has the largest body of evidence to support its use (38).

Nonetheless, in order to obtain valid and comparable data using accelerometry, there are important methodological issues to address: criteria for daily wear time to make up a valid day and total number of valid days; placement of the monitor; choice of epoch; and cut-points for SED and different intensity levels of PA (36, 37). Because there are several choices available for each step of data processing, these decisions depend on the research questions of the study (39). When accelerometers are used to measure PA, researchers must determine the amount of wear time needed to provide a reliable estimate of PA and thus be included in further analysis (40). The number of days the accelerometer is worn must be able to provide a reliable estimate of the participant's habitual PA. In addition, the number of hours the accelerometer is worn to produce a valid day must both be long enough to remove days when the monitor was not worn as well as short enough to avoid unnecessary days being removed from further analyses (40). As a reliable measure will rely on a combination of both factors, longer daily wear and fewer days can achieve the same reliability as shorter daily wear and more days (40). Although a minimum of 4 days of measurements has been a widely accepted standard for achieving an adequate reliability coefficient (r =.8), 3 days of wear with ≥7 to ≥10 hours daily has shown a reliability coefficient of .7, which is deemed satisfactory (41). As

the first day of wear is viewed as likely to produce somewhat higher estimates of PA not seen on subsequent days (30, 41), a much used solution is to discard the first day of measurement (30).

The ActiGraph accelerometer is typically worn in an elastic belt on the right hip, or on the non-dominant wrist where the appropriate location is dependent on specific research objectives (42). For children and adolescents, a higher adherence is seen for the wrist-worn versus the hip-worn monitors (37). Nonetheless, waist-worn monitors are still widely applied in research studies of PA (43-46).

Because earlier versions of accelerometers had poorer storage capability, an epoch of 60 sec was usually applied to enable additional days of monitoring (47). Newer versions have considerably more storage capabilities and thus enable a shorter epoch to be used. Children's activity level can be intermittent and made up of short bursts of higher intensity PA lasting less than 15 sec (48). A 60 sec epoch will not capture these bursts. Shorter epoch lengths generate a more detailed picture of PA within each time interval. There is some consensus that shorter epochs (1-15 sec) should be obtained to provide a more accurate representation of the PA level of young people, especially with regard to children (37, 47).

There are multiple cut-points available for categorising PA intensity. Despite several attempts to find universal cut-points for the different age groups, there is still no consensus in the literature regarding use of intensity based cut-points for children and adolescents (37). However, multiple calibration studies have found that a SED cut-point of <100 counts per minute (cpm) showed excellent classification accuracy, this cut-point is now frequently applied (38, 49). Despite more variation in the literature regarding the best cut-point to assess MVPA, a cut-point of around 2200 cpm has shown the best classification accuracy when comparing different cut-points in youth (49). The proportion of time spent in MVPA will depend on the processing criteria of the accelerometer (50). To exemplify this point, more people will meet PA recommendations if the cut-point for MVPA is set lower than if it is set higher. However, by also including the total volume of daily PA (total PA) in the data analyses, a less processed measure of PA is available (50).

1.2.2 Physical activity in adolescence

Physical activity has multiple acute and more long-term benefits for adolescent health. It is well-established that PA contributes to lower levels of overweight and obesity in adolescents, in addition to reducing the risk of obesity in adulthood, improving cardiometabolic biomarkers by increasing HDL-C levels, reducing triglyceride- and glucose levels and lowering blood pressure among adolescents with hypertension, as well as increasing bone health by enhancing bone mass, -structure and strength of the bones (14, 51, 52). Experiences from a variety of PA also support the natural

development, as well as contribute to positive development of motor skills (26, 53). Further, beneficial effects on some mental health outcomes, including cognition, have been shown (14, 18, 51). In addition, PA during adolescence tracks moderately into adulthood (54, 55), and is therefore a factor of importance for maintaining an active lifestyle in a life-course perspective. In a long-term perspective, the lack of sufficient amounts of PA (a.k.a. physical inactivity) is associated with increased risk of non-communicable diseases (e.g. cardiovascular disease, type 2 diabetes and different types of cancer) and premature death (56). Although the onset of most of these diseases is during adult life, their aetiologies often trace back to behaviours during childhood and adolescence (7, 27).

Physical activity recommendations

In order to stay healthy and promote development, the WHO states that all children and youth should be physically active daily as part of play, games, sports, transportation, household chores, recreation, physical education, or planned exercise (26, 57). The current recommended dose for children and adolescents aged 5-17 years is to perform *[…]at least 60 minutes per day of moderate- to vigorous-intensity, mostly aerobic, physical activity, across the week. Vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, should be incorporated at least 3 days a week* (57, p25). Although a substantial number of health benefits occur with 60 minutes of moderate- to vigorous intensity (MVPA) per day, the dose-response relationship is less studied among children and adolescents, further limiting the possibility to address threshold values or identify the exact shape of the dose-response curve (57). The Norwegian recommendations for PA (58, p12) are derived from the international recommendations and currently state that: 1) *Children and adolescents should engage in at least 60 minutes of physical activity every day. The activity should be of moderate- to vigorous intensity. At least three times per week, physical activity of vigorous intensity that increases muscle- and bone strength should be implemented.* 2) *Physical activity in excess of 60 minutes per day provides additional health benefits.* 3) *Reduce sedentary behaviour*. More recently it has become evident that movement behaviours (PA of different intensities, SED and sleep) cluster and interact in a way that "their combined effects extend beyond the individual contribution of each behaviour" (59, piii). As MVPA only makes up <5 % of the 24-hour day, sleep (~40 %), SED (~40 %) and LPA (~15 %) accounts for the remaining parts of the 24 hours (60). Consequently, it is suggested that their relationship should be viewed as co-dependent (59). Canada has thus developed the first 24-hour movement guidelines for children and youth which integrate recommended levels of PA, SED, and sleep (59). This way of viewing movement behaviours as co-dependent has also been adopted by Australia, who developed national 24-hour movement guidelines for children and young people in 2019 (61).

Physical activity level in children and adolescents

Globally, data from 2016 showed that about 81 % (77.6 % boys and 84.7 % girls) of (1.6 million) school-going adolescents (11-17 years) did not meet the current PA recommendations (62). This assessment was solely based on self-reported questionnaire data. Although not based on global data, an international assessment of PA measured by accelerometry (The International Children's Accelerometry Database [ICAD]), found that only 9 % of boys and 1.9 % of girls (5-17 years) met the PA recommendations (63). However, both estimates are based on strict criteria requiring participants to accumulate ≥ 60 min of MVPA every day to meet PA recommendations. In addition, both estimates are subject to multiple methodological challenges (62, 63). Still, they provide useful estimates of the proportion of children and adolescents meeting PA recommendations using strict criteria for adherence. If meeting PA recommendations instead are based on achieving an average of ≥ 60 min/day, the proportion of participants meeting PA recommendations increases (63). In a recent study using ICAD data to present variations in accelerometer measured activity level of (47.497) European children and adolescents, meeting PA recommendations was defined as achieving an average of at least 60 min of MVPA per day (64). Here, authors found that 29 % of children (age 2-9.9 years) and 29 % of adolescents (age 10-18 years) met the PA recommendations. In comparison, Norwegian data from a nationally representative study population found that 44 % of 15-year old girls and 55 % of 15-year old boys met the PA recommendations accumulated as an average of at least 60 min/day (65).

Trends in physical activity

To be able to monitor PA levels among youth over time, it is important to explore secular- and longitudinal changes. In a Norwegian context, surveillance of PA among population-based samples of children and adolescents have been conducted regularly for three waves (Physical activity among Norwegian children study [PANCS] 1-3) and thus allow exploration of secular trends from 2005 to 2018 (43, 65, 66) (see table 1). The data from these studies show no significant change in PA volume, except for 9-year old boys, where a reduction in total volume of PA was found in 2018 compared with 2005 and 2011 (65). The same pattern was also evident in adherence to national recommendations for PA, where the proportion of 9-year old boys achieving an average of ≥ 60 min MVPA/day decreased by 6 % from 2005 to 2018 (65). Findings from the three waves of PANCS also indicated a similar pattern of reduction in PA levels among 6- and 9- year old girls, however, these changes were not statistically significant (65). Further, there has also been a shift in accumulated time in SED and light PA (LPA) where both 9- and 15-year olds spent more time sedentary and less time in LPA in 2011 than in 2005 (43). Between 2011 and 2018 an additional increase in SED at the expense of LPA was evident among boys. This was, however only significant among 9-year olds (67).

Table 1. Physical activity level among young people in Norway presented as adherence to national recommendations (%) and total volume (mean (95% CI)).

Year/Study	Adherence to national PA recommendations[a]		Total PA (cpm)	
	Girls	Boys	Girls	Boys
2005/PANCS 1*				
9-year olds	74.0	89.7	597 (567, 627)	698 (671, 726)
15-year olds	48.5	52.5	428 (404, 452)	479 (448, 511)
2011/PANCS 2*				
9-year olds	69.4	86.8	582 (563, 602)	694 (671, 717)
15-year olds	40.8	55.0	410 (393, 428)	492 (469, 516)
2018/PANCS 3*				
9-year olds	68.1	83.6	584 (564, 603)	636 (611, 662)
15-year olds	44.1	55.3	422 (402, 442)	493 (465, 522)

Note: Total PA (cpm) = measure of average daily PA volume, cpm = counts per minute
[a] ≥60 min/day of MVPA, defined as a daily average of ≥60 min MVPA per day.
* Source: Steene-Johannessen et. al (65)

International secular trends from the Health Behaviour in School-aged Children Study [HBSC] show a somewhat similar pattern when comparing self-reported PA data on 11, 13 and 15-year olds from two waves of data collection (2014 and 2018). This study found that MVPA declined in about 33% of the included countries between 2014 and 2018, particularly among boys, and that there were little evidence of an increase in PA within the different countries (8).

An exploration of PA levels across age groups of the Norwegian PANCS studies shows that boys of all age groups are more active than girls and that PA levels decline from 9- to 15 years (43, 66, 67). This is consistent with international trends from large scale surveys (ICAD and HBSC), which show that PA level declines throughout childhood and adolescence and that boys are consistently more active than girls (8, 63, 64). However, there is a relatively large time span between data collection points included in the ICAD-studies (1999-2016) which may make them susceptible to being influenced by secular trends with decreased PA levels over time (63, 64). To be able to describe patterns of PA more accurately throughout childhood and adolescence, longitudinal data is required, preferably with annual data collection points.

In recent years, data from several longitudinal studies exploring patterns of PA during childhood and adolescence have emerged from varying countries (43, 44, 46, 68). This has also given rise to an increase in review studies that have synthesized the results of longitudinal studies (69-71). Both individual studies as well as systematic reviews support those from cross-sectional studies showing a decrease in PA level from childhood to adolescence as well as throughout adolescence. In addition, they find that boys tend to be more active than girls throughout childhood and adolescence. Results from the longitudinal analyses of the Norwegian PANCS studies showed the reduction in PA to be

evident among both sexes in measures of total PA, time spent in LPA and MVPA, in addition to the odds of meeting PA recommendations (43). Further, an increase in SED was found in the same period. The PANCS studies nevertheless only provide longitudinal data at two points in time with a six-year interval (from 9 to 15 years of age), thus including a large timespan between measurements. Although their findings suggest a clear reduction in PA, it remains unknown whether this decrease is linear or not, thus emphasising the need for further exploration of this trend by more frequent measurements. Despite these issues, the pattern found in the PANCS studies is in agreement with results from Corder et al. (44) which showed that the decrease in PA was replaced with SED during early adolescence in British youth. Another longitudinal study from England found the decline in PA levels to start from age 7, and to be similar among boys and girls (68). In contrast, Corder et al. (44) and Dumith et al. (71) found that sex differences in MVPA decreased over time because of a greater decline in PA among girls in younger ages (9-12 years) and among boys in later adolescence (13-16 years). Evidence from a recent review suggests this sex difference to be further reduced over the transition to young adulthood (69).

1.3 Mental health

In the WHO's definition of health, mental health is included as an integral part of overall health (72). According to this definition, good health can only be achieved with good mental health (72). However, mental health itself is a complex concept and not all dimensions have been well defined (22). Nevertheless, the WHO has constructed an overall definition which is commonly referred to in research. It defines mental health as "[…] *a state of well-being in which an individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and make a contribution to the community"* (72, Key facts). Gustafsson et al. (22, p13) emphasize that among children and adolescents mental health also includes "[…] a *sense of identity and self-worth; sound social relationships; the ability to be productive and learn; and the ability to use developmental challenges and cultural resources to maximize growth"*. Both definitions underline the more positive conceptualizations of mental health and reveal the multidimensional nature of mental health as a construct, which makes its operationalization and measurement in research a complex matter.

Mental health has traditionally been considered as the presence or absence of mental illness. More recent thinking, however, acknowledges mental health as a multidimensional concept including both negative illness dimensions (e.g. depression and anxiety) as well as positive dimensions or what may be called affirmative mental health (e.g. MWB and self-esteem) (72, 73). Keys (74) introduced the concepts "flourishing" (which includes positive feelings and positive functions in life) and "languishing" (which includes feelings of emptiness and stagnation) to differentiate the positive dimensions of mental health from mental health problems (MHP) and (diagnosed) mental illness.

There is currently broad agreement that the absence of MHP or mental illness does not necessarily imply the presence of high levels of affirmative mental health and vice versa (75, 76). The *two continua model* proposes that mental illness and affirmative mental health are related, but distinct dimensions which follow different trajectories allowing a person to, for example, experience high levels of MWB (in other words, they are flourishing) despite being diagnosed and living with depression (75). In order to ensure a multidimensional measure of mental health in an adolescent population, both dimensions should be assessed (76). Additionally, when exploring the relation between mental health and PA, different dimensions of mental health may associate differently with PA.

Mental Wellbeing

There is general agreement that wellbeing is a multidimensional construct that extends beyond simply feeling happy or being satisfied with life (77). MWB has major consequences for health and social outcomes (78) and incorporates different aspects of wellbeing relating to emotional, psychological and social dimensions (22, 79). Emotional wellbeing is sometimes referred to as *hedonic wellbeing*, and includes feelings of happiness, satisfaction with and interest in life. Psychological wellbeing is sometimes referred to as *eudaimonic wellbeing*, and includes positive individual functioning and self-realization (75). Whereas emotional and psychological wellbeing mainly focus on individual fulfilment, social wellbeing is made up of positive societal functioning in terms of functioning optimally in society and being of social value especially in relation to relationships (75). These three dimensions of wellbeing are indicative of an individual's overall MWB as it includes positive feelings and functioning, as well as the social aspect of wellbeing (74, 76). Indicators of such a wellbeing model include measures of self-esteem, a sense of belonging, engagement, self-determination and control and quality of life (22, 79).

Self-esteem

Self-esteem is generally viewed as the evaluative aspect of self-knowledge that reflects the extent to which people like themselves and believe that they are competent (80). Self-esteem reflects one's perception and cannot be viewed as accurate or inaccurate. Consequently, a person with high self-esteem will have a highly favourable view of the self, whereas a person with low self-esteem will have a more uncertain or negative evaluation of the self (80). There is an emerging consensus that these self-evaluations are domain-specific (people may evaluate the self differently in different domains of life), giving rise to a shift towards measuring domain-specific self-esteem alongside global self-esteem (19). Because these two categories of self-evaluation can coexist, domain-specific self-esteem represents self-evaluations of competence or adequacy in different arenas, and global self-

esteem represents the overall sense of worth as a person and is not made up by the sum of the domain-specific scores (20).

Mental health problems

MHP refer to conditions or states that are perceived as stressful, but not to the extent that they are characterised as a diagnosis (23). They can broadly be divided into internalizing and externalizing problems. Internalizing problems refer to emotional problems (e.g. depression and anxiety) and the negative emotions are directed at oneself (22). Conversely, externalizing problems refer to behavioural problems (e.g. conduct disorders, aggressiveness and anti-social behaviour, or attention deficit and hyperactivity) and the negative emotions are directed at others (22). In the 21st century, a number of social changes have occurred that might bear a negative influence on mental health of children and adolescents; e.g. increasing social inequalities, changes in family environment, parental MHP including mental illness, increasing exposure to screen time, internet and social media and increasing pressure within the school setting (81). There are many detrimental consequences of adolescent MHP for their health and education (82). For example, MHP can have a negative effect on academic achievement (22) and impair further educational attainment (83). MHP are also associated with financial problems and troubles within close relationships later on (23). In addition, MHP and mental disorders are seen to increase the risk of physical health problems and diseases and premature mortality (11, 23). Further, MHP during childhood and adolescence may also increase the likelihood of more severe mental disorders later in life (23, 82).

1.3.1 Assessment of mental health

Mental wellbeing

Measuring MWB among children and adolescents may be challenging as the instruments rely on the participant's own perception of constructs (such as life satisfaction and happiness), which they may not yet be fully capable of conceptualizing (76). Nonetheless, measuring young people's wellbeing has become increasingly important given its relevance to understanding human development. In a systematic review, Rose et al. (76) emphasised that the increased focus on MWB among adolescents necessitates the use of validated scales that can assess improvements in wellbeing without ceiling effects. To date, there are multiple instruments for assessing MWB among adolescents (e.g. *WHO-5 well-being index [WHO-5]*, *Affectometer 2, PGI Well-being scale [PGI]*, *EPOCH measure of adolescent well-being [EPOCH], Mental-health continuum-short form [MHC-SF]* and *Warwick-Edinburgh Mental Well-Being Scale [WEMWBS]*). Some of these have specifically been developed for adolescents, while others have been adjusted to fit the age group (76).

WEMWBS is an instrument that is increasingly used to assess MWB. Originally it was developed for adults (78), but a psychometric study of the instrument has shown the scale to have strong internal consistency (Cronbach's alpha of .87 [95% CI .85, .88]) when applied to adolescents from 13 years of age and older (84). Further, the instrument has been shown to be moderately correlated with other instruments that assess MWB (WHO-5, MHC-SF and psychological wellbeing domain in Kidscreen), and moderately negatively correlated with Strengths and Difficulties Questionnaire [SDQ]) (84). The instrument assesses both the emotional (e.g. happiness) and psychological (e.g. positive functioning) dimensions of an individual's wellbeing by its responses to 14 positively worded items (78). Previous research has shown that the interpretation can be different for positively vs. negatively worded items and that there is some indication that participants might prefer positively worded items (76). Tennant et al. (78) concluded that a validation study among a British adult population showed the scale had no ceiling effects. However, a Norwegian validation study (85) found evidence for a small ceiling effect among adolescents. This points towards the instrument not being sufficiently discriminating between adolescents with high levels of MWB. As MWB can vary by culture, instruments developed in one country may need to be assessed for relevance for use among the same age group outside that country (77, 86). Validation studies among Norwegian adolescents, however, indicated that the instrument was suitable for that population (85).

The *revised version of Self-Perception Profile for Adolescents (SPPA-R)* measures self-evaluation in different domains and serves as measures of self-esteem (19, 20). The instrument was initially developed for children, but has undergone changes to fit an adolescent population (20) and has been widely used in a large body of research (19). 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 (19, 20). The instrument comprise 35 statements evenly distributed between seven domain-specific subscales (scholastic competence, social acceptance/social competence, athletic competence, physical appearance, romantic appeal, close friends and global self-worth). The validity of the original version was problematic, hence the revision of the scale. SPPA-R shows substantially better reliability, better convergent and factorial validity than the original version (19). While global self-worth measures self-esteem directly and is an evaluation of how much one likes oneself as a person, the domain specific items consist of self-judgements of ability in specific arenas of one's life (20). In the specific domains explored in the current thesis, athletic competence measures one's perceived ability to do well in sports. Social competence refers to having the skills to get others to like oneself and understanding what it takes to become popular.

Mental health problems

It is important to have valid and reliable instruments that can assess a broad range of MHP across a variety of settings (87). Consequently, several instruments designed for assessing self-reported MHP among young people exists (e.g. *SDQ, Youth Outcome Questionnaire [YOQ], Beck Youth Inventories [BYI], Mood and Feelings Questionnaire (MFQ), and Center for Epidemiological Studies Depression Scale for Children [CES-DC]*). Which to use is largely dependent of the purpose of the measure (i.e discriminative, predictive or evaluative), characteristics of the instrument (e.g. intended population, measure length) and quality of the psychometric properties of the instrument (87).

The SDQ is a brief behavioural questionnaire constructed for 4-17 year olds which has been widely applied in large epidemiological studies (88, 89). It offers a balanced coverage of behaviours, emotions and relationships (90). The questionnaire exists in different versions for completion by teachers or parents, and a similar version for self-report, intended for older children and adolescents (90). It consist of 25 questions separated into 5 different scales (emotional symptoms, conduct problems, hyperactivity, peer problems and prosocial behaviour) where the first four generates a "total difficulties score" (ranging from 0-40 where higher scores are associated with increasing difficulties) and the prosocial scale generates a positive score (88). Goodman and Goodman (88) found that the odds of disorders increase at a constant rate across the range of total difficulties-scores with no evidence of threshold effects (for low scores). Although the instrument is deemed suitable for comparing average scores over time or between groups (88), a review of child self-reported measures of mental health and wellbeing points out that the use of a three-point Likert scale may limit variability in the derived data. This may further lead to insensitivity to change and/or floor or ceiling effects when it is used as a measure of change (91). Nevertheless, the SDQ is a much-used measure of MHP among young people, and has demonstrated satisfactory reliability and validity among both children and adolescents (92). An established Norwegian translation is available.

1.3.2 Mental health in adolescence

Adolescence is a period of life characterised by rapid emotional, physical and social changes. These changes can be perceived as stressful, and thus experiencing some sort of MHP during adolescence is common (7, 82). In most cases the distress is temporary, particularly if the experienced briefly, but for some adolescents they persist into adulthood (7, 11). There exit few global estimates of the prevalence of MHP. However, the WHO (93) estimates that about 20 % of the world's children and adolescents have a mental health disorder. In 2019, mental disorders represented the 4th leading global cause of disability-adjusted life-years among youth (10-24 years), and thus serves as a large contributor to adolescent's overall health burden (94). In Norway, it is estimated that, at any time, eight % of children and adolescents suffer from a mental disorder, while 15-20 % have reduced

functions due to MHP (95). To date, less is known about positive dimensions of mental health among children and adolescents. Nonetheless, when exploring international levels of life-satisfaction (which may serve as an indicator of MWB), most adolescents report this to be high, where an average score of 7.8 out of 10 was reported. It is important to note, however, that girls consistently reported lower levels than boys and older adolescent reported lower levels than younger adolescents (8). This is in line with data on life satisfaction from Norway which shows an average score of 7.9 out of 10 (96).

Trends in mental health

To date, there also remains a dearth of knowledge regarding trends of positive dimensions of mental health, especially among children and adolescents. Still, secular trends in life satisfaction among children and adolescents (aged 11, 13, 15 years) have been explored in the HBSC study. Data (from the HBSC-study) show levels of life satisfaction having remained stable for the study population between 2002 and 2018. However, girls and older adolescents reported lower levels of life satisfaction (96). Data from Norway from the same surveys showed an increase in life satisfaction during the same period (96) (see table 2).

Exploring international trends of MHP, studies find small (96) to substantial (82) increases in levels of MHP across countries, especially with regard to internalizing problems (81). The sex-specific pattern of MHP indicates a considerably larger deterioration in MHP over time among adolescent girls than boys (81, 96). However, as there were considerable country differences evident, caution is required regarding cross-national generalization of national trends (82, 96). In a Norwegian context, results differ somewhat across studies. The majority of studies show evidence of an increase in MHP during the different waves of study (97-99) (see table 2). They nevertheless find different onsets and trajectories of such increase. Further, 2/4 studies show that the increasing trend in MHP is larger among older adolescent girls relative to younger adolescents and boys (97, 98).

In parallel to the exploration of secular trends in MHP, there has been an ongoing debate whether the increase in MHP is real or not. Alternative hypotheses have proposed that it may be a consequence of a greater awareness of MHP and a corresponding rise in social acceptance of such problems. In the same vein, this might mean that there is more frequent reporting and help-seeking, improved screening, more medicalization of feelings and behaviours previously considered as normal as well as a broadening of diagnosis of mental disorders (82, 99). However, compelling evidence suggests that despite the changes in how symptoms are perceived and reported, the underlying rates of MHP have also changed, especially in high-income countries (81, 82).

Table 2. Secular trends in mental health among young people in Norway presented as life satisfaction and measures of mental health problems.

Author, year/study	Year of data collection	Participants/N	Results	Conclusion
Cosma et. al, 2020 (96) / HBSC*	2002-2018	11-, 13- and 15-year olds / 915.054 (international study sample)	1. **Life satisfaction:** Significant change from 2002-2018 (boys and girls) 2. **Psychosomatic complaints:** No change between 2002-2018 (boys and girls)	1. Significant positive change in life satisfaction. 2. No change for psychosomatic complaints.
Potrebny et. al, 2019 (97) / HBSC	1994, 1998, 2002, 2006, 2010, 2014	11-16-year olds / 27.476	**Psychological health complaints:** 1. Increase between 1994-2010, decrease between 2010-2014 (boys and girls) 2. Three-way interaction between sex, age, time suggest larger increase in older adolescent girls	1. Significant increase in psychological health complaints between 1994-2014. 2. Larger increase for older adolescent girls.
Sletten and Bakken, 2016 (98) / Ung i Oslo [Youth in Oslo]	1996, 2006, 2015	14-17-year olds / 28.892	**Depressive symptoms:** 1. Boys: No change between 1996-2006, small significant increase between 2006-2015. Increasing variance in depressive symptoms over time indicative of increased polarisation. 2. Girls: Significant increase between 1996-2006, more pronounced increase between 2006-2015.	1. A small significant increase in depressive symptoms among boys between 2006-2015. Further, an increased polarisation where percentage of high and low symptom loads increases. 2. An approximate doubled prevalence of depressive symptoms among girls from 1996-2015
von Soest and Wichstrøm, 2014 (99) / Ung i Norge [Youth in Norway]	1992, 2002, 2010	16-17-year olds/ 9.000	**Depressive symptoms:** 1. Increase between 1992-2002, no change between 2002-2010 (boys and girls). 2. Increasing variance in depressive symptoms over time indicative of increased polarisation.	1. Significant increase in depressive symptoms between 1992-2002. 2. Increased polarisation where percentage of high and low symptom loads increases.

* A cross-national study. Norwegian data extracted from analyses.

1.4 Academic achievement

As education increases knowledge, cognitive, social and emotional skills of individuals (100), it is considered to be a powerful determinant of adolescent health and human capital as well as a driver of socio-economic processes (7). From a policy perspective, it is considered to be a cost-effective measure to improve health and reduce crime (100). The academic achievement attained during education "*represents performance outcomes that indicate the extent to which a person has accomplished specific goals that were the focus of activities in instructional environments […]"* (101, Introduction, first paragraph).

1.4.1 Assessment of academic achievement

Academic achievement is a very wide-ranging domain and covers a broad diversity of educational outcomes. Hence, the definition of it depends on the indicators used to measure it (101). According to Steinmayr et al. (101) these indicators can broadly be divided into *general indicators* such as procedural and declarative knowledge acquired in an educational system, *curricular-based criteria* such as grades or performance on an educational achievement test, and *cumulative indicators of academic achievement* such as educational degrees and certificates. Their common denominator is that they represent intellectual effort and are able to address the intellectual capacity of a person (101). For adolescents still under compulsory education, standardized tests or grades represent the most used ways of assessing academic achievement (102).

Grades/GPA

The grades from compulsory education are normally presented as a grade in a specific subject, composite scores of grades in certain subjects, or grade point average (GPA) (103). GPA represents the average score achieved in all subjects and measures a broad range of competence (104). Assessment of academic achievement through grades is based on criteria set by The Norwegian Directorate for Education and Training (i.e. the curriculum), which evaluate the knowledge and skills pupils develop throughout compulsory education (105). However, the use of grades is criticised for being a subjective assessment which is not standardized across teachers (106). Although student grades cannot be considered sufficiently objective to enable international comparison, they represent a legal criterion to assess this in a national context (102). A grade is also an indicator that may influence a student's future as it forms the basis for further educational opportunities and work/employment possibilities (102).

National standardised tests

Assessment of academic achievement through national standardised tests is normally presented as results from the different tests, or as composite scores of such (103). In Norway standardised national tests are administered by The Norwegian Directorate for Education and Training and

conducted annually for grade 5, 8 and 9 pupils (equals approximate ages of 10-, 13- and 14 years) (107). They assess competence in reading, numeracy and English and serve as a mid-term assessment for the schools as well as measure for quality development at all levels in the school system (107). Although standardized test scores provide an unbiased measure of academic achievement (104), they will merely assess a narrow range of what is taught in class as well as the skills and competence of the pupil (107) and might end up reflecting intellectual capacity rather than academic achievement (104).

1.4.2 Academic achievement in adolescence

To be able to assess and compare academic achievement across countries, the Programme for International Student Assessment (PISA) survey was developed in 2000. Since then, it has been conducted every 3rd year for 15-year olds with ever increasing countries participating (108). The survey measures the students' competence in reading, mathematics and science and is currently viewed as the best marker for international comparison of academic achievement. International results on adolescents' performance in mathematics, science and reading from the PISA 2018 survey show large differences between the 79 participating countries. However, when exploring trends in performance over time it becomes evident that, on average, the mean performance in all three areas have remained stable between 2015 and 2018 (109). The Norwegian PISA results have varied in all three areas from 2000 until 2018, but the changes have not pointed towards any clear directions. Compared to the OECD average from 2018, the Norwegian students achieved on average in science, and above average for both reading and mathematics. The conclusion therefore remains the same as for the international results: the performance is stable over time (108).

National trends in academic achievement can also be assessed through exploration of trends in Norwegian GPA at the end of compulsory education (10th grade). During the last five years, a small increase in GPA has been evident (110). Sex specific data reveals that the improving trend has been somewhat higher for girls than for boys resulting in increased differences between the sexes during the last 10 years (110) (see table 3).

Additionally, Norwegian trends in academic achievement can be explored through standardised national tests. The average scores from the Norwegian standardised national tests have not changed substantially from 2014 to 2019 and shows that there are more boys achieving the highest mastery levels in numeracy, whereas the same is true for girls in reading. In English, boys and girls perform more evenly (111) (see table 3).

Table 3. Academic achievement among adolescents presented as mean GPA and mean results on national tests among boys and girls.

Year	GPA[1]		National tests[2] English		National tests[2] Reading		National tests[2] Numeracy	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
2010/2011	4.20	3.79						
2011/2012	4.20	3.80						
2012/2013	4.21	3.81						
2013/2014	4.25	3.85						
2014/2015	4.30	3.86						
2015/2016	4.34	3.90	50	50	51	49	50	51
2016/2017	4.37	3.92	50	50	51	49	49	51
2017/2018	4.41	3.96	50	50	51	49	49	51
2018/2019	4.43	3.97	50	51	51	49	49	51
2019/2020	4.54	4.10	50	51	51	49	48	51

Note: GPA = grade point average

[1]GPA is calculated by summing all school grades from end of compulsory education (10th) grade and divided by the number of school subject.

[2]National test scores from grade 8. results. (Results are presented on a scale where 50 points represent the mean (SD = 10)). Test scores are only available from year 2015/2016.

Source: https://www.udir.no/tall-og-forskning/statistikk/statistikk-grunnskole/

1.5 Physical activity and mental health in adolescence

Previous research has shown PA to be associated with mental health outcomes among children and adolescents (17, 18, 21, 51, 73, 79). Due to the rapidly expanding body of evidence within this field in the past few years, several reviews and umbrella reviews have been published on the topic (17, 18, 21, 51, 73). More specifically, two recent umbrella systematic reviews conclude that PA can be effective for reducing depression or depressive symptoms and improving self-perceptions among adolescents (18, 73)**.** There has been less research attention paid to the relationship between PA and anxiety, but the current evidence suggests an association (18). The assessment of PA and MWB is less explored, but has been addressed in reviews by Whitelaw et al. (79) and Rodriguez-Ayllon et al. (21). They concluded that PA has the potential to improve MWB in adolescents. The reason for this cautiousness is because they conclude that the association may be contingent on the context within which PA is carried out (21) as well as reliant of other beneficial mechanisms changing at the same time (79). However, in another review by Poitras et al. (51), the relationship between (objectively measured) PA and indicators of MWB (measured as quality of life and self-rated health) were less clear due to the majority of studies showing that an increase in PA did not improve MWB indicators. Moreover, causality is only partially supported for PA and depression and currently not supported for the other mental health outcomes (18). Nonetheless, it is important to underline the difficulty of synthesizing results from studies from different countries, on different age groups using different outcome measures of mental health as well as different ways of measuring PA.

To add to the complexity of this relationship, the strength of the relationship between PA and indicators of mental health are found to be weak to moderate across studies (18, 21). In addition, the reviews cited above, as well as many of their individual studies, were rated as low quality (73), limitations that are important when evaluating relationships especially with regard to their possible causal role. Methodological weaknesses in study design and measurement of PA have been put forwards as the major limitations of the current knowledge base (18, 21, 73). In addition, PA's relationship with some mental health outcomes remains less studied than others, primarily with regards to anxiety and positive dimensions of mental health (21). To address some of these methodological challenges, recent studies have used objective measures to obtain more precise PA estimates (see table 4 for selected studies using objective measures to assess PA). Results from studies using an objective measure of PA tend to show no association with various mental health outcomes more frequently compared to those based on self-report. Thus, there is a need to more fully explore this relationship using an objective measurement of PA.

Little is known about the putative interacting mechanisms behind the effects of PA on mental health outcomes, but different explanatory theories exist. The conceptual model of Lubans et al. (17) proposed neurobiological, psychosocial and/or behavioural mechanisms, which may work in parallel or via interactions with each other or other mechanisms. The neurobiological hypothesis holds that PA may enhance mental health through changes made to the structural and functional composition of the brain and propose several different mechanisms for such change (17). A well-known explanatory theory for neurobiological mechanisms proposes that PA stimulates the release of hormones (e.g. endorphins) which induce positive changes to the mood and further may promote MWB and protect against MHP (21, 112). On the other hand, the psychological hypothesis views the link between PA and mental health to come from PA's potential ability to satisfy basic psychological needs through social interaction with others, which also may create a sense of belonging, achieving mastery through accomplishing different PA tasks, enhancing self-perception of appearance and providing opportunities for autonomy (17, 79). In addition, the link may be explained psychologically by the 'distraction' hypothesis which holds that PA may serve as a distraction from more stressful parts of life and thus influence levels of mental health (79). Lastly, the behavioural hypothesis suggests that the association between PA and mental health is mediated by changes in other behaviours relevant to mental health (e.g. sleep-related factors, diet, recreational screen-time, etc.) (17). Overall, the research was insufficient to form conclusions on the proposed mechanisms (17).

Table 4. Overview of selected cross-sectional and longitudinal studies exploring the relationship between objectively measured physical activity and variables of mental health among children and adolescents.

Author, year	Country	Methodology	Age of participants*	Measure of PA	Measure of MH	Result
Bell et. al, 2019 (113)	England	Longitudinal	12-13 years	Total PA, MVPA	Mental wellbeing (WEMWBS) and symptoms of mental disorders (SDQ)	**No association**
Hume et. al, 2011 (114)	Australia	Cross-sectional and longitudinal	14.4 years	MVPA, VPA, (+SED)	Depressive symptoms (CES-DC)	**No association**
Johnson et. al, 2008 (115)	USA	Cross-sectional	12 years (only girls)	Total PA, LPA, MVPA, VPA, (+SED)	Depressive symptoms (CES-D)	**No association:** Total PA, LPA, MVPA, VPA and depressive symptoms **Positive association:** modest inverse association between SED and depressive symptoms
Opdal et. al, 2019 (116)	Norway	Longitudinal	16.23 years	MVPA, Number of steps	Mental distress (HSCL-10)	**No association**
Sánchez-Oliva et. al, 2020 (117)	Spain	Cross-sectional and longitudinal	8-18 years	Total-PA, MVPA, (+SED)	HRQoL (KIDSCREEN-10), positive affect, and negative affect (PANASN).	**Positive association**
Toseeb et. al, 2014 (118)	England	Longitudinal	14.5 years	Total PAEE, MVPA	Depressive symptoms (MFQ)	**No association**
Van Dijk et. al, 2016 (119)	Netherlands	Longitudinal	13.6 years	Total PA	Depressive symptoms (CES-D) Self-esteem (RSE)	**No association**
Wiles et. al, 2012 (120)	England	Cross-sectional	13.8 years	Total PA MVPA	Depressive symptoms (MFQ)	**Positive association:** Inverse association between total PA and depressive symptoms **No association:** MVPA and depressive symptoms

Note: MH = Mental health, SED = Sedentary behaviour, LPA = Light intensity physical activity, MPA = Moderate intensity physical activity, VPA = Vigorous intensity physical activity, MVPA = Moderate-vigorous intensity physical activity, WEMWBS = Warwick Edinburgh Mental Wellbeing Scale, SDQ = Strengths and Difficulties Questionnaire, CES-D/DC = Center for Epidemiological Studies Depression Scale / for Children, HSCL-10 = Hopkins Symptom Checklist-10, HRQoL = Health-related quality of life, PANASN = Positive and Negative Affect Schedule, PAEE = physical activity energy expenditure, MFQ = Mood and Feelings Questionnaire, RSE = Rosenberg Self-Esteem Scale.

* For longitudinal studies; age of participants at first data collection.

1.6 Physical activity and academic achievement in adolescence

There has long been an assumption that regular PA could contribute to academic achievement via enhancement of brain function and cognition (17). More specifically, research has shown that the pathways in which PA and cardiorespiratory fitness may influence brain structure and function include alterations in thickness of grey matter (121) and integrity of white matter (122), alterations in brain plasticity (123), as well as improvements in attention, working memory and executive functioning (124). Further, it is hypothesised that the benefits of these PA/fitness-related changes may enhance academic achievement through improvements in learning and memory (103, 121, 124, 125).

The volume of studies exploring the relationship between PA and measures of cognition and academic achievement has increased substantially in recent years, alongside an increase in systematic reviews (51, 103, 106, 126). Although a recent systematic review found strong evidence for beneficial effects of additional PA or adaptation of the PA curriculum on mathematics performance (126), the relationship between PA and overall academic achievement was not clear across reviews (51, 103, 126). This ambiguity is also found in observational research studies using objectively measured PA, where findings ranged from a direct or indirect positive association (104, 127-130), no association (131-135) to a negative association (102, 136) among children and adolescents (6-18 years) (see table 5). The lack of consensus across previous research relates to methodological issues concerning assessment of PA (e.g. self-reported vs. objectively measured PA) and academic achievement (e.g. the use of school grades vs. standardised tests) (103, 106, 126). Further, a large proportion of the published studies make use of a cross-sectional study design thus limiting the conclusions to be drawn thereafter (103). Donnelly et. al (106) underscore that despite the large increase in publications within this field of research in recent years, relative to other fields, it is still considered to be in its infancy, thus accounting for some of the differences in methodology used. Consequently, systematic reviews emphasize that the relationship between PA and overall academic achievement is not yet conclusive and that results should be interpreted cautiously, further warranting more ‘high-quality’ research (103, 126).

Table 5. Overview of selected cross-sectional and longitudinal studies exploring the relationship between objectively measured physical activity and academic achievement among children and adolescents.

Author, year	Country	Methodology	Age of participants*	Measure of PA	Measure of AA	Mediation	Result
Booth et. al, 2014 (127)	UK	Cross-sectional & Longitudinal	11, 13, 16	MVPA	National tests		**Positive association:** longitudinal associations for MVPA-English (all); MVPA-Maths (all); MVPA-Sciences (girls only)
Bueno et. al, 2021 (135)	Brazil	Cross-sectional	11.3	MVPA (+SED)	School grades		**No association**
Corder et. al, 2015 (133)	UK	Longitudinal	14.5	MVPA (+SED)	National tests (GCSE)		**No association**
Esteban-Cornejo et. al, 2014 (136)	Spain	Cross-sectional	6-18	MPA, VPA, MVPA	School grades		**Negative association**
Estrada-Tenorio et. al, 2020 (102)	Spain	Cross-sectional	13-15	MVPA	School grades		**Negative association**
Kwak et. al, 2009 (128)	Sweden	Cross-sectional	16	LPA, MPA, VPA	School grades	Fitness	**Positive association:** VPA-AA (girls only)
Lima et. al, 2019 (130)	Denmark	Longitudinal	7-12	MVPA, VPA (+SED)	National tests	WC	**Positive association:** indirect association between MVPA-AA and VPA-AA mediated by WC
Maher et. al, 2016 (129)	Australia	Cross-sectional	9-11	MVPA (+SED)	National tests		**Positive association:** MVPA-AA in 2 domains (writing and numeracy); SED-AA in 5 domains
Oliveira et. al, 2017 (134)	Portugal	Cross-sectional	10-18	MVPA	School grades		**No association**
Owen et. al, 2018 (104)	Australia	Cross-sectional & Longitudinal	13.4	MVPA	National tests		**Positive association:** longitudinal association for MVPA-AA (girls only); cross-sectional association for MVPA-AA (boys only)
Syväoja et. al, 2013 (131)	Finland	Cross-sectional	12.2	MVPA (+SED)	School grades		**No association**
van Dijk et. al, 2014 (132)	Netherlands	Cross-sectional	12-14	Total PA, MVPA	School grades		**No association** (in overall results)

Note: AA = Academic achievement, SED = Sedentary behaviour, LPA = Light intensity physical activity, MPA = Moderate intensity physical activity, VPA = Vigorous intensity physical activity, MVPA = Moderate-vigorous intensity physical activity.

* For longitudinal studies; age of participants at first data collection.

1.7 Additional factors related to predictor and/or outcomes

To be able to explore the direct association between PA and the two outcomes, it is important to control for covariates. Although it is highly unlikely that the models used in this thesis have incorporated all the potential influencing factors, they have been based on the factors identified in previous research as being associated with the predictor or the outcome.

BMI

Bodyweight is seen to influence levels of PA among adolescents. International data show that children (from 6-years and onwards) and adolescents who are categorised as overweight or obese are less physically active compared to their normal weight peers (63). Data on Norwegian youth show the same pattern where those who are categorised as overweight or obese, are less likely to adhere to current PA recommendations than their normal weight peers (137).

Bodyweight may also associate with academic achievement. This association has been reported in a previous systematic review on children and adolescents (138). However, the same review also concluded that, to date, there was insufficient high-quality data to support a significant relationship (138). In addition, systematic reviews find bodyweight to be bi-directionally associated with mental health problems in adolescents (139, 140).

Seasonality

The calendar year is divided into different seasons which differ with regard to weather conditions and amount of daylight. In a Norwegian context in particular, periods of low temperatures, frequent and heavy rain falls, strong winds, snow, and short amounts of daylight may occur. These conditions may influence the activity pattern of children and adolescents and must therefore be taken into account when exploring habitual PA (141, 142). A review exploring seasonal variation in objectively measured PA among children and adolescents found such variation in the majority of studies, which was more pronounced in younger than older age groups (142). This is consistent with findings from a Norwegian study of PA among a nationally representative sample of children and adolescents (141). This study found substantial seasonal differences in the activity level of 9-year olds, where the activity level was higher in spring than in fall and winter. Among 15-year olds, there were no significant differences found in activity level across seasons, although the odds of adhering to PA recommendations was significantly higher in spring than in winter (141).

There is some evidence to suggest that there is also a significant relationship between season and mood in otherwise mentally healthy study samples. Despite only being explored in an adult population, Harmatz et. al (143) found mild seasonal mood fluctuations which displayed a negative peak in winter, the lowest scores during summer, with scores from spring and fall in between these

peaks (143). In a more recent study of the Canadian population (12-24 years and 25+ years), higher levels of depressive symptoms were found in winter months compared with summer months (144). This trend was more evident among youth (12-25 years) than adults (25+ years), and especially among those reporting mild depressive symptoms. Where moderate and severe symptoms were reported, no seasonal variance was seen.

Socio-economic status (SES)

There is a social gradient in health, which means that the lower the social position of individuals, the worse their health, both in terms of physical and mental health (5). This social gradient is also apparent in relation to PA, where adolescents with higher SES are more physically active than those with lower SES (145). Further, the academic achievements through education are also strongly related to SES (5). There is compelling evidence that the social inequalities in educational outcomes further affect physical and mental health, later income, employment and quality of life (5). These patterns are evident across the entire social gradient. Until recently, health inequalities among children and adolescents have been relatively neglected in research compared to inequalities among adults (146). Children and adolescents lack scores on the most used indicators of SES (occupation, income, and education). Consequently, different indicators must be used. A common approach is to use parental levels of SES (146). Adolescent reporting of parental SES, however, is problematic both conceptually and methodologically. Conceptually, it is debated whether parental SES can be used as a proxy for SES among children and adolescents (147). Methodologically, such reporting is prone to high rates of missing data due to failure to respond or inadequate reporting (146, 147). Family affluence serves as a robust determinant of adolescent health and is seen to covary with the socioeconomic gradient (148).The Family affluence scale (FAS) is an instrument developed for measuring SES among children and adolescents and serves as a widely applied proxy for SES (146). The six items of FAS are sought to represent the material resources of the adolescent's family, their patterns of consumption and purchasing power across Europe and North America (146). The suitability of FAS as a measure of SES is dependent of the population being studied and research question posed (149). The latest version, (FAS III) is considered to provide a flexible way of assessing absolute and relative inequalities between groups of children and adolescents, both within and between countries (146). The items showed high test-retest reliability ($r = 0.9$) and consistency in reporting between child and parent ($r = 0.8$) (149). However, as the aim of the instrument is to obtain an international comparative measure of wealth among adolescents, its ability to differentiate within the highest levels of affluence is poor and ceiling effects have been seen in highly affluent study samples (150). In particular, Torsheim et. al (150) found ceiling effects to be present for several items

of FAS III for the Norwegian study sample, further indicating that these items are very common in a Norwegian setting (e.g. having a dishwasher in the household).

2. Study aims

Although more frequently explored in recent years, several gaps remain in the current knowledgebase relating to the relationship between PA and the outcome variables mental health and academic achievement. An overarching problem is still that the majority of studies have relied on self-reported measures of PA. Further, there remains a dearth of knowledge about longitudinal associations, as the vast majority of studies have used a cross-sectional design which are subject to cohort effects and cannot address changes over time experienced by an individual. The timing and frequency of measurements during important adolescent years (12-16 years of age, representing the three years students attend lower secondary school in Norway) is also insufficient. The three papers this thesis is built on aim to increase knowledge about the longitudinal relationship between PA and mental health and PA and academic achievement through a formative period of life.

The specific aims of paper I-III are:

- **Paper I**
    1. To explore the (cross-sectional) relationship between objectively measured PA level, various dimensions of mental health and academic achievement among adolescents.

- **Paper II**
    1. To explore whether longitudinal changes in objectively measured PA [total PA and MVPA] were associated with changes in academic achievement directly or via mediation of WC or sleep duration.
    2. To explore whether there were differences between boys and girls.

- **Paper III**
    1. To explore whether changes in movement categories [total PA, MVPA and SED] were associated with MHP or MWB.
    2. To explore whether different PA transitions were associated with MHP or MWB

3. Methods

The thesis is based on the work package *Physical activity, school and mental health* which is part of the overarching "Schools, learning and mental health" study (sWell-study), anchored at Inland Norway University of Applied Sciences. The Research Council of Norway financed the sWell study (grant number: 238212/F60).

3.1 Study design and sampling

Physical activity, school and mental health is a prospective cohort study involving 11 lower secondary schools in Norway (see figure 1). Data were collected on an annual basis within the first semester of each academic year from 2016 to 2018 and generated data from 8th grade, 9th grade and 10th grade, which constitute the time at lower secondary school in Norway. Prior to data collection (Spring 2016), a pilot study was conducted with 8th grade students in three classes in two of the participating schools. Procedures and measurements were tested out and discussed with the students in focus groups retrospectively. In **paper I**, we report from the first wave of data collection. **Papers II-III** are based on all three waves of data collection.

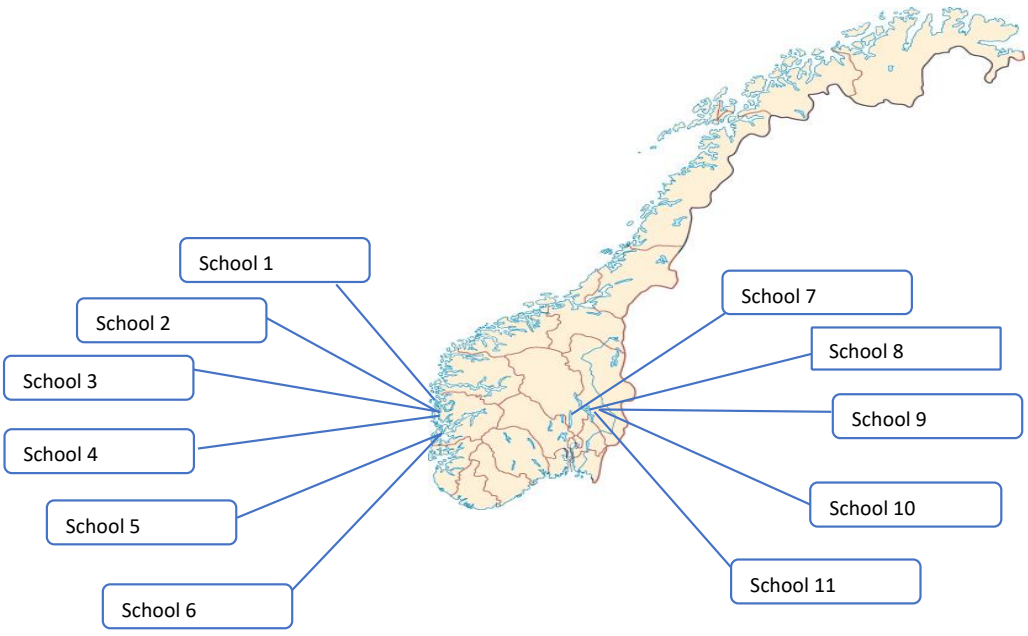


Figure 1. Map of the participating schools in Norway

Schools were purposively recruited on the basis of important characteristics. This was done to ensure a study sample that included schools with a geographical location from both East and West, of different sizes, ethnic and socio-economic compositions, and different scores on national tests at a school level. Although our selection of schools was sought to be illustrative of lower secondary schools in Norway, the selection procedure limits our possibility to generalize the findings to Norwegian lower secondary schools in general.

Initial contact was made with the school leader through an email and follow-up phone call, inviting the school to participate in the study. Following the initial contact, a meeting was held at each school to inform them about the purpose and design of the study. Because the potential participants of the study were minors, information about the study was also given at a parent meeting in the start of 8th grade. Following this, information was also given to the pupils about a week prior to the first data collection. Data collection were conducted through two school visits eight days apart, as well as collection of school grades after the first semester of each academic year. At the first visit, the anthropometric variables were measured. In addition, the accelerometers were placed on each participant. At the second visit, the accelerometers were collected, and the participants completed an online questionnaire during of a school lesson (see appendix I).

Study sample

A total of 1,001 pupils were invited to participate in the study, of which 599 (59.8 %) consented in the first wave of data collection (T1) in 2016 (see figure 2). In the second wave of data collection (T2) in 2017, participation of pupils who did not participate in T1 was permitted, including those pupils who had changed schools between 8th and 9th grade. Forty pupils were lost to follow up at T2 because they either withdrew from the study or changed schools. This gave a participation of 581 (58.0 %) pupils in T2. In the third wave of data collection (T3) new participants were not given the opportunity to enter the study. Twenty-nine pupils were lost to follow up at T3 because they withdrew or changed schools. This gave a participation of 552 (55.1 %) pupils at T3. The longitudinal participation rate with T1 as the eligible sample (n = 599) shows a participation rate of 97.0 % and 92.2 % at T2 and T3 respectively.

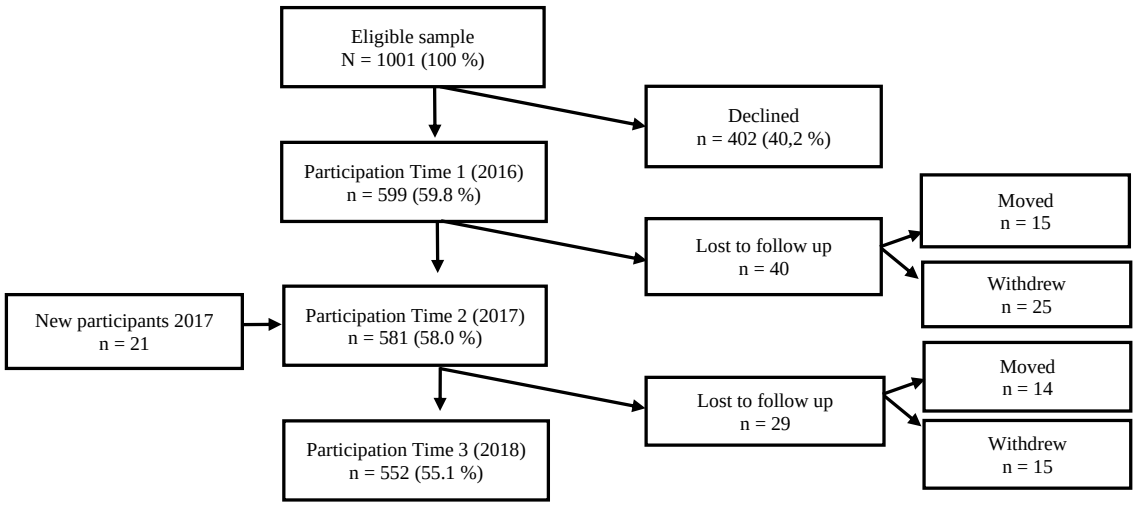


Figure 2. Flowchart of the study sample.

3.2 Measures

Data were collected at school visits from September to January 2016, September to December 2017 and September to January 2018.

3.2.1 Anthropometrics

Trained research personnel performed all anthropometric measures (**paper I-III**). 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 for all the anthropometric measurements. In line with standard practice, bodyweight measures were adjusted by subtracting 0.3 kg to account for clothing (43). Body mass index (BMI) was calculated using weight and height ($kg \cdot m^{-2}$).

Waist circumference (WC) was measured with a medical measuring tape midway between the lowest rib and the top of the iliac crest at the end of gentle expiration. Measurements were conducted twice if the difference was ≤1 cm and three times if the difference was >1 cm. The average value of the two closest measurements was used in the further analyses of the data (**paper II**).

3.2.2 Physical activity

In all three waves of data collection, ActiGraph GT3X+ and ActiGraph GT3X-bt (ActiGraph, LLC, Pensacola, Florida, USA) were used to measure physical activity (see figure 3). The only difference

between the two versions is that the latter enables Bluetooth technology for wireless data transfer. This is a small (4.6 x 3.3 x 1.5 cm) and lightweight (19g) monitor that uses a 3-axis microelectromechanical systems accelerometer which is capable of detecting both static (e.g., force of gravity detected when stationary) and dynamic accelerations (42, 151). The ActiGraph GT3X+ uses vector magnitude data (i.e. the square root of the sum of squared activity counts from three axes (37)) to distinguish if the monitor is worn or not (151). The accelerometer generates raw acceleration in a range of 0.05-2 g with a bandwith of 0.25-2.5 Hz. In order to capture human movement as accurately as possible, this bandwith gives full weight to a frequency of acceleration of 0.75 Hz and lowered weight to lower and higher movement frequencies progressively (37). Although PA at vigorous intensities can produce accelerations up to 3.4 Hz (37), these settings are applied to best capture normal human movement (151). The raw acceleration data (counts) allow for user defined sampling intervals called epochs (42), where lower epoch rates generates more detailed data.

Figure 3. The ActiGraph GT3X-bt worn at the right hip.

Assessment protocol

The accelerometer was fitted on the right hip of each participant using an elastic band (see figure 3). They were instructed to wear the accelerometer for all waking hours for seven consecutive days, and only remove it during water activities and while sleeping. To minimize the potential influence of reactivity, the accelerometer was initialized to start recording at 06:00 the following day enabling one day of familiarization (152).

Data reduction

ActiLife (ActiGraph, LLC, Pensacola, Florida, USA) was used for all accelerometer data handling (initialization of monitors, downloading of files and further processing of data). As the cut-points used for intensity specific analysis are based on output from the vertical axis, data from the vertical axis of the GT3X+/GT3X-bt was used as output for all further processing. This allows application of previously developed algorithms for the vertical axis (37), which further enable comparison of PA level with previously conducted studies on similar age groups (43). The accelerometer data were collected in a 10 sec epoch (which translates to number of counts accumulated every 10 sec). However, the data were aggregated up to a 60 sec epoch for the PA intensity analyses. We used a

pre-set sampling frequency of 30 Hz, which is in line with the majority of studies using ActiGraph GT3X+/bt (37). Data were included if the participants had ≥480 min of wear time a day (40, 43). Intervals of ≥ 20 consecutive minutes with no acceleration recorded was defined as non-wear time. Data recorded between 00:00 and 06:00 were excluded from the analysis. As analysis showed that participants with ≥2 days of valid measurements (T1 and T2) and ≥1 day of valid measurements (T3) did not differ significantly from those with ≥4 days of valid measurements, these were included in the further analysis.

Outcome variables from the accelerometer were three-fold:

1) 'Total PA' originates from cpm and serves as an overall measure of physical activity (**papers I-III**).
2) Accumulated time in various intensities based on the amount of time with cpm below or above different thresholds (**papers I-III**).
3) Adherence to the national recommendations for physical activity (**paper III**).

Cpm is the average count per minute (counts·min^{-1}) for the entire assessment period, and is derived by dividing the total activity counts for a valid day by the sum of minutes of wear time that day for all valid days of measurement. This enables a summary of raw data that has not undergone any other transformation than the determination of wear time/non-wear time. To explore intensity specific physical activity all epochs containing cpm values within different thresholds, called cut-points, were summed, and divided the wear time into SED, LPA and MVPA. To enable comparison with other Norwegian adolescents, this study used the same cut-points as The European Youth Heart study (EYHS) (153) and PANCS (43) (see table 6). Although cut-points vary, a cut-point of <100 cpm to define SED and cut-points close to ≥2000 cpm to define MVPA are much used in the literature. Adherence to national recommendations for physical activity is defined as participants accumulating an average value of ≥60 min of MVPA/day during valid days of the assessment period. This means that a participant can obtain 70 min of MVPA one day, and 50 min MVPA another day and still adhere to the recommendation of an average of ≥60 min of MVPA/day.

Table 6. Cut-points defining different intensities within physical activity

Cut-points	**Cpm**
Sedentary behaviour (SED)	< 100 cpm
Light PA (LPA)	100-1,999 cpm
Moderate to vigorous PA (MVPA)	≥ 2,000 cpm

Note: Cpm = Counts per minute.

3.2.3 Academic achievement

The assessment of learning through grades is conducted at the end of every semester as midterm grades (grades attained halfway through a school year) or as end-of-term grades (grades attained at the end of a school year). Midterm grades are an assessment of achievement based on what the student has learned in each subject at the end of first semester (of that school year). For subjects that carry on throughout all three years of lower secondary school, the midterm grades and the end-of-term grades represent the same type of assessment, merely conducted at the end of different semesters. The student's competence throughout mid-term- and end-of-term evaluations partly forms the assessment of final grades which is the final assessment of a subject and forms the basis for admission to upper secondary education (154). The grade range in Norway is 1-6, where grade 1 equals very low competence, grade 2 equals low competence, grade 3 equals fairly good competence, grade 4 equals good competence, grade 5 equals very good competence and grade 6 equals excellent competence in a subject (155, §3-5).

In this study, midterm grades were used as a measure of academic achievement (**paper I and II**). GPA (grades in all subjects / no. of subjects) was used as the primary indicator of academic achievement. In **paper I**, the midterm grade in Physical Education was used as an indicator of academic achievement in a practical subject.

3.2.4 Mental wellbeing

In **paper I and III** the WEMWBS was used to measure mental wellbeing (84) (see appendix I). This short and psychometrically robust scale can monitor mental wellbeing at a population level. The instrument consists of 14 positively worded items relating to the different aspects of mental wellbeing, and requires response on a 5-point Lickert scale (1= '*none of the time*' to 5 = '*all of the time*') based on their experience over the last two weeks. An overall score is created summing the values from each item to a score with a theoretical range from 14-70, where higher scores indicate higher level of mental wellbeing (78). The instrument was translated into Norwegian by Smith, Alves, Haug and Aarø (see appendix II). We used this translation, but made minor linguistic amendments based on feedback from students after it had been piloted (see appendix III).

Unintentionally, the WEMWBS was assessed in a six-point Likert scale from *not at all* (0) to *all the time* (5) in the current study. 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*.

3.2.5 Self-esteem

In **paper I**, three subscales (global self-worth, athletic competence and social competence) from SPPA-R were used to measure domain specific self-esteem (19) (see appendix I). The revised

instrument consists of 35 statements divided into seven domain-specific subscales, 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 different scale scores are obtained by reverse scoring the negative statements before the mean item score is calculated.

3.2.6 Mental health problems

In **paper I and III**, the SDQ was used to measure MHP (88) (see appendix I). The instrument comprises 25 questions divided into five different scales of five questions each (emotional symptoms, conduct problems, hyperactivity, peer problems and prosocial behaviour). Each item can be answered in a 3-point Likert scale 'not true', 'somewhat true' or 'certainly true'. A 'total difficulty score' ranging from 0-40 was created by summing all subscales except prosocial behaviour (92). **Paper I and III** report the continuous score from the total difficulty score.

3.2.7 Socio-economic status

In **paper I-III**, FAS III was used as a proxy for SES (see appendix I). The instrument consists of six questions reflecting material affluence (146, 149). A score on relative family affluence was derived by summing scores on all six questions and categorising them into broader groups of the 20 % lowest, 60 % middle and 20 % highest material affluence (149, 156).

3.3 Ethics

The study procedure was conducted according to the ethical guidelines presented in the Declaration of Helsinki. Through a preliminary assessment form to the Regional Committee for Medical Research Ethics, the project was considered to fall outside the Health Research Act and thus not subject to application. Hence, the study was registered by the Norwegian Centre for research data (NSD) (see appendix IV). Prior to data collection, written, informed consent was obtained for both the participating student and his/her parent/legal guardian (see appendix V). The student could withdraw from the study at any time and have his/her data deleted. At the end of the study (31.12.2020), all data were anonymised.

All anthropometric measures were conducted by trained personnel in separate rooms without any view from the outside. Based on our experience from data collection in T1, and in understanding that being measured by personnel of the opposite sex can be perceived stressful, same sex measurements were introduced from T2 and onwards. The students were also informed that if any of the measurements made them uncomfortable, they could omit them. This was also explicitly stated upon completing the questionnaire. Moreover, there was always one or more personnel from the project present and available for questions when the students were completing the questionnaire.

Both the anthropometric measurements and some of the instruments in the questionnaire obtains sensitive data which may stir up thoughts and feelings in the participating adolescents. Consequently, an agreement was made with the school nurse in each school to be the contact person if any student felt the need to talk about things related to their participation in the study.

Following the end of project, feedback to the participating schools regarding school results as well as overall results from the project would be provided.

3.4 Statistics and data processing

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 and Stata Statistical Software, version 16.0 (Copyright 1985-2019 StataCorp LLC), Texas 77845 USA. A two-tailed alpha level of 0.05 was used for statistical significance. Descriptive data are presented as frequencies, mean and SD where appropriate. Paired T-tests were used to explore longitudinal differences between variables in T1 and T3 and between T1 and T2 (see table 7a and b). To explore correlations between MHP and MWB, Pearson's bivariate correlation analyses with 95% confidence intervals (CIs) based on the Fisher Z-transformation were used. Further, to analyse the differences in key variables between participants with longitudinal PA-data ('valid PA T1+T3') vs. participants not providing longitudinal PA-data ('missing valid PA T1+T3') (see table 9), independent-samples T test was used for the parametric data and Mann-Whitney U test was used for the non-parametric data.

3.4.1 Sample size

In **paper I and III**, measures of mental health were used as primary outcome variables. Sample size calculations were performed using a two-tailed test assuming Type I error rate of 0.05 and statistical power of 0.8. Calculations showed that to detect a difference of 1.0 points +/- from an average WEMWBS score of 49, with SD 8.0, 396 participants was needed.

3.4.2 Paper I

In **paper I** we explored cross-sectional associations between PA and outcome variables of mental health and academic achievement. Associations between the predictor variable; PA, and outcome variables of mental health and academic achievement (GPA and physical education) were analysed using multiple linear regression model. The analyses were adjusted for interactions of sex, SES, season of data collection (1: Sept-Oct, 2: Nov-Jan) and BMI.

Imputations were performed for SDQ and SPPA-R according to standard procedures. As Little's MCAR test showed that variables from WEMWBS were not missing completely at random, imputations could not be performed for this instrument. The results from the instruments measuring mental health (SDQ, WEMWBS and SPPA-R) were all converted into continuous scores according to standard

procedures before entering the models. To account for possible clustering of the study population, 'school' was included as a cluster variable to obtain robust standard errors.

3.4.3 Paper II

In **paper II**, we explored associations between PA and academic achievement. In the first model, cross-sectional associations between PA and academic achievement in T1-T3 were analysed separately for boys and girls using multiple linear regression model adjusted for interactions of SES, season of data collection and BMI. In model two, associations between longitudinal changes in PA (total PA and MVPA) and academic achievement (GPA) were explored directly and through mediation of change in WC or sleep-duration. Change scores (Δ) were created by subtracting T3-values from T1-values. The new variables entered the multiple linear regression analyses where they were adjusted for the following:

- Analyses including Δtotal PA were adjusted for T1-covariates of sex, SES, BMI and season of data collection.
- Analyses including ΔMVPA were adjusted for T1-covariates of sex, SES, BMI and season of data collection in addition to wear time of the accelerometer.
- Analyses including ΔWC were adjusted for T1-covariates of sex, SES and season of data collection.

In model three, associations between changes in PA (total PA and MVPA) from T1 to T3 and academic achievement at T3 were analysed using a multiple linear regression model. Analyses were adjusted for academic achievement at T1 and T1-covariates of sex, SES, BMI and season of data collection. In addition, analysis including ΔMVPA was adjusted for wear time of the accelerometer. To account for possible clustering of the study population, 'school' was included as a cluster variable in all analyses to obtain robust standard errors.

3.4.4 Paper III

In **paper III**, we explored associations between movement categories (total PA, MVPA and SED) and mental health. In the first model, cross-sectional associations between PA (total PA and MVPA) and variables of mental health (MWB and MHP) in T1-T3 were explored separately for boys and girls using a multiple linear regression model adjusted for interactions of SES, season of data collection and BMI. In model two, change scores (Δ) were created by subtracting T3-values from T1-values. Associations between changes in PA (total PA, MVPA and SED) from T1 to T3 and variables of mental health (MWB and MHP) at T3 were analysed separately for boys and girls using multiple linear regression model. Analyses were adjusted for T1-variables of MHP/MWB, BMI, SES, and season of data collection. All analyses in models one and two were adjusted for school-level clustering and all

analyses of MVPA and SED were adjusted for wear time of the accelerometer. In model three, lifestyle transitions and mental health was explored. Lifestyle transition profiles were created based on whether participants adhered or not to national PA recommendations in T1 and T3. Thus, four profiles were created: 'Active maintainers' consisted of those adhering to PA recommendations in T1 and T3; 'move to inactive' consisted of those adhering to PA recommendations in T1, but not in T3; 'move to active' consisted of those not adhering to PA recommendations in T1, but adhered to them in T3; and 'inactive maintainers' consisted of those not adhering to PA recommendations in T1 or in T3. Differences between groups were analysed using a multiple linear regression model, adjusted for T1-variables of MHP/MWB, BMI, SES, season of data collection and sex.

4. Summary of results

4.1 Characteristics of the study sample/participants (Papers I-III)

The baseline study sample consisted of 599 consenting adolescents from 11 different schools. Table 7 a and b show the descriptive characteristics of the study sample from T1 to T3. Among girls, significant changes between T1 and T3 were seen for all key variables except SED. For boys, significant changes were evident in the anthropometric variables; BMI and WC, sleep duration, the movement categories; SED, LPA and MVPA, the mental health variable; global self-worth, and in GPA. Through exploration of changes between T1 and T2 the pattern was similar to that of T1-T3 in all variables except those measuring PA. For girls, there were only significant changes in the amount of LPA. For boys a significant difference for SED was found. The analyses exploring longitudinal changes in the movement categories; SED, LPA and MVPA were conducted using variables not adjusted for wear time of the accelerometer. In **paper II**, wear time adjusted variables were used in the same type of descriptive reporting, hence the difference in significance level for longitudinal change in MVPA for boys. For descriptive purposes, variables not adjusted for wear time should have been used. However, this serves as no additional error than a difference in reporting of descriptive data in **paper II** vs. **paper III** and the thesis.

Table 7a. Descriptive characteristics and mean differences on possible confounding variables of the study sample by sex, all time points (mean ± SD unless otherwise specified)

Characteristic	**Time 1 (2016)** All	**Time 1 (2016)** Girls	**Time 1 (2016)** Boys	**Time 2 (2017)** All	**Time 2 (2017)** Girls	**Time 2 (2017)** Boys	**Time 3 (2018)** All	**Time 3 (2018)** Girls	**Time 3 (2018)** Boys
N (min-max)	599 (527-597)	326 (283-323)	273 (244-273)	581 (500-577)	316 (283-313)	265 (209-257)	552 (461-525)	304 (269-301)	248 (192-239)
Age (y)		13.3 (0.3)	13.4 (0.3)		14.3 (0.3)	14.4 (0.3)		15.3 (0.3)	15.4 (0.3)
Height (cm)		161.7 (6.9)	163.9 (8.6)		165.0 (6.6)	171.3 (8.2)		166.3 (6.4)	176.9 (7.5)
Weight (kg)		52.8 (9.9)	53.0 (11.8)		56.6 (9.8)	60.7 (13.5)		59.2 (9.8)	66.8 (13.6)
WC (cm)		70.5 (8.8)	73.2 (9.7)		71.4 (7.7) ††	75.3 (10.0) ††		70.9 (7.4)**	76.4 (9.4)**
BMI (kg/m²)	19.8 (3.2)	20.0 (3.1)	19.6 (3.3)	20.7 (3.3)	20.8 (3.0) ††	20.5 (3.7) ††	21.4 (3.4)	21.4 (3.0)**	21.3 (3.7)**
Sleep duration (h)		9.1 (0.8)	9.3 (0.9)		8.7 (0.9) ††	8.7 (0.9) ††		8.4 (0.9)**	8.4 (0.9)**
SES (n)									
Lowest N (%)	136 (23.7)	76 (24.5)	60 (22.7)	75 (14.0)	45 (15.5)	30 (12.3)	72 (14.1)	41 (14.3)	31 (13.7)
Middle N (%)	346 (60.3)	188 (60.6 %)	158 (59.9)	352 (65.8)	197 (67.7)	155 (63.5)	339 (66.2)	191 (66.8)	148 (65.5)
Highest N (%)	92 (16.0)	46 (14.8)	46 (17.4)	108 (20.2)	49 (16.8)	59 (24.2)	101 (19.7)	54 (18.9)	47 (20.8)

Note. WC = Waist circumference, BMI = body mass index, SES = socio-economic status. As all participants did not provide valid data on all key variables, the n of the different variables will differ somewhat and is thus presented as min-max values in the table.

* Significant change of variable between T1 to T3, p ≤.05. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3

** Significant change of variable between T1 to T3, p ≤.001. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3

† Significant change of variable between T1 to T2, p ≤.05. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T2

†† Significant change of variable between T1 to T2, p ≤.001. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T2

Table 7b. Descriptive characteristics and mean differences on PA and outcome variables of the study sample by sex, all time points (mean ± SD unless otherwise specified)

Characteristic	**Time 1 (2016)** All	**Time 1 (2016)** Girls	**Time 1 (2016)** Boys	**Time 2 (2017)** All	**Time 2 (2017)** Girls	**Time 2 (2017)** Boys	**Time 3 (2018)** All	**Time 3 (2018)** Girls	**Time 3 (2018)** Boys
N (min-max)	599 (527-597)	326 (283-323)	273 (244-273)	581 (500-577)	316 (283-313)	265 (209-257)	552 (461-525)	304 (269-301)	248 (192-239)
Total PA (CPM/d)[a]	434.4 (152.6)	402.2 (118.6)	474.4 (178.7)	432.1 (155.0)	399.9 (127.5)	476.8 (177.5)	415.8 (173.2)	383.5 (138.3)*	460.9 (204.7)
SED (min/d) [a]	558.0 (65.1)	565.7 (55.4)	548.4 (74.4)	553.1 (71.4)	561.3 (64.6)	541.7 (78.7) [†]	555.0 (84.0)	564.1 (69.6)	542.1 (99.6)*
LPA (min/d) [a]	166.2 (33.5)	161.4 (32.3)	172.2 (34.1)	159.6 (33.7)	153.9 (32.2) [††]	167.6 (34.3)	138.9 (33.5)	137.6 (30.4)**	140.8 (37.3)**
MVPA (min/d) [a]	58.4 (21.2)	54.0 (18.5)	63.9 (22.9)	57.3 (22.0)	53.6 (19.4)	62.4 (24.3)	53.4 (24.1)	50.1 (21.4)*	58.1 (26.7)*
Meeting act.reg (%)	43.9	36.3	53.3	44.0	37.1	53.6	35.4	29.5	43.8
Mean valid days	5.8 (1.4)	5.9 (1.3)	5.7 (1.4)	5.2 (1.7)	5.4 (1.6)	4.9 (1.7)	4.6 (2.0)	5.1 (1.8)	4.0 (2.1)
Mean wear time (min)	783.1 (67.0)	781.6 (63.4)	785.0 (71.3)	770.0 (78.6)	768.9 (74.5)	771.6 (84.2)	747.3 (97.1)	751.8 (84.4)	741.1 (112.3)
GPA	4.0 (0.7)	4.1 (0.7)	3.8 (0.6)	4.1 (0.7)	4.3 (0.7) [††]	3.9 (0.7) [†]	4.2 (0.8)	4.4 (0.8)**	4.0 (0.7)**
MHP	9.8 (5.2)	10.0 (5.1)	9.7 (5.4)	10.8 (5.7)	11.3 (5.8) [††]	10.1 (5.3)	11.3 (5.3)	12.0 (5.3)**	10.4 (5.2)
MWB	56.0 (9.0)	55.0 (8.9)	57.1 (9.1)	54.5 (10.3)	52.2 (10.5) [††]	57.3 (9.4)	52.8 (10.8)	50.6 (11.0)**	55.9 (9.6)
GSW	3.3 (0.6)	3.2 (0.6)	3.5 (0.5)	3.1 (0.7)	3.0 (0.8) [††]	3.3 (0.6) [†]	3.0 (0.7)	2.8 (0.8)**	3.3 (0.6)**

Note. Total PA (CPM) = average daily counts per minute, CPM/d = counts per minute per day, min/d = minutes per day SED = average daily sedentary behaviour, LPA = average daily light physical activity, MVPA = average daily moderate to vigorous physical activity, Meeting act.reg = Meeting national recommendations of an average of ≥ 60 min MVPA per day, GPA = grade point average, MHP = mental health problems, MWB = mental wellbeing, GSW = Global self-worth. As all participants did not provide valid data on all key variables, the n of the different variables will differ somewhat and is thus presented as min-max values in the table.

[a] Adjusted for valid days

* Significant change of variable between T1 to T3, p ≤.05. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3

** Significant change of variable between T1 to T3, p ≤.001. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3

[†] Significant change of variable between T1 to T2, p ≤.05. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T2

[††] Significant change of variable between T1 to T2, p ≤.001. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T2

As the score distribution of WEMWBS was positively skewed throughout T1-T3, the study population demonstrated high levels of MWB at all study points (see figure 4 a-c). Likewise, the number of participants belonging to the 'Close to average' category of SDQ ranged from 75 % - 84 % throughout the study, overall displaying a study population with normal distribution of MHP (see table 8). The correlations between MHP and MWB were moderate throughout the study (T1: r= -0.44, 95% CI -0.51, -0.37; T2: r= -0.45, 95% CI -0.52, -0.38; T3: r= -0.53, 95% CI -0.60, -0.47) indicating that they are distinct, but related dimensions.

Table 8. Score distribution of SDQ within a 4-band categorization in T1-T3 (n + %).

	Expected population distribution	**T1 (2016)**	**T2 (2017)**	**T3 (2018)**
'Close to average' (0-14)	80 %	483 (84.0 %)	404 (75.0 %)	378 (77.5 %)
'Slightly raised' (15-17)	10 %	48 (8.3 %)	66 (12.2 %)	65 (13.3 %)
'High' (18-19)	5 %	14 (2.4 %)	27 (5.0 %)	32 (6.6 %)
'Very high' (20-40)	5 %	30 (5.2 %)	42 (7.8 %)	13 (2.7 %)
Total	100 %	575 (100 %)	539 (100 %)	488 (100 %)

Note. 4-band categorisation and expected population distribution (89).

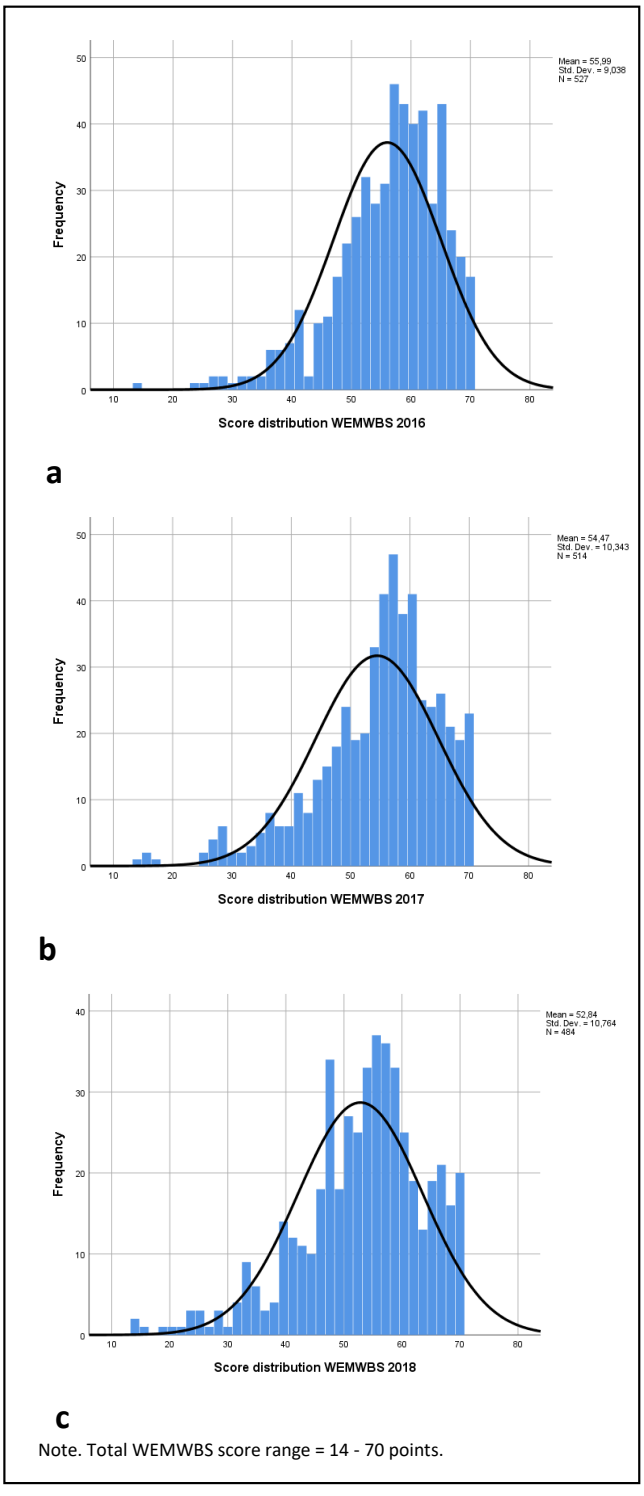


Figure 4 a, b and c. Score distribution of WEMWBS in **a** = T1, **b** = T2, **c** = T3

4.1.1 Loss to follow-up on valid PA measurements

There were too few participants lost to follow-up to conduct any meaningful loss to follow-up analysis (see figure 2). However, in order to explore whether there were systematic differences between participants who were included and excluded from longitudinal analyses, differences in key variables from T1 between the group with longitudinal PA-data ('valid PA T1+T3'), and participants not providing longitudinal PA-data ('missing valid PA T1+T3') were analysed (see table 9). Valid PA measurements for T1 and T3 were used as the grouping variable as longitudinal PA serves as the main predictor variable in **paper II and III**. Overall, the group that did not provide valid PA measurements for T1 and T3 had significantly lower BMI and showed higher levels of total PA and MVPA as well as lower levels of SED than the 'valid PA T1+T3' group. In addition, they had a significantly poorer GPA and higher score on MHP than the 'valid PA T1+T3' group. For the remaining variables, there were no significant differences between the groups.

Table 9. Differences in key variables between participants who provided valid PA measurements in T1 (2016) and T3 (2018), and participants who did not provide valid PA measurements at both time points.

Variable T1		n	Mean (SD)	P	95 % CI
BMI (kg/m²)	'missing valid PA T1+T3'	143	19.21 (3.09)	.016	-1.35,-0.14
	'valid PA T1+T3'	418	19.95 (3.23)		
Total PA (CPM/d)[a]	'missing valid PA T1+T3'	134	463.56 (156.72)	.011	8.61, 67.50
	'valid PA T1+T3'	438	425.50 (150.34)		
SED (min/d)[a]	'missing valid PA T1+T3'	134	535.41 (76.62)	≤.001	-41.86, -17.07
	'valid PA T1+T3'	438	564.88 (59.53)		
LPA (min/d)[a]	'missing valid PA T1+T3'	134	163.96 (34.65)	.377	-9.43, 3.75
	'valid PA T1+T3'	438	166.89 (33.20)		
MVPA (min/d)[a]	'missing valid PA T1+T3'	134	61.51 (22.59)	.055	-.089, 8.10
	'valid PA T1+T3'	438	57.50 (20.63)		
GPA	'missing valid PA T1+T3'	160	3.75 (0.66)	≤.001	-.464, -.227
	'valid PA T1+T3'	437	4.10 (0.65)		
MHP	'missing valid PA T1+T3'	153	10.54 (5.18)	.050	.001, 1.93
	'valid PA T1+T3'	422	9.57 (5.21)		
MWB	'missing valid PA T1+T3'	139	56.31 (8.91)	.631	-1.33, 2.19
	'valid PA T1+T3'	388	55.88 (9.09)		
SES[b]	'missing valid PA T1+T3'	153	298.6	.269	
	'valid PA T1+T3'	421	283.5		

Note. BMI = body mass index, Total PA (CPM) = average daily counts per minute, CPM/d = counts per minute per day, min/d = minutes per day SED = average daily sedentary behaviour, LPA = average daily light physical activity, MVPA = average daily moderate to vigorous physical activity, GPA = grade point average, MHP = mental health problems, MWB = mental wellbeing.

[a] Adjusted for valid days

[b] Non-parametric data. Analysed by Mann-Whitney U test.

4.2 Paper I

Aim: To explore the relationship between objectively measured PA level, various dimensions of mental health and academic achievement among adolescents in Norway.

Cross-sectional associations between PA and variables of mental health and academic achievement are shown in table 10. Total PA was positively associated with MWB, self-perception of athletic competence and self-perception of social competence. It was not associated with global self-esteem or MHP. As a change of 1 cpm is too small to reflect any meaningful change in outcome variable, the value was scaled up 100 times, showing changes in outcome variable occurring after changes of 100 cpm. A change of 100 cpm predicted an equivalent increase in scores of MWB, self-perceived athletic competence and self-perceived social competence with β 0.71, 0.10 and 0.03 respectively.

There were no associations between total PA and GPA. However, sub-analyses showed a significant association between total PA and grade in physical education for girls, where an increase of 100 cpm showed an equivalent increase of β 0.20 (p≤.001) higher grade in physical education. By dividing the groups into quartiles based on activity level, results showed a significant increase in girls' physical education grades in all quartiles compared to the lowest quartile (lowest 25 %). Among boys the differences between the lowest quartile were only significant compared to the third and fourth quartile (see table 3 in paper I).

TABLE 10: Associations between physical activity and measures of mental health and academic achievement analysed with a multiple linear regression model (n=474-537)

	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 competence	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 is measured by SDQ score. Academic achievement is measured by GPA in all subjects, β = standardized regression coefficient

[a] Adjusted for cluster sampling

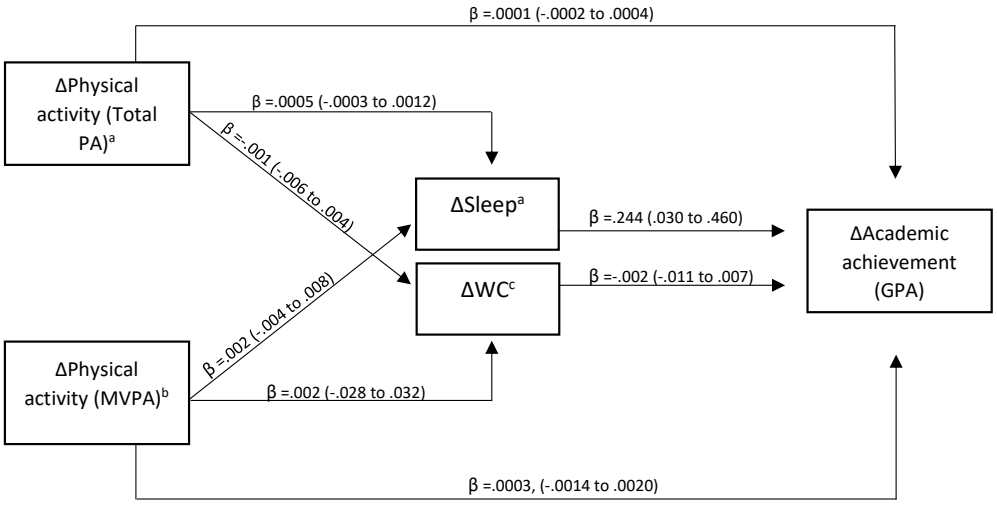
[b]Adjusted for cluster sampling, sex, BMI, SES and season of data collection

All measures are scaled up 100 times showing changes in outcome variables occurring after changes of 100 cpm.

4.3 Paper II

Aim: (1) To explore whether longitudinal changes in objectively measured PA [total PA and MVPA] were associated with changes in academic achievement directly or via mediation of WC or sleep duration. (2) To explore whether there were differences between boys and girls.

As analyses showed no interaction by sex, all main analyses of the study population were conducted collectively. Longitudinal analyses showed that neither change in volume (total PA) or intensity (MVPA) of PA were directly associated with change in academic achievement (see figure 5). No indirect association via WC or sleep duration were present either. Exploration of prospective associations between change in PA (total PA or MVPA) and academic achievement in T3 did not provide any evidence of an association (figure A.1 in Paper II).



Note. MVPA = moderate to vigorous physical activity, WC = waist circumference, GPA = grade point average, β = standardized regression coefficient.

[a] Adjusted for baseline sex, BMI, SES, season of data collection and cluster sampling

[b] Adjusted for accelerometer wear time, baseline sex, BMI, SES, season of data collection and cluster sampling

[c] Adjusted for baseline sex, SES, season of data collection and cluster sampling

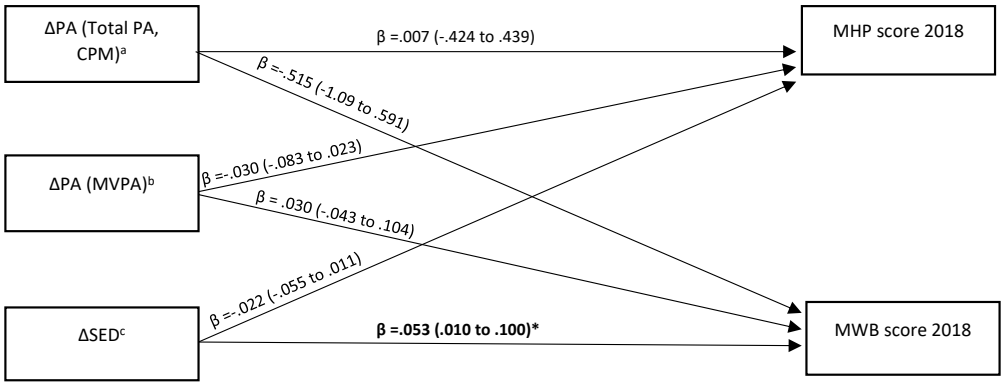
Figure 5. Parameter estimates of the regression coefficient of the longitudinal associations between changes (2016-2018) in physical activity (total PA and MVPA), WC, sleep duration and academic achievement. (n= 379-468)

4.4 Paper III

Aim: (1) To explore whether changes in movement categories [total PA, MVPA and SED] were associated with MHP or MWB. (2) To explore whether different PA transitions were associated with MHP or MWB.

As interaction analyses showed that there was an interaction by sex, main analyses were conducted for boys and girls separately. Figure 6 shows that there was a significant positive association between change in SED and MWB score in T3 among boys. There were no other associations between movement categories and variables of mental health. Among girls, figure 7 shows a significant positive association between change in total PA and score on MWB in T3.

Differences in MHP or MWB were also explored via PA transition profiles (see table 2a and 2b in paper III). Results showed a significant difference in MHP-score at T3 between 'inactive maintainers' and 'move to active' (p=.013), and between 'active maintainers' and 'move to active' (p=.018) in the crude analyses. However, both differences disappeared in the adjusted analyses. Further, the adjusted analyses showed a significant difference in MHP-score of 1.3 units at T3 between 'inactive maintainers' and 'move to inactive' (p=.033).



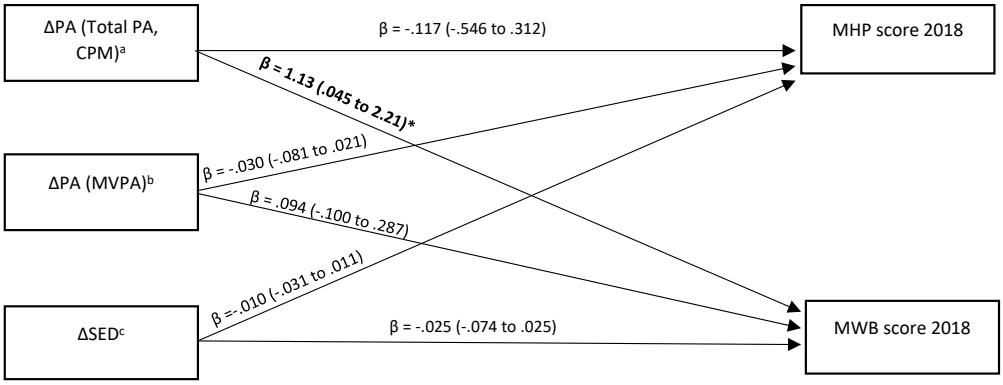
Note: MHP = Mental health problems, MWB = Mental wellbeing, MVPA = Moderate-to-vigorous physical activity, SED = Sedentary behaviour

[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.

[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 6. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among **BOYS**. (n = 139-159).



Note: MHP = Mental health problems, MWB = Mental wellbeing, MVPA = Moderate-to-vigorous physical activity, SED = Sedentary behaviour

[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.

[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 7. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among **GIRLS**. (n = 196-222).

5. General discussion

This thesis presents data from a longitudinal study exploring associations between objectively assessed PA and academic achievement and objectively assessed PA and variables of mental health. In the first part of the discussion, the results of the three papers will be discussed. Further, a methodological discussion of the study design, selection bias and measurements will be addressed, followed by a summary of strengths and limitations of the thesis and its related papers. Lastly, implications and perspectives for future research are presented.

5.1 Main findings

In **paper I**, we found positive cross-sectional associations between PA and MWB, self-perception of athletic competence and self-perception of social competence, supporting a relationship between PA and positive dimensions of mental health. It is, nevertheless, important to note that the associations were very small, making their consequence for real life difficult to infer. We found nothing to indicate a relationship between PA and MHP and between PA and academic achievement.

Longitudinal findings from **paper II**, support those of **paper I**, showing no relationship between volume or intensity of PA and academic achievement, either in the main analyses or via mediation of WC or sleep duration.

In **paper III**, a positive association between an increase of SED and MWB at T3 was found among boys. In girls, a modest positive association between total PA and MWB at T3 was found. There was no relationship between change in any movement categories (total PA, MVPA, SED) and MHP at T3.

5.2 Physical activity and mental health

As previously shown by Clarke et. al (84), analyses in the current study sample showed MHP and MWB to be moderately negatively correlated, thus underscoring the foundation of the dual continuum model which states that they are distinct, but related dimensions.

5.2.1 Positive dimensions of mental health

Mental wellbeing

Paper I found a positive association between total PA and MWB in the cross-sectional data from T1. **Paper III** also showed a positive association between change in total PA from T1 to T3 and MWB. However, the result from **paper III** was only significant for girls. It is important to underline that both these findings were small, as an increase in PA level of approximately 20 % per day (100 cpm/day) was associated with an increase of 0.71 (**Paper I**) and 1.13 (**Paper III**) higher MWB score. Intensity specific PA was not explored cross-sectionally, but the longitudinal data showed no relationship between change in MVPA and MWB in the study sample. Further, there were no differences in the relationship with MWB across different PA-transition profiles. The overall interpretation of the

pattern between PA and MWB nevertheless points towards volume or intensity of PA not being a primary factor for levels of MWB.

The focus on MWB is a relatively new direction within the research on PA and mental health. Consequently, the number of comparable results from previous research is small. In a recent systematic review by Rodriguez-Ayllon et. al (21), (self-reported and objectively measured) PA was found to associate positively with variables of MWB (i.e. self-image, satisfaction with life and happiness, and psychological wellbeing) suggesting that increased PA levels may influence MWB depending on type of PA being undertaken. On the contrary, in a systematic review by Poitras et. al (51), the majority of studies did not show any association between objectively measured PA and variables of MWB (i.e. quality of life, self-rated health and psychosocial health). A direct comparison with the current data must nevertheless be cautious as there are considerable differences in measurements used to assess MWB. While previous studies have used different measures which cover a broad range of positive affective states and functioning in personal and social life (21, 51), the current study has used one of few solely positive scales that integrates psychological (eudaimonic) and emotional (hedonic) aspects of wellbeing (WEMWBS) (84), and thus provides a multidimensional measure of MWB. Nevertheless, a recent longitudinal study provided some opportunity for comparison as it explored the relationship between objectively measured PA and MWB using WEMWBS among English adolescents of equal age (113). They found no evidence of a relationship with either volume or intensity of PA and MWB. Viewed in light of the results from the current study, this may indicate that other factors may, to a larger degree than PA, contribute to the MWB of adolescents. However, as cross-national comparisons of results with regards to mental health are not straight forward, firm conclusions regarding the role of PA for MWB cannot be made at this point. It is important to note that PA may well be related to MWB, albeit in a more complex way than hitherto hypothesised across the whole movement spectrum.

Paper III also explored the longitudinal relationship with SED and MWB and found a significant positive relationship between these variables for boys. No association was present for girls. The size of the relationship equals an increase in SED of 60 minutes from T1-T3 being equivalent to 3.2 higher MWB score. Although consensus regarding what constitutes an important change in WEMWBS is yet to be reached, the instrument is found to be responsive at both individual and group/population level (157). At an individual level, a change of 3 or more units (1 SEM) has been interpreted as important (157). Building on this, the current change of 3.2 units is can be considered an important change in MWB. As this, to our knowledge, is the first time the relationship between objectively measured SED and MWB measured by WEMWBS has been explored, there are no directly comparable studies. However, the systematic review by Rodriguez-Ayllon et. al (21) has explored the

relationship between SED and an umbrella term of MWB, covering a broad range of positive affective states and functioning in personal and social life. On the contrary to results from **paper III**, they found an inverse association between SED and the MWB outcomes 'satisfaction with life' and 'happiness'. For the remaining outcomes, the association was either unclear or there were insufficient amounts of studies testing the association to conclude.

It is important to underline that as SED were measured by accelerometry in the current data, the context of this behaviour is not known. A further discussion therefore becomes speculative. Previous research has shown that different sedentary behaviours (e.g. screen-based vs non-screen-based SED) may associate differently with mental health (158, 159). More specifically, mentally active SED, such as office work or knitting/sewing has been shown to reduce the risk of depressive symptoms and depression among adults, whereas passive SED (e.g. watching TV) did not show any equivalent effect (160, 161). There may also be differences within screen time depending on whether this is passive (e.g. TV-viewing) or active (e.g. gaming), where passive screen time is associated with mood- and anxiety disorders among adolescents, while active screen time is not (162). At the same time, research shows that gaming has become increasingly popular and a source of social interaction, especially among boys (163, 164). In a Norwegian setting, 84 % of boys at lower secondary school reported gaming at least one hour per day in 2018-2020 (165). It could thus be plausible that the social interplay gaming offers might be one explanation for the results of the current study. Hoare et. al (166) also discuss the potential of social media platforms to hold protective effects for mental health through their ability to connect and interact with peers.

Self-esteem

The relationship between PA and global- and domain-specific self-esteem was explored cross-sectionally in **paper I**. Results from these analyses suggested no relationship between PA and global self-esteem. Although the body of evidence on the PA and self-esteem-relationship has seen a rapid increase in recent years, the results are not consistent across studies. A recent review of reviews thus concluded that the picture is mixed (18). Nonetheless, their broad definition of PA led to inclusion of reviews exploring leisure time PA, yoga, recreational dance, and muscle-strengthening exercise which might have influenced their conclusions. A second umbrella systematic review (73) found a positive association in half of the included reviews, further elucidating the mixed picture of this relationship. They conclude that the relationship between PA and self-esteem is small-to-moderate and discuss whether the wide range of terminology for self-esteem could be one explanation for the conflicting results across reviews. This is also supported by Biddle et. al (18), who further points out that some studies only explore global self-esteem, ignoring potentially more relevant sub-domains of

self-esteem. It is also argued that global self-esteem might be too distant from specific behaviours, such as PA, which may have a closer link to relevant sub-domains of self-esteem (119). **Paper I** support such an explanation as results showed significant positive associations between PA and the self-esteem domains athletic competence and social competence, but not for global self-esteem. Perceived athletic competence has also previously been found to associate positively with PA levels among Norwegian adolescents (167). However, this was through self-reported PA.

The domain, athletic competence assesses one's perception of an ability to do well in sports (20). Haugen et. al (167) discuss the potential of having experiences related to PA may benefit perceived athletic competence. It is thus possible that being more physically active might bring about broader experiences within sporting activities, further generating a greater belief in one's ability to do well in sports. Social competence, on the other hand, refers to having the skills to get others to like oneself and understanding what it takes to become popular (20). Being physically active or participating in sports is generally viewed as socially approved behaviours among adolescents which further contributes to them being encouraged and subsequently valued for their engagement in such activities (168). In a Norwegian cultural context, being active is also considered to be a valuable trait (169). This might offer one explanation for the association between PA and social acceptance found in the current study. In addition, the social arena of PA and sports may provide opportunities for friendships and feeling valued, which may facilitate further improvements in perceived social competence (168). Nonetheless, it is important to note that the current data only showed small associations between total PA and the self-esteem domains, as about a 20 % increase in average daily PA level was associated with a 0.12 (athletic competence) and 0.04 (social competence) unit increase in self-esteem measures.

5.2.2 Mental health problems

There were no cross-sectional association between total PA and MHP among the study sample (**paper I**). One potential explanation for this could be that the pathways between PA and MHP might not be immediate but take longer to develop. The current study was able to explore this with its longitudinal design. **Paper III** thus explored whether change of PA volume or intensity between T1 and T3 were associated with MHP at T3. The results showed no evidence of such relationship either among girls or boys in the current study. As the relationship could be bi-directional, models were reversed to explore whether change of MHP were associated with volume or intensity of PA (see additional files 1 & 2 in paper III). Results showed no evidence of a bi-directional relationship between the variables of interest. There was thus no evidence for a relationship developing between the ages of 12/13-15/16. However, it cannot be ruled out that the time frame of the follow-up was still too short for a relationship to develop. Results from **paper I and III** nevertheless support

conclusions drawn from previous studies using a longitudinal design and measuring PA objectively (113, 114, 116, 118, 119). Toseeb et al. (118) propose that the relationship between PA and depressive symptoms might be small or non-existent during the adolescent years, as research more frequently reports positive associations in adult populations. This is also addressed by Opdal et. al (116) who propose that PA may serve another function for adolescents than for adults. Although reviewing the evidence of a relationship between PA and depression among adolescents, for which they also do find support, Biddle et. al (18) underscore that the link seems less consistent than for adults. Results of the current study together with those of previous studies might therefore suggest that other factors play a more prominent role for the level of MHP during adolescence.

Paper III further explored the longitudinal association between change in SED and MHP at T3. The results showed no associations either for girls or boys. This is in contrast with previous systematic reviews and meta-analyses who explored the effect of SED on indicators of mental health and found (1.) consistent evidence for a relationship between depressive symptomatology and psychological distress, and leisure time screen use (166, 170) and (2.) association between higher time spent in SED and depression (21). The latter further reported that there was insufficient evidence regarding the relationship with other indicators of negative mental health, such as anxiety, stress, and negative affect. However, it is important to note that the majority of studies included in these reviews have explored self-reported measures of SED or screen-time. Both Hoare et. al (166) and Liu et. al (170) conclude that the relationship is between leisure time screen use and negative mental health indicators, not SED in general. These differences will limit a direct comparison of results. On the other hand, an earlier longitudinal study using the same objective measure of SED as the current study, reports that objectively measured SED was unrelated with depressive symptoms among adolescents (114), and thus supports findings from **paper III**. In contrast, a cross-sectional study only including adolescent girls (12 years) found a modest inverse association between SED and depressive symptoms (115). A systematic review and meta-analysis of objectively measured SED and different health outcomes among children and adolescents conclude that the association between SED and mental health outcomes, to date, is uncertain (171). Consequently, there remains a dearth of relevant research to sufficiently address this relationship.

5.2.3 Too mentally healthy?

Throughout all time points of the study, the sample means were low for MHP and high for MWB. (see figure 4 a-c and table 8). Stronger effects of PA have been found in populations with clinical diagnoses (18, 73). This might indicate that the study sample is too mentally healthy for an association to be present. The influence of PA on overall mentally healthy study samples might not have the potential for further improvements in MHP and MWB, or may not have the power to

counteract other, more important influences of their lives, thus explaining the lack of significant associations within the current and comparable studies. It has also been argued that in study samples where few experience change in their mental health, associations with change of PA level will be difficult to find (116). Although sensitivity analyses show that there was a significant decrease in MWB score as well as an increase in MHP score among girls from T1-T3, the mean scores of boys and girls (and main proportion of students) were still within normal range and indicative of a mentally healthy study sample. This may further strengthen the argument that the overall good level of mental health in the study sample makes any contribution of PA negligible.

5.3 Physical activity and academic achievement

The relationship between PA and academic achievement was explored cross-sectionally in **paper I** and **II**. The cross-sectional findings revealed no strong association between the variables. **Paper II**, nonetheless, found a significant positive association between the variables in the cross-sectional analyses of data from T2 (see table 2, **paper II**). Sensitivity analyses showed this association only to be significant among boys (see supplementary table S2, **paper II**). It might be possible that associations between PA and academic achievement differ between academic years at lower secondary school. However, it is important to note that the association was very small as an increase of daily PA volume of approximately 20 % was equivalent to a 0.045 increase in GPA. As several tests were performed in **paper II**, we cannot rule out the possibility that this finding was a result of chance. Such an explanation is strengthened by the fact that there were no patterns in the findings to suggest a consistent relationship between the variables.

Further, **paper II** explored the relationship between PA and academic achievement in more depth with its longitudinal design, aiming to understand whether a potential relationship could be direct or indirect, or dependent on PA intensity. Results from this paper showed no indication of a direct longitudinal relationship between PA (total PA and MVPA) and academic achievement. This is in line with results from Corder et. al (133) who explored MVPA at 14.5 years and its association with academic achievement at 16 years. Nevertheless, results contrast with those found in Booth et. al (127) who reported a positive relationship between MVPA at 11 years and subsequent academic achievement at 16 years, as well as results from Owen et. al (104) who found a positive longitudinal association between change in MVPA and change in academic achievement among girls, but not boys. Only the current study and Owen et. al (104) obtained repeated measures of both predictor and outcome, and thus allowed exploration of any temporal relationships. As results differ across these two studies, additional research is needed to explore this further. The main proportion of previous research using objectively measured PA has made use of a cross-sectional design (see table 5). Consequently, the further discussions will include both prospective- and cross-sectional studies to

enable a broader discussion of the current evidence base. Collectively, previous research shows a diverse picture of this relationship among children and adolescents (including positive associations, negative associations, and no associations). Results from the current study thus support (131-135) and contrast (negative association: (102, 136), positive association: (104, 127-130)) previous research. Although objectively measured PA has been explored in all above-mentioned studies, there are still inherent methodological differences across studies (e.g. study design, age of participants and measure of academic achievement), complicating any further discussion about the reasons for differences in results (see table 5 for detailed information of studies).

Nevertheless, there might be several possible explanations for the results of the current study. First, adolescence is characterized by considerable physical and cognitive development (172). This means that the follow-up period may not have been sufficiently long for any association to emerge. In a cohort study with 30-year follow-up, positive associations were seen between self-reported PA and subsequent educational attainment 30 years later (173). The authors nevertheless underline that the strength of the association was somewhat dependent on prior academic achievement. As PA was self-reported, and no studies using objectively measured PA with equally long follow-up have been conducted, we cannot conclude whether the association is dependent on measure of PA or not.

On the other hand, a potential relationship might also be a result of more immediate effects of PA (103, 106), and thus only accessible through targeted PA bouts performed at school (103). If this is the case, the current study design will not be able to detect any relationship as PA was measured as daily averages and midterm grades was obtained at the end of first semester.

Any relationship between PA and academic achievement might not be direct but be indirect and act via mediators. Previous research found WC to be a mediator in the longitudinal relationship between PA and academic achievement among children (130). To our knowledge, this hypothesis had not previously been explored amongst adolescents. **Paper II** thus sought to explore whether the same relations were present among an adolescent study sample. However, no evidence for such an indirect association among adolescents was found. As Lima et. al (130) explored the relationship among a younger age-group (7-12 years) and used a different measure to assess academic achievement (standardised national test scores), this might account for the differences found in results. The evidence base among children and adolescents is currently too low to draw any conclusions on this relationship among young people.

Further, it has been hypothesized that changes in cognitive and mental health outcomes from PA can be mediated by changes in relevant and associated behaviours, such as length and quality of sleep (17). Several variables related to length or quality of sleep have been associated with both predictor

and outcome amongst children and adolescents (174). **Paper II** sought to explore whether sleep duration could serve as a potential mediator in the prospective relationship between PA and academic achievement in an adolescent population. Results from the current study showed no indication of such an indirect relationship. This is in line with a previous study which found that bedtime did not mediate any relationship between objectively measured PA and academic achievement (175). In the current study however, sleep duration was calculated from self-report using two questions which asked about the usual times for going to bed or getting up in the morning on school nights (for details, see supplementary file, table S1 in **paper II**). Likewise, Syväoja et. al (175) also used self-report, asking a question about the usual time for going to bed on school nights. Although these measures provide rough estimates of longer and shorter sleep durations among the participants, they are not a precise measure of the actual amount of sleep. There might thus be nuances to this relationship that the current study as well as that by Syväoja et. al (175) were not able to detect.

Previous research has proposed that there might be an intensity-dependent association as higher levels have been associated more frequently with academic achievement in some study samples (127, 128). On the other hand, other studies do not find any evidence of intensity related associations with MVPA (119, 131, 133-135), leaving a mixed picture of the relationship. **Paper II** found no evidence of an intensity dependent association between change in MVPA and GPA among the current study sample. However, as all of the above-mentioned studies explored the relationship between MVPA and academic achievement, it cannot be ruled out that isolated associations between VPA and academic achievement still might be present. Kwak et. al (128) analysed MPA and VPA separately and found only VPA to be associated with academic achievement, however solely among girls.

No clear direct or indirect relationship was found between volume or intensity of PA and academic achievement and thus suggests they are largely unrelated in the current study sample. However, there was nothing to suggest a detrimental effect of PA on academic achievement either. This is supported by previous studies showing no associations (131-135) suggesting that PA still has a role in providing beneficial effects on physical health among adolescents (14). In the two studies showing a negative association between PA and academic achievement, one underlined that the negative association was weak (136). The other found a negative association only to be present for PA during weekdays and displayed a curvilinear relationship, suggesting that participants with MVPA close to national recommendations were more likely to have higher academic achievement (102). These results do not, however, present an unequivocal negative relationship.

5.4 Physical activity, mental health, and academic achievement – multifactorial concepts

The current study has explored different associations between PA and SED, variables of mental health and academic achievement through the three years of lower secondary school in Norway, thus monitoring the development of and relationship between important constructs during the adolescent years. Our research focus and related questions are based on hypothesised models of potential relationships. In that regard it is important to acknowledge that all models are simplifications of complex mechanisms. Consequently, PA/SED, mental health, academic achievement and their potential associations are each multifactorial and represent complex processes, which might be influenced by numerous biological, environmental and social factors beyond those included in the current project (17, 79, 102, 176). Authors of a recent systematic review and meta-analysis exploring effects of PA interventions on mental health outcomes also highlight the complexity of measuring PA and mental health in an adolescent population (177). Further, both systematic reviews from Lubans et. al (17) and Neill et. al (177) conclude that the relationships between PA and cognitive or mental health is still not fully clear and could be influenced by other neurobiological, psychological and behavioural factors which are currently not included in their reviews. Whitelaw et. al (79) adds that both PA and mental health are manifest in social context as well as experienced by individuals in subjective ways, thus complicating research on these factors.

Furthermore, the contribution of factors to the outcomes may not work independently but be interrelated. Lubans et. al (17) underscore that multiple independent mechanisms may influence the cognitive or mental health outcomes both in parallel or via interaction with each other. This interrelation between factors is also highlighted by Faught et. al (178) who explored the simultaneous relationship between self-reported MVPA, sleep, diet and screen time on academic achievement. They found that while some health behaviours did not have an individual impact on academic achievement, combined with other healthy behaviours they still may support the outcome. Estrada-Tenorio et. al (102) adds to this by underscoring that variables linked to lifestyles only provide a small part of a complex map of factors that interact to explain academic achievement. Viewed in light of each other, this highlights the complexity of this field of research within the adolescent period of life. The expectation of any predictive model finding strong and enduring associations which are able to explain a large amount of the total variance may not be justified when considering all factors that contribute in different ways. Still, it remains important to explore these potential relationships further in-depth, building on results from previous research in the search for

new knowledge, which further may have implications for practice, and thus could contribute to improving young people's everyday life.

5.5 Methodological discussion

5.5.1 Study design

Papers I-III all present results based on cross-sectional data. As predictor and outcome are ascertained at the same time, they provide a snapshot of a population at one point in time. Their ability to say anything about temporal sequencing and thereby assess causal inference thus remains limited (179). The study design is often referred to as 'prevalence' studies, and is appropriate for exploring the health of populations (180). Such surveillance is useful in situations where data on a population is limited as well as serving as a source of hypothesis generation (180). In Norway there has been a lack of knowledge about the relationships between PA and variables of mental health and academic achievement in the period covering the years at lower secondary school (12-16 years). The cross-sectional data generated from this project thus serve as an important contribution to the overall knowledge base on these variables and relationships among adolescents in Norway.

Papers II-III further present results based on a prospective cohort study where participants were followed annually from 8th to 10th grade (12/13 years – 15/16 years of age). As a cohort study tracks the same people over time, it represents the best way of exploring the development of a behaviour or an association (181, 182). Adolescence is a formative period of life during which young people undergo physical, mental, emotional and cognitive development (7). These changes may influence their PA level, mental health and academic achievement. It is thus important to explore these constructs and their potential relationships using a longitudinally perspective, hence the prospective cohort study design. Nonetheless, when exploring relationships, it is important to underline that only high quality experimental study designs can infer causality between predictor and outcome with any degree of certainty (182). However, although evidence will be less than those from large randomised controlled trials with little loss to follow-up, sophisticated prospective cohort studies may also be able to assess causal inference if key criteria are addressed (183). First, (1.) predictor must be collected prior to the outcome, and (2.) control for outcome at baseline must be made to rule out reverse associations (181-183). In addition, (3.) potential confounding factors at baseline must be controlled for, (4.) high-quality measurements of predictor, outcome and covariates should be used, (5.) a large sample size should be obtained, as well as (6.) conducting robust statistical modelling, preferably using data from three waves. Lastly, (7.) sensitivity analyses to explore robustness to potential bias should be conducted. If all of these criteria are met satisfactory, causal inference may be possible to address (183). In the current study, several of these criteria have been met. In **papers II-III** (and to some extent **paper I**), criteria 1-4 have all been accounted for. As criteria 5 regarding

sample size will vary depending on the research question, there are not any clear-cut definitions on what a 'large sample size' is. In the current study the overall study sample ranged from 552 to 599 participants in T1-T3 and was deemed sufficiently large according to power calculations. Nevertheless, it is important to note that far from all participants provided valid measurements for all variables in the three waves of study. Consequently, most analyses contain a somewhat lower n. The available study samples for the different analyses presented in **papers I-III** are nonetheless deemed satisfactory. Criteria 6 underlines that data from three waves preferably should be used in the statistical modelling thus allowing to control for prior levels of predictor in T1 and exploring how T2 predictor is associated with T3 outcomes (183). The current study has obtained measurements from three waves but has only used change scores derived from T1 and T3 in the longitudinal analyses and are thus not able to fully fulfil this criterion. Finally, criteria 7 regarding sensitivity analyses have not been adequately met in **papers I-III**. All things considered and regardless of results, it would thus not be appropriate to draw any firm conclusions regarding causality from the different papers of this study. Nevertheless, relationships between PA and variables of mental health and academic achievement have been explored using a strong study design and well-established and validated measurements, giving greater confidence in the results. Knowledge from the current study may therefore be viewed as important steppingstones for targeted intervention studies to build on in order to further explore the role of PA on MHP, MWB and academic achievement in adolescence.

The initial aim of the study was to obtain data at the beginning of each academic year (8th, 9th and 10th grade) and provide a longitudinal line of data through lower secondary school. This would have enabled a comparison of the participants from when they started at lower secondary school, through the beginning of their final year. However, due to logistical challenges related to numbers of accelerometers, sufficient personnel to implement the study, as well as fitting the data collection within each school's calendar, it was not feasible to obtain all data within that period. Consequently, some of the participants provided data in mid-September, while other provided data in mid-January. This may have introduced differences in the data provided as a consequence of seasonality (142, 144), but also on the amount of time spent in various grade levels at the time of data collection which may be of relevance for how they respond to the instruments measuring mental health, as well as their PA level. To account for this, season of data collection was adjusted for in all analyses. Because comparability of individual data across years is important when exploring trends over time, we ensured that the data collection was conducted at the participating schools at approximately the same time each year. However, we cannot rule out that a different timing of the data collection (e.g. 2nd term, and thereby capturing the end of 10th grade as well as their graduation grades) might yield different results.

5.5.2 Selection bias

There are several ways of including participants for a prospective cohort study. Although not a guarantee of generalisability, a random selection of participants from the relevant population remains the best approach to aim for this (184). Nevertheless, this is not always a feasible option, and as such, different methods can be used with the limitations they introduce. The current project has made use of non-random sampling which limit conclusions regarding generalisability. However, the sampling procedure sought to ensure that the participating schools were likely to be broadly representative of lower secondary schools in Norway by including schools that represented a diversity regarding geographical location (urban/suburban/rural), school size, type of school (grades 1^{st}-10^{th}/8^{th}-10^{th}), SES of the school and the school's average on standardised national tests. As the participation rate of the study was close to 60 %, 40 % of the invited students decided not to participate. Previous research shows that there often exist systematic differences between participants and non-participants in research studies, and that it is seldom completely random who decides to participate in research studies or not, also known as the "healthy volunteer effect" (185, 186). Participation often correlates with social, educational and health conditions, which further may correlate with risk factors that are defined as outcomes of the study (187). When the population under study is children and adolescents, it is rather difficult to obtain information about the non-participants. Because of their age, they do not yet possess a finished education, occupation or income, which serve as much-used indicators in adult populations (188). However, it is possible to use other indicators, such as parental SES as a proxy (188), or by estimating SES from the economic profile of the area of the schools they attend (189).

To date, research regarding adolescent non-participation in research studies remains limited. However, Winding et. al (190) found a slight over-representation of adolescents living in homes with higher income and education, being brought up by two adults and achieving higher school grades among participants compared to non-participants in a Danish youth cohort. They further explored the losses to follow-up and found these differences to be increased. Although these findings are context specific and cannot be generalised to other studies, they largely support analysis of non-participation among adults (191). It is nonetheless important to note that a higher participation rate will not necessarily eliminate the possibility of selection bias (191) in the same sense that a lower participation rate will not necessarily induce selection bias (187). In the current study, it was not possible to conduct any analyses on the non-participants to explore whether they differed from the participants. As **papers II-III** explored longitudinal data, analyses of those dropping out of the study in T2 or T3 were possible. However, there were few dropouts (see figure 2): 40 related to withdrawing from the project and 29 changed schools. Consequently, such analyses would not yield useful

information about loss to follow-up. However, the current study has collected a large amount of information from the participants and far from everyone provided full sets of measurements for all variables for all data collections. As PA represents the predictor in all hypotheses of the current thesis, we explored whether there were systematic differences between participants with longitudinal PA-data 'valid PA T1+T3' compared with participants not providing longitudinal PA-data 'missing valid PA T1+T3'. Analyses found the 'valid PA T1+T3' to hold lower levels of total PA and MHP, as well as higher levels of SED, BMI, GPA. These results differ somewhat from a previous study exploring longitudinal changes of PA in Norwegian adolescents. They found those providing valid PA data at both time points to have lower BMI (boys and girls) as well as spending more minutes in MVPA (girls) than those lost to follow-up (43). However, it is important to note that although results from analyses of the participants from the current study were significant, differences between the groups varied in size for the different outcomes. This may nevertheless point towards a somewhat selective effect in the loss to follow-up in prospective analyses. Caution should be applied, therefore, regarding the interpretation of these results.

5.5.3 Methodological consideration of measurements

Physical activity

Because the goal of PA epidemiology among others is to gain a better understanding of the relationship between PA and different health outcomes, the validity and reliability of the measures is essential (27)**.** Because of the inherent challenges regarding assessment of PA via self-report among children and adolescents, systematic review studies of the relationship between PA and mental health or academic achievement underscore the necessity of being cautious in the interpretation based solely on self-report (103, 192). The majority of studies comparing self-report with objective measures of PA find low-to-moderate correlations. Thus, it is not surprising that the level of consistency between studies using different measures is low (27). Differences in measures could therefore serve as an explanation for the differences across studies using self-reported or objectively measured PA.

Nonetheless, it is important to note that there is an ongoing discussion whether self-reported and objectively measured PA in fact do measure the same construct of PA. Measuring PA by an objective measure, such as accelerometry, generates information about frequency and duration of movements with different intensities, and does not indicate type or context of activity (103, 131, 133). Self-report on the other hand, may obtain details regarding type and context of the activity undertaken (103, 133). If associations between PA and academic achievement or mental health is dependent on type or context of activity rather than time spent in PA with different intensities, accelerometry will not capture this. In relation to the association between PA and academic achievement, skill-specific

activities (e.g. activities requiring balance, agility, motor control and coordination) that typically do not generate activity counts in an accelerometer, may still capture PA in a wider sense, and thereby be related to academic achievement (103, 131, 175). This hypothesis is supported by a previous systematic review showing a positive relationship between both fine- and gross motor proficiency and academic achievement in mathematics and reading among children and adolescents (193). The authors underline that while the relationship with fine motor proficiency was most pronounced among children, gross motor proficiency in the form of upper limb coordination, speed, and agility, were also evident among adolescents. Hence, objective and self-reported measures of PA may therefore assess different constructs and contexts of PA which further may associate differently with academic achievement (131).

In relation to the association between PA and mental health, there has been an increase in research exploring the relevance of the social context in which the PA takes place and its relationship with variables of mental health (194, 195). Doré et. al (194) found team sports to associate with MWB among older adolescents, while individual sports or informal group PA was not. In relation to MHP, Sabiston et. al (195) found that participation in team sports during high school was associated with lower levels of depressive symptoms in early adulthood, while individual sport participation was not. It has been suggested that the reason for the differences found between individual sports and team sports may be due to the social interaction team sports offer (194, 195). As measurement of social context by accelerometry is not possible, this may explain some of the discrepancies in findings between self-reported- and objectively measured PA and variables of mental health.

Papers I-III have addressed methodological weaknesses in previous research by their use of an objective measure to assess PA. However, by doing so, the contextual information about type of activity and social context of the PA were unavailable. Consequently, to what degree, if any, these contextual PA factors could influence the relationship PA has with academic achievement and mental health (MWB and MHP) in the current study remains unknown.

Shortcomings of accelerometry

Although serving as the method of choice to assess free-living PA among children and adolescents (36, 37), accelerometers also have some limitations. While not being completely waterproof, they cannot measure water activities. Further, accelerometers might not be sufficiently sensitive to capture patterns of SED because of their limitations in the measurement of posture (158). Because they are worn at the hip they also underestimate the energy cost for cycling, upper-body movements, load-carrying activities, and do not take inclination of terrain into account (27, 196). **Paper I-III** sought to account for some of these issues by registering the time spent swimming and/or

cycling in course of the wear period of the accelerometer. Throughout all three time points, the main proportion of pupils reported 0-1 hours of both activities (see appendix VI). Consequently, swimming and cycling was not considered to contribute to underestimating the true activity level, at least not to a large degree.

Despite recent attempts to unify accelerometer data processing criteria (37), there is currently no consensus regarding this, which has further implications for data comparability across studies using different criteria. Data used in **paper I-III**, have been processed according to criteria used in the PANCS studies (43, 65, 66) which have obtained cross-sectional and longitudinal data from nationally representative samples of Norwegian 6-, 9- and 15-year olds. This provides the opportunity for the current PA data to be compared with data from these studies. However, by doing so, PA data from this thesis might not be directly comparable with other studies using different criteria for data processing (e.g. criteria for wear time, non-wear, valid days and cut-points for different intensity levels). Although a recent review exploring data processing criteria did not find sufficient evidence to recommend non-wear criteria for adolescents (37), a minimum of 60 minutes of consecutive zeros has been suggested as the most realistic non-wear criteria when assessing SED and patterns of SED (197). The SED analyses presented in **paper III** used 20 minutes of consecutive zeros as non-wear criteria, and may thus have classified periods as non-wear which might in fact have been time spent in SED.

Mental health

For pre-clinical psychological states (referred to as MHP in this thesis), several instruments designed for use among adolescents have been developed (87, 91). The evidence from systematic reviews indicates that a common approach is to include different instruments as comparable measures (21, 51). In **paper I and III**, MHP was measured using the SDQ (88). Since there is to date, insufficient research exploring the relationship between objectively measured PA and MHP measured by SDQ among an adolescent age group, a wider comparison with studies assessing preclinical psychological state of mental health by different instruments was conducted (e.g. Hopkins Symptom Checklist-10 (116), (Short/) MFQ (118, 120), CES-DC (119)). It is thus important to acknowledge that each instrument may assess different nuances of these states, further limiting their direct comparability.

Likewise, there are different views on what constitutes MWB. Lubans et. al (17) also underline that there is some conceptual overlap across the most common indicators of MWB. Consequently, MWB is measured by different indicators such as life satisfaction, happiness, self-image, global self-esteem, psychological resilience, quality of life, positive- and negative affect (17, 21, 96, 117). The instruments used to assess MWB among adolescents tend to measure one specific dimension of

MWB, rather than acknowledging the multidimensional nature of the construct that extends beyond simply feeling happy or being satisfied with life (77). By using WEMWBS, **paper I and III** have included an instrument that integrates different dimensions of MWB into a more holistic model which is relevant to the period of adolescence. As with preclinical psychological states of mental health, caution must thus be applied when comparing results from different MWB instruments, as they may not be directly comparable.

Further, in addition to the established limitation of self-report among children and adolescents (198), research also discusses the challenges of measuring MWB as it relies on one's own perception of constructs which children and adolescents may not yet be equipped to fully conceptualise (76). Moreover, there may be cultural differences in MWB, where instruments developed in one country may need to be tested for relevance and adjusted to fit a diverse adolescent population from a different country (76, 78). In **paper I and III**, MWB was measured by WEMWBS (78) which is validated for use amongst adolescents from 13 years and onwards (84). However, through piloting the Norwegian translated version, small linguistic changes were made in order to increase the clarity of some of the statements amongst the 8th graders (12-13 years of age) (see appendix III for further details regarding linguistic changes), further underlining the point made by Rose et. al (76) regarding conceptualisation of constructs amongst children and adolescents.

With regard to research on self-esteem, a core problem is that the field is complex and full of definitional and conceptual ambiguity (18). Although constructs of the self differ, they are often used inconsistently or interchangeably (e.g self-esteem, self-worth and self-concept), hence complicating any direct comparison across studies, as well as systematic reviewing of the current research (18, 73). Further, it is debated whether these inconsistencies may account for the conflicting findings reported in reviews and umbrella reviews (73). In **paper I**, SPPA-R was used as a measure of self-esteem among adolescents (19, 20). This measure obtains a score of the respondent's overall sense of worth as a person, entitled 'global self-worth' in addition to domain-specific evaluations of the respondent's competence in different arenas of life. It is underscored that 'global self-worth' is analogous to overall self-esteem and thus enables comparisons of measures of these constructs (20).

Academic achievement

For adolescents still under compulsory education, academic achievement is mainly assessed through school grades or standardised tests (102) and the current evidence base shows that both measures are much used (103). However, whether or not these two indicators of academic achievement in fact are comparable is debated. Further, it must also be recognised that there are differences within each of these indicators. While some studies have used GPA as an overall measure of academic

achievement through school grades, others have used the grade in a specific subject (e.g. mathematics) or a grade average of a compilation of subjects (e.g. mathematics, first- and second language). Additionally, as there are differences within type of standardised tests, these may also differ across studies (106). **Paper I and II** used GPA to measure academic achievement. Results from these studies are compared with research which has used both indicators as a measure of academic achievement. Consequently, interpretation of results may be limited by such a comparison and this may have accounted for some of the differences across studies.

5.5.4 Summary: Strengths and limitations of study design and measurements

First, the measurements used in this study are viewed as a key strength. While accelerometry is used to measure PA in all papers (**paper I-III)** thus eliminating bias associated with self-report (27), **Paper I and III** make use of validated instruments to measure variables of mental health and **paper I and II** use grades obtained from school records to assess academic achievement. Further, anthropometric variables (height, weight, and waist circumference) were measured directly by trained personnel (**paper I-III**). Second, the longitudinal design of the study, where all variables were measured at all time points represent a major strength. Third, the loss to follow-up from T1-T3 were very low (see figure 2), creating a strong longitudinal line of data which enabled exploration of the temporal nature of potential relationships (**paper II and III**). Forth, important covariates were controlled for. Fifth, serving as a less processed variable of PA, average cpm has been presented as a measure of PA volume in all papers (**paper I-III**), thereby avoiding problems related to the lack of consensus in the generation of cut-points for different intensity levels. Fifth, the adherence to PA measurements were high throughout all time points (T1 = 96 %, T2 = 87 %, T3 = 88 %. For further details see appendix VII). There are also several limitations to the study that needs to be addressed. First, although accelerometry serves as a good measure to assess habitual PA in adolescents (30), it is limited by its insufficient ability to accurately assess upper body movements, load-carrying activities, activities on a gradient, cycling and swimming (27, 196). Further, despite the knowledge that a shorter epoch should be applied when obtaining accelerometry measured PA among children and adolescents, the data was aggregated up to a 60 sec epoch when exploring minutes in PA with different intensities (**paper II-III**). Although the intermittency of activity is reduced with age most likely reducing the potential error in precision, it cannot be ruled out that this might have levelled off some of the time spent in MVPA. This will further lead to less accumulated time in MVPA and subsequently an underestimation of the prevalence of participants being categorized as adhering to national recommendations for PA (64). Further, as consensus regarding intensity specific cut-points for PA is yet to be decided upon, comparison with studies using different cut-points is limited (**paper II and III**). In addition, **paper III** obtains data on SED. As accelerometers have limitations to their

measurement of postures (158), this may have led to a less precise measure of patterns of SED in the study sample. Second, **paper I and III** report on variables of mental health. Despite using validated instruments, these may still introduce limitations. The potential of the instrument to be insensitive to change over time (SDQ), along with problems regarding ability to sufficiently discriminating within high (SDQ and WEMWBS) and low scores (SDQ) (85, 91), may limit their ability to assess associations within overall healthy study samples. Third, FAS III was used to obtain data on SES in **paper I-III**. A cross-national psychometric validation of this instrument showed it to discriminate poorly at the higher end of the affluence spectrum, thus revealing ceiling effects for a number of items among the Norwegian study sample (150). This may have entailed an insufficient differentiating of SES in the current study sample. Forth, as the sampling procedure for inclusion of schools in the project was not conducted at random, no definite conclusion regarding generalisability can be drawn. In addition, because the participation rate was 60 % at T1 and no drop-out analysis was possible to conduct, this may have introduced some selection bias into our findings. Analyses of participants providing longitudinal PA data (T1 and T3) compared with participants not providing valid measurements at both time points showed that there were significant differences between the groups (see table 9). Lastly, the inclusion of participants relied on power calculations conducted for the variable MWB (WEMWBS). In retrospect, we acknowledge that power calculations should have been obtained for all outcome variables.

6. Conclusions

Based on this thesis, the following conclusions can be drawn:

I. Overall, there was no clear evidence of any association between intensity or volume of PA or SED and MHP in an overall healthy adolescent study sample, either in the cross-sectional or the longitudinal data. This suggest that MHP may be better explained by factors other than time spent in different movement categories.

II. The relationships between intensity or volume of PA or SED and MWB were less clear, with some evidence suggesting a positive, but small relationship between PA volume and MWB among all in the cross-sectional data from T1. However, the longitudinal data only showed such a relationship to be present among girls. For boys however, a positive relationship between SED and MWB was evident in the longitudinal data.

III. The relationships between PA and measures of self-esteem were only explored cross-sectionally at T1 and solely by their relationship with volume of PA. There was no evidence for a relationship between PA and global self-esteem. However, small relationships between the domain-specific self-esteem measures 'athletic competence' and 'social competence' and PA volume were evident.

IV. No evidence for a direct or indirect relationship between intensity or volume of PA and academic achievement was found either in cross-sectional or longitudinal data, suggesting that they were largely unrelated in the current study sample.

7. Implications and future directions

Doing well at school as well as sustaining good mental health are seen to be critical determinants of adolescents' current and future health as well as of their future educational and social outcomes (5, 7-9). Consequently, it is important to contribute further knowledge on how to best promote and support adolescents' mental health and achievement through, for example, physical activity. This study presents novel data on the relationships between PA and variables of mental health and academic achievement during the three years adolescents attend lower secondary school in Norway. The findings provided in this study suggest that for an overall healthy adolescent study sample, no strong relationships between PA and variables of mental health or academic achievement was present in this period of life. This is, nonetheless, not synonymous with concluding that PA is unimportant for adolescents' mental health and academic achievement. However, it contributes to the recognition of the multifactorial and complex nature of these constructs. The results suggest that several questions remain and should be further explored in future research.

First, it is important to consider how mental health is operationalised and measured when exploring its relationship with PA and SED. As there is a lack of consistency regarding both operationalisation of concepts and instrument used to measure mental health, there is a need to further explore relationships between PA and various indicators of mental health by replicating previous study designs and applying these to different study samples to explore whether results differ. Furthermore, the different dimensions of mental health (e.g. MHP and MWB) may have a different relationship with PA. Future research should therefore provide a rationale for each specific dimension to be explored as well as justification for specific measurement instruments.

Although serving as a more precise measure of volume and intensity of PA, accelerometers are unable to obtain information on type and context of PA which are factors that also may be of relevance to mental health. Consequently, it is important for future research to explore this relationship further including both objective- and self-reported measures to be able to obtain a more in-depth understanding of all aspects of PA and whether they relate differently with MHP. Moreover, the current national recommendations for PA for children and adolescents states that the activity undertaken must be of moderate to vigorous intensity to provide an effect on health (58). However, the foundations of these recommendations can only provide evidence of a dose-response relationship between PA and all-cause mortality, cardiovascular disease mortality and incidence of type 2 diabetes among adults (199). Hence, there are, to date, insufficient evidence for dose-response relationships between PA and health outcomes in children and adolescent. It may be possible that, if a dose-response relationship exists between PA and different variables of mental

health, improvements require a different 'dose' of PA than for variables of physical health as well as different 'doses' for different age groups (e.g. lower intensity, more context specific, different duration and frequency). Consequently, there is a need to explore whether recommendations for mental health may differ from those for physical health.

The data accelerometers are able to provide regarding SED are also limited to volume and pattern and cannot address which SED have been undertaken. Because different types of SED (e.g. mentally active vs. mentally passive SED) may associate differently with constructs of mental health (161, 162), future research might combine objective measures with subjective measures to enable contextual information is captured and potentially generate a more detailed picture of the relationship between SED and constructs of mental health among adolescents.

Although the short-term relationship between PA and academic achievement has been explored extensively in recent years, the evidence is still inconclusive regarding this relationship. Consequently, there is a need for more high-quality studies using objective measures as well as equal assessment of academic achievement to ensure better comparability across studies. Moreover, there is still limited research on the long-term relationship between PA and later academic achievement and educational success, especially with regard to use of objective measures to assess PA.

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Paper I

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

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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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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.

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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.

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Paper II

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Physical activity and academic achievement among Norwegian adolescents: Findings from a longitudinal study

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ABSTRACT

Regular physical activity (PA) has been associated with academic achievement, but the evidence is mainly based on cross-sectional research and self-reported measures of PA. The purpose of the current study was to explore the longitudinal relationship between objectively measured PA and academic achievement among a cohort of adolescents in Norway between 2016 and 2018. As a secondary aim, an indirect relationship via waist circumference (WC) and sleep duration was assessed. Data from 599 adolescents (54.4% female, mean age at baseline ± SD 13.3 ± 0.3 years) were collected annually during their three years at lower secondary school. PA was measured objectively using accelerometry. Academic achievement was assessed using grade point average (GPA) from school records. Linear regression analysis was performed to explore associations between longitudinal changes in measures of PA (Total PA and moderate-to-vigorous PA [MVPA]) and academic achievement directly or via mediators. Results showed no significant associations between Total PA or MVPA and academic achievement, either in the main analyses or through mediation of WC and sleep duration. The results contribute to a growing evidence base of studies showing no association between objectively measured PA and academic achievement among adolescents.

1. Introduction

Succeeding academically during compulsory education is associated with broad and enduring advantages for later educational success, income, and better physical and mental health (Marmot, 2010). This well-documented association highlights the importance of identifying factors that might contribute to academic achievement. There has long been an assumption that regular physical activity (PA) could positively contribute to academic achievement via enhancement of cognition (Lubans et al., 2016).

The volume of studies exploring the association between PA and academic achievement has increased substantially in recent years, alongside an increase in systematic reviews (Donnelly et al., 2016; Marques et al., 2017; Poitras et al., 2016; Singh et al., 2018). However, results are inconsistent, and most reviews conclude that there is a need for further research that addresses the methodological weaknesses of studies. The majority of studies have used a cross-sectional design, which is subject to cohort effects and cannot provide information about changes in predictor or outcome experienced by a single individual (Dumith et al., 2011). A longitudinal design can overcome these inherent limitations and is thus preferable when exploring associations between predictor and outcome variables that might develop over time.

The lack of comparable measurements across studies has been put forward as an additional explanation for the inconsistency in findings (Marques et al., 2017). Studies in which PA has been assessed by self-report tend to find an association with academic achievement (Kantomaa et al., 2016; Kristjansson et al., 2010; Suchert et al., 2016), whereas those in which PA has been objectively measured frequently report null-findings (Corder et al., 2015; Oliveira et al., 2017; Syväoja et al., 2013; van Dijk et al., 2014). However, the number of studies that have used an objective measurement of PA remains small (Owen et al., 2018). In their review, Marques et al. (2017) explored the relationship between academic achievement and PA both by self-report and objective measures. They found that while self-reported PA was consistently and

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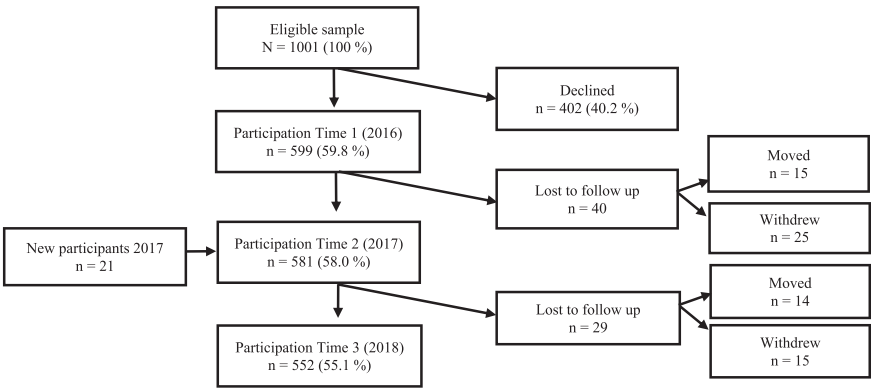


Fig. 1. Study population and participation.

positively associated with academic achievement, there was an inconsistent relationship between objectively measured PA and academic achievement. There was, nevertheless, nothing to suggest that there was a detrimental effect of PA. This is also supported by Syväoja et al. (2013) who assessed intensity-specific PA both by accelerometer and self-report. They found no association between objectively measured moderate-to-vigorous physical activity (MVPA) and grade point average (GPA), whereas they found a positive association between self-reported MVPA and GPA. They suggest that this inconsistency might be explained by these measurements not necessarily measuring the same construct of PA. Children and adolescents are especially at risk of over- or under-estimating PA levels through self-report because of a more pronounced tendency than adults for recall and social desirability biases (Adamo et al., 2009). Marques et al. (2017) thus state that conclusions based solely on self-reported PA should be interpreted with caution. Given that objective measures can produce more robust estimates of PA (Adamo et al., 2009), their use has been advocated (Poitras et al., 2016).

PA is often quantified as total volume (total PA) or time spent in different intensities (Chomistek et al., 2017). Previous search shows that there might be differences in relationship with academic achievement depending on PA measure used (Booth et al., 2014), where positive associations have been reported more frequently for higher intensities (Kwak et al., 2009). However, research also shows evidence of a negative relationship between MVPA and academic achievement (Esteban-Cornejo et al., 2014; Estrada-Tenorio et al., 2020). There is, therefore, a need to explore this further.

Any association between PA and academic achievement might not, however, be direct, but indirect and act via mediators. Evidence regarding potential biological or psychosocial mediators is scarce, indicating a need for mediation studies (Singh et al., 2018). Obesity has been shown to be negatively related to both PA and cognitive functioning (Chang et al., 2017) and its role in the hypothesised relationship between PA and cognition has been explored in a review by Chang et al. (2017). They found two studies exploring weight status as a potential mediator of the association between PA and cognition, both conducted on an adult population. Although both studies found evidence of a mediating effect of obesity, only one study was reported to sufficiently test the mediator model. Evidence of mediation among adults was therefore limited. However, Lima et al. (2019) found an association between both MVPA and VPA and academic achievement mediated by body composition measured by waist circumference (WC) among children. To our knowledge, this has not previously been explored among adolescents.

Lubans et al., (2016) propose that changes in cognitive functions resulting from PA might be mediated by changes in associated behaviours, such as sleep duration. Khan et al. (2015) found that longer sleep duration was associated with higher levels of PA, and in a systematic review (Chaput et al., 2016), evidence of an association between longer sleep duration and better academic achievement among children and youth was found. Sleep duration might then serve as a mediator in the relationship between PA and academic achievement and has not, to our knowledge, been explored hitherto. Syväoja et al. (2018) found a negative indirect association between self-reported MVPA and academic achievement via later bedtime, solely among girls. However, no relationship was present for objectively measured MVPA.

The purpose of this study is, therefore, to explore whether longitudinal changes in objectively measured PA [Total PA and MVPA] are associated with changes in academic achievement directly or via mediation of WC or sleep duration. We also explore whether there are differences between boys and girls.

2. Method

2.1. Design and participants

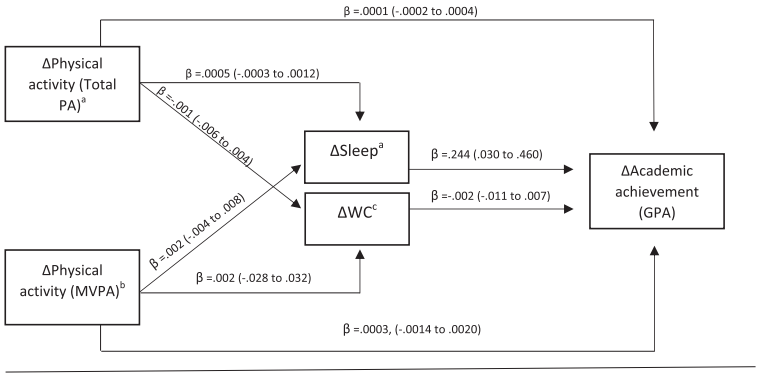
A prospective cohort study was carried out, which collected annual data from adolescents in 11 different schools during their three years in lower secondary school (normal age range 12–16 years). The schools were purposively recruited from three counties on the east and west side of Norway and were selected on the basis of school size, type of school (grades 1–10 or 8–10) location (urban, suburban and rural), socio-economic status (SES) and schools average score on National tests. Detailed description of the methodology has been published elsewhere (Barth Vedøy et al., 2020).

Data collection was conducted annually during the first semester of 8th, 9th, and 10th grade (2016–2018) for the predictor and mediator variables and at the end of first semester for the outcome variable. The study population consisted of all consenting adolescents starting in 8th grade in the autumn of 2016. Fig. 1 shows the number of adolescents invited and the proportion who participated throughout the three waves of the study.

2.2. Measurements

2.2.1. Physical activity

Physical activity was measured objectively using accelerometry (ActiGraph GT3X+ and GT3X-bt, LLC, Pensacola, Florida, USA). The monitor was placed on the right hip in an elastic belt. The participants were asked to wear it for seven consecutive days. Research staff attached the monitor during the first school visit to ensure correct placement. The



Note. MVPA = moderate to vigorous physical activity, WC = waist circumference, GPA = grade point average, β = standardized regression coefficient.
[a] Adjusted for baseline sex, BMI, SES, season of data collection and cluster sampling
[b] Adjusted for accelerometer wear time, baseline sex, BMI, SES, season of data collection and cluster sampling
[c] Adjusted for baseline sex, SES, season of data collection and cluster sampling

Fig. 2. Parameter estimates of the regression coefficient of the longitudinal associations between changes (2016–2018) in physical activity (Total PA and MVPA), WC, sleep duration and academic achievement. (n = 379–468).

participants were instructed to wear the monitor during all waking hours except while swimming or doing other water activities. The monitor was initialised to start recording at 06:00 the day after it was delivered to the participants. After excluding data recorded between 00:00 and 06:00 and all intervals of ≥20 consecutive minutes of no recording (non-wear), data were included if the participants had ≥480 min of valid activity recordings each day. Analysis showed that participants with 2–3 days (Time 1 and 2 [T1 and T2]) and 1–3 days (Time 3 [T3]) of valid measurements did not differ from those with ≥4 days, and were thus included in further analysis. A 10-second epoch was used to register number of counts. For intensity specific analyses, data were aggregated to a 60-second epoch. The use of these criteria are in accordance with previous research using ActiGraph on similar age groups (Dalene et al., 2018b; Owen et al., 2018). As an overall measure of PA (Total PA), average counts·min^{-1} (CPM) throughout the assessment period was used. We defined sedentary behaviour (SED), light PA (LPA) and moderate to vigorous PA (MVPA) as <100 CPM, 100-1999 CPM and ≥2000 CPM respectively. These cut-points are in accordance with previous research on adolescents in Norway (Dalene et al., 2018b).

When returning the accelerometer, participants were asked to register the amount of time spent doing activities that are poorly measured with the accelerometer (cycling) or required removal of the device (swimming). Time spent swimming and/or cycling among the majority of participants in this study was very low and these data were thus not included in further analyses.

2.2.2. Academic achievement

Academic achievement was assessed through the midterm grades from school records. Grade point average (GPA) was used as the indicator of academic achievement. GPA represents the average score achieved by the pupil in all subjects. In Norway, pupils in the same grade follow the same core subjects. The grade range is 1–6 where 6 represents the highest achievement possible. In the post-hoc analysis, the study sample was divided into a low GPA group (GPA 1.00–3.99) and a high GPA group (GPA 4.00–6.00) based on GPA T1.

2.2.3. Waist circumference

WC was measured to the nearest 0.5 cm with a medical measuring tape midway between the lowest rib and the top of the iliac crest at the end of gentle expiration. Measurements were conducted twice if the difference was ≤1 cm and three times if the difference was >1 cm. The average value of the two closest measurements was used.

2.2.4. Sleep

The participants reported the average times for going to bed and getting up in the morning on school days in a questionnaire (Supplementary Table S1). To estimate sleep duration, we subtracted and added 30 min to the lower (before 06:30/20:00) and upper (after 08:00/24:00) categories, respectively. In the remaining categories, the midpoint was used (e.g. 07:00–07:30 recoded to 07:15). The following algorithm was used for participants going to bed before 24.00: (sleep duration = 24 – CTIME.HOURS (bedtime – out of bed)) and (sleep duration = CTIME. HOURS (out of bed – bedtime)) for those going to bed after 24.00. This yielded sleep duration in hours for the participants (Dalene et al., 2018a).

2.2.5. Additional covariates

According to previous research, the following variables may influence the variables of interest: sex, body mass index (BMI), SES and seasonality (Faught et al., 2017; Owen et al., 2018; Rich et al., 2012). BMI was calculated using weight and height (kg·m^{-2}). 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., 2018b).

SES was measured through The Family Affluence Scale. This scale measures material affluence, and can be used as a proxy for SES (Hartley et al., 2016). Based on this scale, a score of *relative family affluence* was constructed by summing scores on all answers and categorising them in three broader groups (the lowest 20%, the middle 60% and the highest 20%).

Seasonality was defined by two categories depending on the time of data collection at the different schools (1: Sept–Oct, 2: Nov–Jan).

2.3. Data analyses

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 and Stata Statistical Software, version 16.0 (Copyright 1985–2019 StataCorp LLC), Texas 77,845 USA. Descriptive

data are presented as frequencies, mean and SD, and 95% confidence intervals (CI) where appropriate. Hayes' Process Macro v3.5 for SPSS was used to explore interactions by sex. As analyses showed no interaction, all data were analysed collectively. To test whether changes in objectively measured PA [Total PA and MVPA] was associated with changes in academic achievement directly or via mediators, variables of change (Δ) were created by subtracting T3-values from T1-values. Associations between the change variables were analysed by linear regression, adjusted for T1 covariates including sex, BMI, SES and seasonality (Fig. 2). All intensity specific analyses were adjusted for wear time of the accelerometer. Mediation of WC or sleep duration was explored through pairwise analyses between predictor and outcome, predictor and hypothesised mediators, and hypothesised mediators and outcome. Further, post-hoc analysis of groups with low GPA (1.00–3.99) and high GPA (4.00–6.00) were conducted to explore whether the pattern differed between these groups.

To test whether changes in PA [Total PA and MVPA] prospectively could indicate academic achievement at T3, linear regression analyses were used, adjusted for T1 covariates. Finally, linear regression analyses of each time point were conducted in order to provide a descriptive supplement to the longitudinal analyses (Table 2). The crude model showed associations between Total PA and academic achievement, whereas the adjusted model corrected for sex, BMI, SES and seasonality. All measures were scaled up to show changes in dependent variables occurring after changes in Total PA of 100 CPM. For informational purposes, separate analyses for boys and girls are presented in Supplementary file, Table S2.

Because of the clustered nature of the data, all analyses were adjusted for school-level clustering.

2.4. Ethics

The study was approved by the Norwegian Centre for Research Data (project no. 48192). As the participants were between 12 and 13 years at the time of enrolment in the study, written informed consent was obtained from pupils and his/her legal guardian prior to data collection.

3. Results

3.1. Descriptive results

BMI, WC and GPA significantly increased in both boys and girls from T1 to T3, while amount of sleep decreased significantly. The two measures of PA decreased significantly among girls from T1 to T3 ($p = .020$ for Total PA and $p \leq 0.001$ for MVPA). This decrease was not found among boys ($p = .589$ for Total PA and $p = .085$ for MVPA) (see table 1).

3.2. Longitudinal results

Neither change in Total PA nor MVPA were directly associated with change in academic achievement (see Fig. 2). No indirect associations via change in WC or sleep duration were present. Post-hoc analyses, where the study sample was divided into high and low GPA groups were conducted (data not shown). The results from these analyses did not deviate from the results of the main analysis.

Results from the prospective analyses showed no associations between change in Total PA or MVPA and academic achievement at T3 (see Fig. A1).

3.3. Cross-sectional results

Table 2 shows the cross-sectional associations between Total PA and academic achievement measured by GPA at T1, T2 and T3. Total PA was significantly associated with academic achievement in T2, but solely in the adjusted analysis ($p = 0.028$) and the association was weak. Gender specific analyses (Supplementary Table S2) shows that this association was only significant among boys.

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

Characteristic	Time 1 (2016) n = 599	Time 2 (2017) n = 581	Time 3 (2018) n = 552
Age			
Boys	13.4 (0.3)	14.4 (0.3)	15.4 (0.3)
Girls	13.3 (0.3)	14.3 (0.3)	15.3 (0.3)
Height (cm)			
Boys	163.9 (8.6)	171.3 (8.2)	176.9 (7.5)
Girls	161.7 (6.9)	165.0 (6.6)	166.3 (6.4)
Weight (kg)			
Boys	53.0 (11.8)	60.7 (13.5)	66.8 (13.6)
Girls	52.8 (9.9)	56.6 (9.8)	59.2 (9.8)
BMI (kg/m^2)			
Boys	19.6 (3.3)	20.5 (3.7)	21.3 (3.7)
Girls	20.0 (3.1)	20.8 (3.0)	21.4 (3.0)
WC (cm)			
Boys	73.2 (9.7)	75.3 (10.0)	76.4 (9.4)
Girls	70.5 (8.8)	71.4 (7.7)	70.9 (7.4)
Sleep duration (h)			
Boys	9.3 (0.9)	8.7 (0.9)	8.4 (0.9)
Girls	9.1 (0.8)	8.7 (0.9)	8.4 (0.9)
Total PA (CPM/d)			
Boys	474.4 (178.7)	476.8 (177.5)	460.9 (204.7)
Girls	402.2 (118.6)	399.9 (127.5)	383.5 (138.3)
SED (min/d)			
Boys	548.4 (74.4)	541.7 (78.7)	542.1 (99.6)
Girls	565.7 (55.4)	561.3 (64.6)	564.1 (69.6)
LPA (min/d)			
Boys	172.2 (34.1)	167.6 (34.3)	140.8 (37.3)
Girls	161.4 (32.3)	153.9 (32.2)	137.6 (30.4)
MVPA (min/d)			
Boys	63.9 (22.9)	62.4 (24.3)	58.1 (26.7)
Girls	54.0 (18.5)	53.6 (19.4)	50.1 (21.4)
Meeting act. reg (%)			
Boys	53.3	53.6	43.8
Girls	36.3	37.1	29.5
GPA			
Boys	3.8 (0.6)	3.9 (0.7)	4.0 (0.7)
Girls	4.1 (0.7)	4.3 (0.7)	4.4 (0.8)

Note. BMI = body mass index, WC = Waist circumference, Total PA (CPM) = average daily counts per minute, SED = average daily sedentary behaviour, LPA = average daily light physical activity, MVPA = average daily moderate to vigorous physical activity, Meeting act.reg = Meeting national recommendations of an average of ≥60 min MVPA per day, GPA = grade point average, CPM/d = counts per minute per day, min/d = minutes per day.

4. Discussion

The aim of the study was to explore whether the longitudinal change in objectively measured PA [Total PA and MVPA] was associated with change in academic achievement directly or via mediators. We found no association between longitudinal changes in PA levels [Total PA and MVPA] and academic achievement in the study sample of Norwegian adolescents, not by analysing the study sample as a whole, by grade specific analysis, or through mediators. There are several possible explanations for these findings.

Previous research shows a diverse picture of the association between PA and academic achievement, and results seem to be somewhat dependent on the way PA is measured. The current study adds to this by showing no significant association between objectively measured PA and academic achievement in the longitudinal analyses. Although assessing PA by an objective measure generates information about duration of movements with different intensities and is generally regarded as producing more robust estimates (Adamo et al., 2009), it does not indicate type of activity (Marques et al., 2017; Syväoja et al., 2013). Given the possible relationship between motor control and cognitive development, skill-specific activities that do not generate

Table 2
Cross-sectional associations between Total PA and academic achievement analysed with a multiple linear regression model (n = 402–570).

	Crude[a]				Adjusted[b]			
	n	β	95% CI	p	n	β	95% CI	p
GPA Time 1	570	−0.009	−0.053, 0.035	0.650	518	0.006	−0.041, 0.054	0.767
GPA Time 2	499	0.026	−0.010, 0.061	0.137	435	0.045	0.006, 0.084	0.028
GPA Time 3	458	−0.021	−0.061, 0.020	0.289	402	−0.010	−0.062, 0.041	0.670

Note. GPA = grade point average, β = standardized regression coefficient.
All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.
[a] Adjusted for cluster sampling.
[b] Adjusted for cluster sampling, sex, BMI, SES and season of data collection.

activity counts might be relevant in explaining the relationship between PA and academic achievement (Marques et al., 2017), an issue that might be addressed in future research. However, analysis showed a cross-sectional association between Total PA and academic achievement at T2. It is possible that the association between PA and academic achievement differs between the years at lower secondary school, although the association was very small, and its consequence in real life difficult to infer. Furthermore, a longitudinal design generates more robust data than a cross-sectional design, putting a stronger emphasis on the results from the former.

Longitudinal associations were explored via change variables of both predictor and outcome. This might affect the results in situations where stability of variables over the follow-up period is high. In the current study, PA decreased significantly among girls, and GPA increased significantly among both boys and girls from T1 to T3. Stability of data is therefore unlikely to explain the results. A ceiling effect might also be an explanation for lack of association when change scores are analysed (Resaland et al., 2016). Those with already high GPA from T1 do not have the same possibility for further increase as those with lower GPA. Post-hoc analyses explored this potential explanation and found no evidence to suggest that a ceiling effect could explain the lack of significant associations in the current study sample.

Adolescence is an extended period of considerable physical and cognitive development (Paus, 2005). The follow-up period may not have been sufficiently long for associations between PA and academic achievement to emerge. A longitudinal study based on self-reported PA with a 30-year follow-up found long-term associations between change in PA (between the years of 12 and 15) and subsequent educational attainment in adulthood (Kari et al., 2017). However, when adjustments for individuals' prior academic achievement were included, the strength of the associations decreased. This suggests that the results are partly influenced by the higher GPA of physically active adolescents, and further raises the question about a selection effect.

In contrast to Lima et al. (2019), the current study showed no mediation effect via WC, neither through analysis of the entire study sample, or grouped by low- and high GPA. While the current study used GPA as a measure of academic achievement, Lima et al. (2019) used a composite score of national standardised tests in Danish and Mathematics. School grades assess a broad range of competencies, but might be influenced by teachers' perceptions (Marques et al., 2017; Owen et al., 2018). Although standardised tests yield an unbiased measure, they only assess a narrow range of the skills and competencies of the pupil (Owen et al., 2018; The Norwegian Directorate for Education and Training, 2019). These differences in outcome measure might serve as an explanation for the dissimilar results. In addition, Lima et al. (2019) targeted a younger age group (7–12 years) than the current study (12–16 years). At a theoretical level, associations might be present among children without tracking into adolescence.

Neither the main nor post-hoc analysis showed any evidence for sleep duration serving as a mediator between PA and academic achievement. Although these results contrast with those of Syväoja et al. (2018) where a subjective measure of PA was used, they are consistent with results from the same study where an objective measure was used.

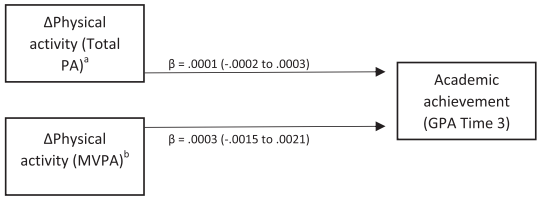
There were no differences between analyses using Total PA and MVPA as predictor variables in the present study, giving no evidence for an intensity-dependent association. This is consistent with previous research which found no direct association between PA and academic achievement in overall analysis of MVPA and/or VPA (Corder et al., 2015; Syväoja et al., 2013; van Dijk et al., 2014). However, Kwak et al. (2009) found a positive association between VPA and academic achievement, solely among girls. In a longitudinal study by Owen et al. (2018), positive associations were found through analysis of associations between changes in MVPA and changes in academic achievement among girls. The enduring differences between studies prevent us from drawing any conclusions regarding the putative role of intensity and gender differences in the analysis of PA and academic achievement. Further research is needed to explore this relationship.

4.1. Strengths and limitations

A key strength of the current study is its longitudinal design where both predictor and outcome are measured at all three time points. Even though the initial participation rate was 60%, and may have introduced some selection bias into the results, the attrition rate from T1 to T3 was very low (see Fig. 1). In addition, the analyses controlled for many well-known confounders. The use of objectively measured PA also strengthens the study's quality. However, use of accelerometers also have some limitations. While worn at the hip and not completely waterproof, their ability to measure upper body movements, load-carrying activities, cycling and swimming are limited (Shephard and Aoyagi, 2012). Time spent swimming and/or cycling among the majority of participants in this study was very low. Consequently, it is unlikely to have led to a large underestimation of activity level. While there remains no consensus regarding cut-points for intensity-specific PA, the present study used the same cut-points as other studies of Norwegian adolescents have done. This may limit comparability across studies using different cut-points. Finally, because the selection of participating schools was not conducted at random, selection bias cannot be ruled out, and generalisability is limited.

5. Conclusion

PA was unrelated to academic achievement in the current study sample, both through a direct association, and via mediators. These results contribute to a growing evidence base showing no relation between objectively measured PA and academic achievement among adolescents. However, it is important to note that although no positive association was found, there was nothing to suggest a detrimental effect of PA either, further implying that PA can be promoted for its well-known beneficial effects on health among adolescents. Future research should explore these associations on a long-term basis where important covariates of SES is also accounted for. Finally, there is a need for research to further explore the potential long-term influence of sleep duration on these associations.



Note. MVPA = moderate to vigorous physical activity, GPA = grade point average, β = standardized regression coefficient.
[a] Adjusted for baseline GPA, sex, BMI, SES, season of data collection and cluster sampling
[b] Adjusted for accelerometer wear time, baseline GPA, sex, BMI, SES, season of data collection and cluster sampling

Fig. A1. Parameter estimates of the regression coefficient (95% CI) of the prospective associations between changes (2016–2018) in physical activity (Total PA and MVPA) and academic achievement Time 3. (n = 401).

CRediT authorship contribution statement

Ingeborg Barth Vedøy: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Visualization. **Knut Ragnvald Skulberg:** Methodology, Formal analysis, Writing - review & editing, Visualization. **Sigmund Alfred Anderssen:** Methodology, Formal analysis, Writing - review & editing. **Hege Eikeland Tjomsland:** Conceptualization, Writing - review & editing. **Miranda Thurston:** Conceptualization, Project administration, Funding acquisition, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Fig. A1.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2021.101312.

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Supplementary file

Table S1. Questions about usual time for going to bed and getting up in the morning on school days from the questionnaire.

Sleep duration	
When do you usually get out of bed on schooldays?	□ Before 06:30, □ Between 06:30 and 07:00, □ Between 07:00 and 07:30, □ Between 07:30 and 08:00, □ After 08:00
When do you usually go to bed on schooldays?	□ Before 20:00, □ Between 20:00 and 21:00, □ Between 21:00 and 22:00, □ Between 22:00 and 23:00, □ Between 23:00 and 24:00, □ After 24:00

Table S2. Cross-sectional associations between Total PA and academic achievement analysed with a multiple linear regression model (n= 402-570)

	Crude[a]				**Adjusted[b]**			
	n	**β**	**95 % CI**	**p**	**n**	**β**	**95 % CI**	**p**
GPA Time 1	570				518			
Boys	254	-0.002	-0.05, 0.04	.931	237	0.0002	-0.05, 0.05	.994
Girls	316	0.05	-0.05, 0.15	.280	281	0.01	-0.08, 0.11	.759
GPA Time 2	499				435			
Boys	208	0.05	-0.01, 0.11	.091	186	0.04	0.006, 0.07	.024
Girls	291	0.07	-0.04, 0.17	.189	249	0.06	-0.04, 0.17	.203
GPA Time 3	458				402			
Boys	190	-0.01	-0.07, 0.05	.667	170	-0.02	-0.07, 0.03	.341
Girls	268	0.03	-0.06, 0.11	.492	232	0.001	-0.09, 0.09	.979

Note. GPA = grade point average, β = standardized regression coefficient

[a]Adjusted for cluster sampling

[b]Adjusted for cluster sampling, 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.

Paper III

Title:

The longitudinal association between objectively measured physical activity and mental health among Norwegian adolescents

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Abstract

Background: Mental health among young people in many countries, including Norway, seems to be deteriorating. Physical activity (PA) has been positively associated with mental health. However, methodological issues related to study design and measurement of PA and mental health outcome currently limits our understanding of the relationship. The purpose of the present study is to explore the longitudinal relationship of objectively measured PA (total PA and moderate-to-vigorous PA [MVPA]) and sedentary behaviour (SED) with mental wellbeing (MWB) and mental health problems (MHP).

Methods: Data from 599 adolescents (54.4 % female, mean age at baseline ± SD 13.3 ± 0.3 years) were collected annually during their three years at lower secondary school. PA was measured using accelerometry. MWB was measured using the 'Warwick-Edinburgh Mental Wellbeing Scale' and MHP were measured by 'Strengths and Difficulties Questionnaire'. Multiple linear regression was performed to explore relationships between changes in PA/SED and MWB/MHP.

Results: Among boys, an increase in SED was positively associated with MWB (β =0.05, 95% CI: 0.01 to 0.10), whereas a small positive association between an increase in total PA and MWB was found in girls (β = 1.13, 95% CI: 0.05 to 2.21). There were no associations between changes in any movement categories (total PA, MVPA, SED) and score on MHP at T3, neither for girls nor boys.

Conclusion: This study provided no clear evidence of any association between change in volume or intensity of PA and MHP among an overall healthy adolescent study sample. There was, however, evidence of a relationship between increased SED and MWB among boys and increased volume of PA and MWB among girls. The relationship between movement categories and mental health may depend on the measurement used to assess both PA/SED and variables of mental health. To improve comparability across studies, future research should include both objective and subjective measures of PA/SED and explore their relationship with variables of mental health. Further there is a profound

need for researchers to be clear on what construct of mental health they are exploring, and how they operationalise its measurement.

Keywords: Physical activity, Accelerometry, Mental wellbeing, Mental health problems, Adolescence, Prospective cohort study

Introduction

Mental health among young people has received increasing attention in recent years especially given its significance for a healthy transition to adulthood [1]. Yet international trends from high-income countries suggest their mental health is deteriorating, particularly among adolescent girls [2-4]. These trends are reflected in the increase in diagnosis and treatment of mental disorders over the past few decades [2]. In 2019, mental disorders represented the 4th leading global cause of disability-adjusted life-years among youth (10-24 years), contributing significantly to adolescents' overall health burden [5]. Similar trends among youth have been reported in Norway, which show that mental health problems (MHP) vary according to age and sex, with older adolescent girls showing a larger increase in MHP over time than younger boys [6]. Although trends are complex, the apparent deterioration in young people's mental health has stimulated extensive research into putative risk and protective factors. The role of physical activity in enhancing mental health and preventing MHP during adolescence has received particular attention as this is a period during which not only most mental disorders occur [7] but also levels of physical activity (PA) decline [8, 9].

There is evidence from umbrella- and systematic reviews to indicate that PA is positively associated with various indicators of mental health among children and adolescents [10-13] and that relationships might be more consistent and robust for PA at higher intensities, (moderate-to-vigorous intensity PA [MVPA]) [14]. However, the strength of these relationships is weak to moderate. Methodological weaknesses in study design and measurement of PA have been put forward as limitations of the current knowledge base [11, 13]. Research using stronger study designs (longitudinal studies) and objective measures of PA have been called for to further clarify the relationship [12]. Alongside these methodological concerns, the conceptualization of mental health has increasingly been recognised as multidimensional, comprising both negative (e.g. depression and anxiety) and positive dimensions (e.g. mental wellbeing [MWB] and self-esteem) [12]. According to Westerhof and Keys' [15] two continua model, MHP or mental disorders and MWB are presented as

two distinct but related dimensions. As they explain, the absence of negative indicators does not necessarily imply the presence of high levels of wellbeing and vice versa. The majority of research in the PA field to date has focused on negative indicators of mental health, such as MHP or mental disorders.

To the best of our knowledge, five longitudinal studies have, in varying ways, sought to address these methodological concerns among adolescents [16-20]. The relationship between PA and MHP was addressed in 4/5 studies, of which no association was found [16-19]. Within the PA-MWB relationship the findings were mixed showing both positive [20] or no [16] association. The heterogeneity of these studies should be noted, however. Not only have they been carried out on samples of young people from various countries where population levels of mental health and related social norms may be different, they have also used diverse instruments to measure MHP and MWB.

Recently, more attention has also been paid to the relationship between sedentary behaviours (SED) and indicators of mental health, and the role of SED in the mental health of young people was thus explored in a recent systematic review [13]. This found evidence for an inverse association between SED and satisfaction with life and happiness, as well as a positive association between SED and MHP. The authors underline the need for future research to explore relationships of SED and other indicators of MWB, for which there is currently minimal evidence.

The purpose of this study was therefore to explore whether changes in movement categories [total PA, MVPA and SED] were associated with MHP or MWB. Further, the study sought to explore whether different PA transitions were associated with MHP or MWB.

Methods

Study design and participants

In 2016, all students starting 8th grade (12-13 years) in 11 lower secondary schools were invited to participate in a prospective cohort study. The schools were recruited from two counties on the east and west side of Norway and were selected on the basis of school size, type of school (grades 1-10 or 8-10) location (urban, suburban and rural), socio-economic status and a school's average score on National tests. Detailed description of the methodology has been published elsewhere [21]. Annual data collection took place during the first semester of 8th, 9th and 10th grade. Figure 1 illustrates students' participation.

Figure 1. Flowchart of the study population and participation.

Measurements

Physical activity

Physical activity was measured objectively, using ActiGraph GT3X+/bt (LLC, Pensacola, Florida, USA). The monitor was placed on the right hip in an elastic belt. The participants were asked to wear it for seven consecutive days. To ensure correct placement, research staff attached the monitor during the first school visit. The participants were instructed to wear the monitor for all waking hours, except while doing water activities. The monitor was initialised to start recording at 06:00 the following day. After excluding data recorded between 00:00 and 06:00 and all intervals of ≥20 consecutive minutes of no recording (non-wear), accelerometer data were included if the participants had ≥480 minutes of valid activity recordings each day. A minimum of 4 days of valid data are recommended to achieve satisfactory reliability [22]. However, as analyses showed that participants with 2-3 days (Time 1 and 2 [T1 and T2]) and 1-3 days (Time 3 [T3]) of valid measurements did not differ from those with ≥4 days, these were included in further analyses. Data was downloaded in a 10 sec epoch but aggregated up to a 60 sec epoch for the intensity specific analysis. As an overall measure of PA (total PA), average counts·min^{-1} (CPM) throughout the assessment period were used. We defined SED, light

intensity PA (LPA) and MVPA as <100 CPM, 100-1999 CPM and ≥2000 CPM respectively. Further, accumulation of an average of ≥60 min MVPA/day was used to categorise participants into meeting/not meeting national recommendations for PA. The use of these accelerometer processing criteria are in accordance with previous Norwegian research conducted on similar age groups [9].

PA transition profiles were created based on the participants meeting/not meeting national PA recommendations in T1 and T3. 'Active maintainers' consist of those adhering to PA recommendations in T1 and T3, 'move to inactive' consist of those adhering to PA recommendations in T1, but not in T3, 'move to active' consist of those not adhering to PA recommendations in T1, but adhered to them in T3, and 'inactive maintainers' consist of those not adhering to PA recommendations in T1 nor in T3.

Mental health problems

MHP were measured using the Strengths and Difficulties Questionnaire (SDQ). The instrument consists of 25 questions divided into 5 scales of 5 questions each (Emotional problems scale, Conduct problems scale, Hyperactivity scale, Peer problems scale and Prosocial scale). Each item can be addressed "not true", "somewhat true" or "certainly true". All scales, except the Prosocial scale, are summed up to create a 'total difficulty score' ranging from 0-40 where a higher score indicates poorer mental health. [23]. The instrument has demonstrated satisfactory reliability and validity among community samples of children and adolescents [24]. The current study used the established Norwegian translation. The continuous 'total difficulty score' was labelled 'MHP' and used as an outcome variable in all analyses.

Mental wellbeing

The Warwick-Edinburg Mental Wellbeing Scale (WEMWBS) was used to assess MWB. This instrument comprises 14 positively loaded items using a 5-point Likert scale (1 = 'none of the time' to 5 = 'all of the time'). Responses were summed to create an overall wellbeing score ranging from 14 to 70, where a higher score indicates higher levels of wellbeing. The instrument is a psychometrically robust

scale showing good content validity and high test-retest reliability [25]. The scale is validated for use among adolescents from 13 years of age and onwards [26] and has been validated for use among Norwegian adolescents [27]. The current study used the established Norwegian translation with minor linguistic amendments. The continuous score was labelled 'MWB' and used as an outcome variable in all analyses

Covariates

As reported in previous literature, covariates may confound the relationship of interest: socio-economic status (SES) [28], body mass index (BMI) [29] and seasonality [30]. The Family affluence scale was used as a measure of SES. The scale measures material affluence and is a widely used proxy for SES [31]. A score of *relative family affluence* can be derived by summing scores on all answers and categorising them into three broader groups (the lowest 20 %, the middle 60 % and the highest 20 %).

BMI was objectively measured and calculated using weight and height ($kg \cdot m^{-2}$), 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 before measurement. Bodyweight measures were adjusted by subtracting 0.3 kg to account for clothing.

Seasonality was defined by two categories depending on the time of data collection at the different schools (1: Sept-Oct, 2: Nov-Jan).

Ethics

The study was registered with the Norwegian Centre for Research Data (project no. 48192). Written informed consent was obtained from both the participants and their legal guardians prior to data collection.

Data analyses

Statistical analyses were performed 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. As analysis showed an interaction by sex, data were analysed separately for boys and girls. Paired T-test was used to explore longitudinal differences between variables in T1 and T3 (Table 1). To explore correlations between MHP and MWB, Pearson's bivariate correlation analyses with 95% confidence intervals (CIs) based on the Fisher Z-transformation were used.

To explore whether changes in movement categories [total PA, MVPA and SED] from T1 to T3 were associated with MWB and MHP at T3, multiple linear regression analyses were used. Change scores were created by subtracting T3-values from T1-values, creating new change variables that entered the model. The models were adjusted for T1-variables of MHP/MWB, BMI, SES, season of data collection. Further, all analyses were adjusted for school-level clustering and all analyses of ΔMVPA and ΔSED were adjusted for each other and wear-time of the accelerometer (Figure 2 & 3). As the associations can be bi-directional, the models were reversed, creating change scores of the mental health variables, and exploring their relationship with the different movement categories at T3 (Additional files 1 & 2).

To explore the influence of PA transitions, dummy variables of the different PA transition groups were created before entering the models alongside T1-variables of MHP/MWB, BMI, SES, season of data collection and sex. Associations between variables of PA transitions and score on MHP or MWB in T3 for the different groups were analysed using multiple linear regression (Table 2a and b). Further, post-hoc analysis of change in minutes of MVPA between T1 and T3 for the different PA transition profiles was conducted using paired T-test (Additional file 3).

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)'. As the SDQ guidelines enables imputations, these have been performed for the instrument according to standard practice. While analysis showed

variables not to be missing completely by random for WEMWBS, imputations were not performed for this instrument.

Results

Descriptive statistics on key variables over the three years of study are shown in Table 1. Significant differences between T1 and T3 were seen for all variables among girls, except SED. For boys, significant differences were evident for BMI, SED, LPA and MVPA. The proportion of students with MHP-scores categorised as normal remained high (boys: 85% - 80%, girls: 84% - 76%) throughout the three time points (see additional file 4). The same pattern was evident for MWB, where the mean scores remained high (boys: 57.1-55.9, girls: 55.0-50.6), the score distributions being positively skewed throughout the three time points (see additional file 5). The correlations between MHP and MWB were moderate throughout the study (T1: r= -0.44, 95% CI -0.51, -0.37; T2: r= -0.45, 95% CI -0.52, -0.38; T3: r= -0.53, 95% CI -0.60, -0.47) indicating that they are distinct, but related dimensions of mental health.

Table 1: Descriptive characteristics of the study sample by sex, all time points (mean ± SD unless otherwise specified)

Characteristic	Time 1 (2016) n = 599	Time 2 (2017) n = 581	Time 3 (2018) n = 552
Age			
Boys	13.4 (0.3)	14.4 (0.3)	15.4 (0.3)
Girls	13.3 (0.3)	14.3 (0.3)	15.3 (0.3)
Height (cm)			
Boys	163.9 (8.6)	171.3 (8.2)	176.9 (7.5)
Girls	161.7 (6.9)	165.0 (6.6)	166.3 (6.4)
Weight (kg)			
Boys	53.0 (11.8)	60.7 (13.5)	66.8 (13.6)
Girls	52.8 (9.9)	56.6 (9.8)	59.2 (9.8)
BMI (kg/m²)			
Boys	19.6 (3.3)	20.5 (3.7)	21.3 (3.7)**
Girls	20.0 (3.1)	20.8 (3.0)	21.4 (3.0)**
MHP			
Boys	9.7 (5.4)	10.1 (5.3)	10.4 (5.2)
Girls	10.0 (5.1)	11.3 (5.8)	12.0 (5.3)**
MWB			
Boys	57.1 (9.1)	57.3 (9.4)	55.9 (9.6)
Girls	55.0 (8.9)	52.2 (10.5)	50.6 (11.0)**
Total PA (CPM/d)			
Boys	474.4 (178.7)	476.8 (177.5)	460.9 (204.7)
Girls	402.2 (118.6)	399.9 (127.5)	383.5 (138.3)*
SED (min/d)			
Boys	548.4 (74.4)	541.7 (78.7)	542.1 (99.6)*
Girls	565.7 (55.4)	561.3 (64.6)	564.1 (69.6)
LPA (min/d)			
Boys	172.2 (34.1)	167.6 (34.3)	140.8 (37.3)**
Girls	161.4 (32.3)	153.9 (32.2)	137.6 (30.4)**
MVPA (min/d)			
Boys	63.9 (22.9)	62.4 (24.3)	58.1 (26.7)*
Girls	54.0 (18.5)	53.6 (19.4)	50.1 (21.4)*
Meeting act.rec (%)			
Boys	53.3	53.6	43.8
Girls	36.3	37.1	29.5

Note. BMI = body mass index, MHP = mental health problems, MWB = mental wellbeing, Total PA (CPM) = average daily counts per minute, SED = average daily sedentary behaviour, LPA = average daily light physical activity, MVPA = average daily moderate to vigorous physical activity, Meeting act.rec = meeting national recommendations for PA, GPA = grade point average, CPM/d = counts per minute per day, min/d = minutes per day.

* Significant change of variable between T1 to T3, p ≤.05. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3 (n = 177-269)

** Significant change of variable between T1 to T3, p ≤.001. Tests are performed on subsamples with valid measurements on outcome variable in T1 and T3 (n = 177-269).

Prospective analyses showed that an increase in SED was positively associated with MWB score in T3 among boys (Figure 2). The magnitude of the association translates to an increase in SED of 60 min from T1 to T3 being equivalent to a 3.2 points higher score in MWB. Among girls, an increase in total PA was positively associated with MWB score in T3 (Figure 3). As a change of 1 cpm is too small to

reflect any meaningful change in outcome variable, the value is scaled up 100 times, showing changes in outcome variable occurring after changes of 100 cpm. This change corresponds to an increase in daily activity level of approximately 20 %. Such an increase in activity level will generate an increased score in MWB of 1.13 points. No associations were found between changes in any movement categories (total PA, MVPA, SED) and score on MHP in T3, neither for girls nor boys (Figure 2 & 3). In the reversed model (Additional files 1 & 2), changes in MHP/MWB were used as predictors and measures of movement categories [total PA, MVPA and SED] in T3 were the outcomes. Neither of these analyses showed any significant relationships between the variables of interest among boys or girls, posing no evidence for a bi-directional association.

Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary behaviour
[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.
[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling
[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 2. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among boys. (n = 139-159).

Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary behaviour
[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.
[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling
[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 3. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among girls. (n = 196-222).

Analyses of differences in MHP and MWB at T3 for different PA transition profiles showed a significant difference in MHP-score at T3 between 'inactive maintainers' and 'move to active' (p=.013), and between 'active maintainers' and 'move to active' (p=.018) in the crude analyses (Table 2a and 2b). However, both differences disappeared in the adjusted analyses. In the adjusted

analyses, a significant difference in MHP-score at T3 was found between 'inactive maintainers' and 'move to inactive', where 'move to inactive' scored 1.3 units higher than 'inactive maintainers' (p=.033).

Table 2a: Inactive maintainers vs three transition profiles on mental health problems and mental wellbeing at Time 3 (linear regression results).

	Inactive maintainers (n=202)	**Move to inactive (n=83)**			**Move to active (n=53)**			**Active maintainers (n=99)**		
		β	**95 %CI**	**p**	**β**	**95 %CI**	**p**	**β**	**95 %CI**	**P**
MHP[a]	ref.	1.11	-0.24, 2.45	.106	2.07	0.44, 3.69	**.013**	-0.09	-1.37, 1.19	.887
MHP[b]	ref.	1.30	0.11, 2.48	**.033**	0.47	-1.00, 1.93	.533	0.41	-0.73, 1.54	.480
MWB[a]	ref.	-0.45	-3.24, 2.35	.755	1.03	-2.41, 4.46	.557	1.62	-1.01, 4.25	.227
MWB[b]	ref.	-1.59	-4.26, 1.07	.240	1.24	-2.05, 4.52	.460	0.77	-1.72, 3.26	.543

Note. MHP[a] ref. = 10.50, MHP[b] ref. = 0.74. MWB[a] ref. = 52.32, MWB[b] ref. = 36.38. MHP = Mental health problems (T3), MWB = Mental wellbeing (T3)

[a] Crude

[b] Adjusted for baseline MHP/MWB, baseline sex, baseline BMI, baseline socio-economic status and baseline season of data collection

Table 2b: Active maintainers vs three transition profiles on mental health problems and mental wellbeing at Time 3 (linear regression results).

	Active maintainers (n=99)	**Move to inactive (n=83)**			**Move to active (n=53)**			**Inactive maintainers (n=202)**		
		β	**95 %CI**	**p**	**β**	**95 %CI**	**p**	**β**	**95 %CI**	**P**
MHP[a]	ref.	1.20	-0.34, 2.74	.127	2.16	0.37, 3.95	**.018**	0.09	-1.19, 1.37	.887
MHP[b]	ref.	0.89	-0.46, 2.23	.195	0.06	-1.53, 1.65	.944	-0.41	-1.54, 0.73	.480
MWB[a]	ref.	-2.07	-5.24, 1.11	.201	-0.59	-4.34, 3.15	.756	-1.62	-4.25, 1.01	.227
MWB[b]	ref.	-2.36	-5.31, 0.58	.116	0.47	-3.06, 3.98	.795	-0.77	-3.26, 1.72	.543

Note. MHP[a] ref. = 10.40, MHP[b] ref. = 1.15. MWB[a] ref. = 53.94, MWB[b] ref. = 37.15. MHP = Mental health problems (T3), MWB = Mental wellbeing (T3)

[a] Crude

[b] Adjusted for baseline MHP/MWB, baseline sex, baseline BMI, baseline socio-economic status and baseline season of data collection

Discussion

The purpose of this study was to explore whether changes in movement categories were associated with MHP or MWB. Our main results showed that an increase in SED from T1 to T3 was associated with a higher MWB score in T3 for boys. Among girls, results indicated that an increase in total PA from T1 to T3 was associated with a higher score on MWB in T3.

The results with respect to the positive association between SED and MWB for boys, contradicts results from a previous systematic review [13]. However, this review includes studies which have measured MWB using different instruments as well as setting no criteria for objective measures of movement patterns. Results might thus not be directly comparable with the current study. To the best of our knowledge, this is the first study to explore the relationship between objectively measured SED and MWB (measured by WEMWBS) among adolescents. Although there is yet no consensus regarding what constitutes an important change in WEMWBS, the instrument has been found to be responsive at both individual and group/population level [32]. At an individual level, a change of 3 or more units (1 SEM) has been interpreted as important [32]. The current study found a 60 min increase in SED to be equivalent to 3.2 points increase in WEMWBS. We interpret this as an important change in MWB among boys in this study. As SED was assessed using accelerometry, we do not know the context of this behaviour. Previous research has shown that distinct sedentary behaviours might associate differently with variables of mental health, e.g. screen-based vs non-screen-based sedentary behaviour [33]. Moreover, recent research has found differences between passive screen time, which has been associated with mood and anxiety disorders, and active screen time which has not [34]. The social interplay which gaming, for example offers, might serve as one explanation for the positive association between SED and MWB in the current study. How SED relates to MWB remains an important focus for future research.

Among girls, results showed that an increase in total PA was associated with a higher score on MWB. As a rather large increase of PA-levels (about 20 %) was equivalent to a somewhat small increase in

MWB score (1.13 points), it was not considered to constitute an important change based on the suggested criteria [32]. Although weak, this association contradicts the results of Bell et al. [16] who found no evidence of an association between total PA and score on MWB (measured using the same instrument) among the same age group. However, Bell et al. [16] measured PA at baseline only and explored changes in outcome three years later. The results cannot, therefore, associate changes in PA with MWB score. The relationship between total PA and MWB among girls in particular, is thus in need of further exploration.

There were no significant associations between movement categories and MHP among girls or boys in the current study. These results are in line with previous research which found no association between volume- [16-18] or intensity [16, 18, 19] of objectively measured PA and measures of MHP among adolescents. This might suggest that MHP are better explained by variables other than change of movement categories. Toseeb et al. [18] discuss whether associations between PA and MHP might be small or non-existent during the adolescent years, as research more frequently reports positive associations in adult populations. Throughout all time points of this study, the sample means were low for MHP and high for MWB. Stronger effects of PA on mental disorders have been found in clinical samples [12], which might indicate that the overall good level of mental health in the study sample makes any contribution of PA negligible. Opdal et al. [19] also argue that in a study sample where few adolescents experience change in their mental health, it is difficult to find associations with change in PA levels. Although the score on MHP increased significantly among girls from T1 to T3, the mean scores of boys and girls in the current study are all within the normal range, and thus indicative of a mentally healthy study sample. The same pattern was also present among British adolescents of the same age where the mean scores were within the normal range and no association was found between volume or intensity of PA and MHP [16].

Analyses exploring the longitudinal associations between PA and MHP through categorisation of participants into different PA transition profiles nevertheless found participants belonging to the

'move to inactive' profile to have a significantly higher score on MHP than 'inactive maintainers'. Previous research has shown that participants changing from an active to a sedentary profile showed larger decrease in positive affect when compared with profiles that showed no reduction in PA [20]. There were, however, no equivalent differences between 'active maintainers' and 'move to inactive' in the current study, providing no clear evidence for such an explanation. In addition, the 95 % CI for the β 'move to inactive' included a very small effect (0.11), which indicates that the 'move to inactive' group is not that different from the 'inactive maintainers'. There were no differences in MWB between different PA transition profiles, further elucidating the weak relationship between PA and MWB in the current study sample. These results contradict those of Sánchez-Oliva et al. [20] who found that belonging to active profiles (participants engaging in lower levels of SED and higher levels of PA) was associated with better MWB (measured by HRQoL and positive affect) than belonging to sedentary profiles (participants engaging in higher levels of SED and lower levels of PA). However, we used meeting/not meeting national PA recommendations in T1 and T3 as the criteria for placement within the different PA profiles. As small changes in activity level may tip a participant from one group to another (e.g. 59 min of MVPA in T1 and 61 min of MVPA in T3), there might not have been a large enough change to produce effects on variables of MHP and MWB. Post-hoc analysis was therefore conducted to explore whether the average MVPA for the different PA transition profiles varied significantly between T1 and T3 (see additional file 3). This analysis showed large and significant changes in MVPA within all groups except Active maintainers. Small changes between T1 and T3 can thus not explain the weak relationship with mental health outcomes.

Methodological considerations

There are several strengths to this study. First, the longitudinal design with very high adherence and the use of accelerometry to measure PA alongside validated instruments to measure variables of mental health are key strengths. Both predictor variables and outcomes were measured at all time points. This created a strong longitudinal line of data and enabled exploration of the temporal nature

of potential relationships, as well as taking into account the changing patterns of PA, which was called for in a recent study [16]. Furthermore, we controlled for important covariates. However, both PA and mental health are multifactorial and complex constructs, which are influenced by several known and unknown factors [10, 35]. Consequently, there are likely to be additional important factors, that we have no measure of, which may override the possible associations between PA and variables of mental health. As there were few significant findings this may suggest that mental health outcomes are better explained by other factors than change in movement patterns, or that our measurements were not sufficiently sensitive to detect patterns that might be present. Although providing an objective measure of PA, accelerometry also has limitations. Monitors are not completely waterproof and must be removed while doing water activities. Further, they underestimate the energy cost for cycling, activities on a gradient and arm-intensive activities [36]. Registration of time spent swimming and cycling was conducted to account for some of these issues. As the main proportion of pupils reported 0-1 hour of both activities, swimming and cycling was not considered to contribute to underestimating the true activity level, at least not to a large degree. In addition, accelerometers might not be sufficiently sensitive to capture patterns of SED because of their limitations in the measurement of posture [33], which may have led to a less precise measure of SED among the study sample. Moreover, despite being validated instruments, the measures of mental health may also introduce limitations. The potential insensitivity to change over time (SDQ), as well as problems with discriminating sufficiently within high (SDQ and WEMWBS) and low scores (SDQ) [27, 37], may limit their ability to assess associations within overall healthy study samples.

Although the non-random sampling prevents us from drawing definite conclusions regarding generalisability, the sampling procedure nevertheless ensures that the participating schools are likely to be broadly representative of secondary schools found in Norway. However, because the participation rate was 60 % at T1, and no drop-out analysis was conducted, this might have introduced some selection bias into our findings. Nevertheless, the loss to follow-up was small,

providing a longitudinal participation rate of 97.0 % and 92.2 % in T2 and T3 respectively when T1 is set as the eligible sample.

Conclusion

This study provided no clear evidence for any association between change of volume or intensity of PA and MHP among an overall healthy adolescent study sample. When MWB was the outcome, a weak association was found with change in total PA, solely among girls, and an association with change in SED among boys. However, as objective measures alone cannot provide information about the context of the SED, future research should combine objective measures with subjective measures to enable such contextual information to be captured and potentially generate a more detailed picture of the relationship between SED and variables of mental health. Further, there is a need to increase the sensitivity of measures of mental health to improve their ability to discriminate within high and low scores, advancing our knowledge on the relationship between PA and variables of mental health in overall mentally healthy study samples. Lastly, to avoid ambiguity, there is a profound need for researchers to be clear on what construct of mental health they are exploring, and how they operationalise their measurements.

Supplementary information

- Additional file 1: Figure 1**.** Association between change in variables of mental health (2016-2018) and intensities of PA in 2018 among boys. (N= 139-159).
- Additional file 2: Figure 2. Association between change in variables of mental health (2016-2018) and intensities of PA in 2018 among girls. (N= 196-222).
- Additional file 3: Table 1. Differences in minutes in MVPA between T1 and T3 analysed by paired T-test.
- Additional file 4: Table 2. Score distribution of SDQ within a 4-band categorization in T1-T3 (n + %).
- Additional file 5: Figure 3. Score distribution of WEMWBS in T1-T3.

Abbreviations

MHP: mental health problems; MWB: mental wellbeing; PA: physical activity; LPA: light intensity PA; MVPA: moderate-to-vigorous intensity PA; SED: sedentary behaviours; CPM: average counts·min^{-1}; T1: time 1; T2: time 2; T3: time 3; WEMWBS: The Warwick-Edinburg Mental Wellbeing Scale; SDQ: Strengths and Difficulties Questionnaire; BMI: Body mass index; CI: confidence intervals; SES: Socio-economic status

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Authors' contributions

IBV: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, Visualization**, KRS:** Methodology, Formal analysis, Writing - Review & Editing, Visualization**, SAA:** Methodology, Formal analysis, Writing - Review & Editing, **MWF:** Formal analysis, Writing - Review & Editing **HET:** Conceptualization, Writing - Review & Editing, **MT:** Conceptualization, Project administration, Funding acquisition, Writing - Review & Editing.

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Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical approval and consent to participate

The study was registered with the Norwegian Centre for Research Data (project no. 48192). Written informed consent was obtained from both the participants and their legal guardians prior to data collection.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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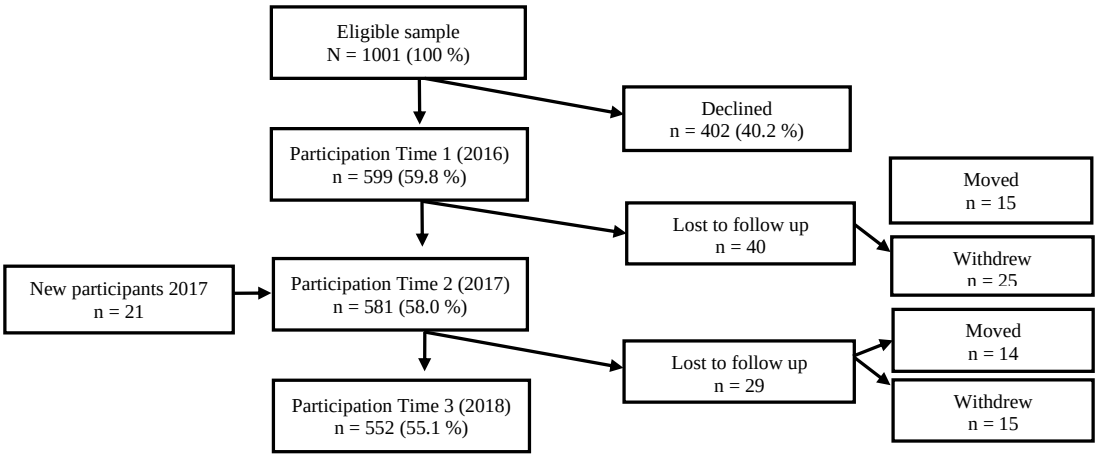
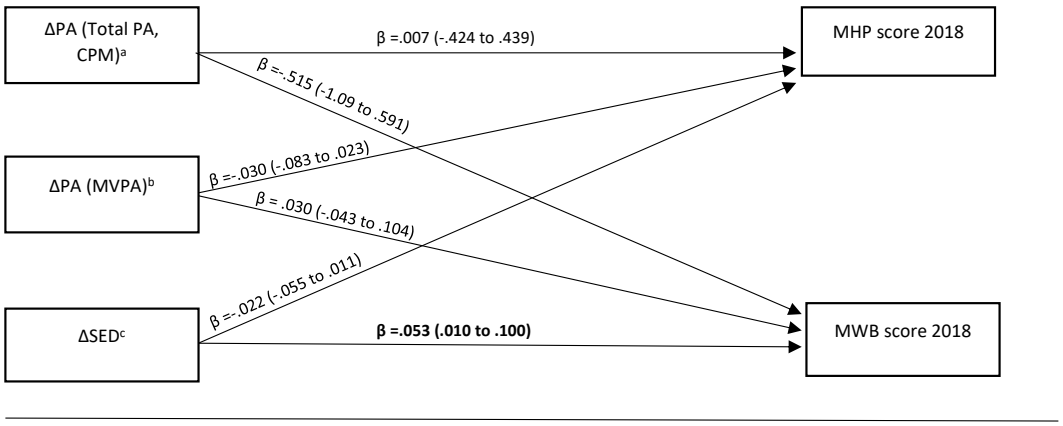


Figure 1. Flowchart of the study population and participation.



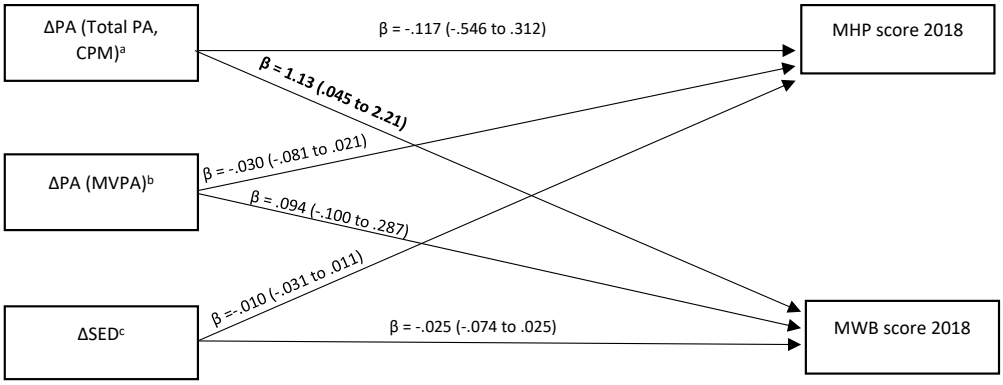
Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary behaviour

[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.

[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 2. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among boys. (n = 139-159).



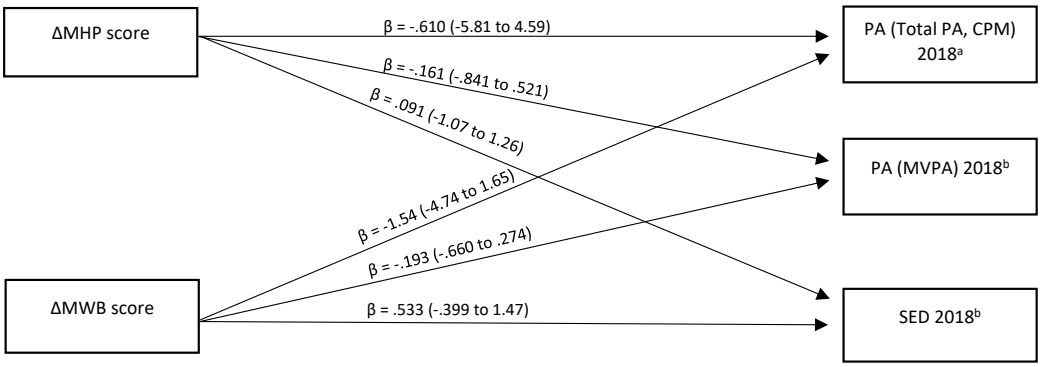
Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary behaviour

[a] Adjusted for baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling. All measures are scaled up 100 times showing changes in dependent variables occurring after changes of 100 CPM.

[b] Adjusted for accelerometer wear time, ΔSED, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

[c] Adjusted for accelerometer wear time, ΔMVPA, baseline MHP/MWB, baseline BMI, baseline socio-economic status, baseline season of data collection and cluster sampling

Figure 3. Association between change in intensities of PA (2016-2018) and mental health outcomes in 2018 among girls. (n = 196-222).

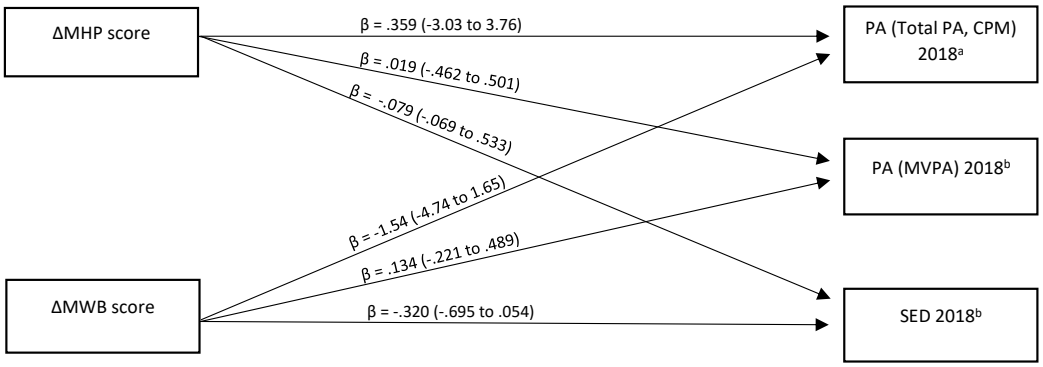


Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary time

[a] Adjusted for baseline sex, BMI, SES, season of data collection and cluster sampling

[b] Adjusted for accelerometer wear time, baseline sex, BMI, SES, season of data collection and cluster sampling

Additional file 1, figure 1. Association between change in variables of mental health (2016-2018) and intensities of PA in 2018 among boys. (N= 139-159)



Note: MHP = Mental health problems, MWB = Mental Wellbeing, MVPA = Moderate to Vigorous Physical activity, SED = Sedentary time

[a] Adjusted for baseline sex, BMI, SES, season of data collection and cluster sampling

[b] Adjusted for accelerometer wear time, baseline sex, BMI, SES, season of data collection and cluster sampling

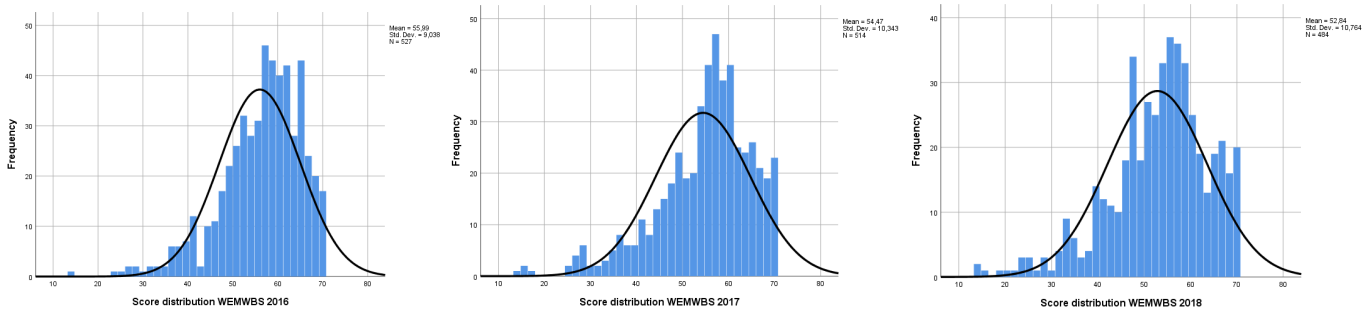
Additional file 2, figure 2. Association between change in variables of mental health (2016-2018) and intensities of PA in 2018 among girls. (N= 196-222)

Additional file 3, table 1. Differences in minutes in MVPA between T1 and T3 analysed by paired T-test.

	n	T1 Mean MVPA (SD)	T3 Mean MVPA (SD)	t	p
Active maintainer	99	79.2 (15.1)	79.7 (17.7)	0.3	.755
Move to inactive	83	74.7 (13.3)	43.8 (11.3)	-15.0	<.001
Move to active	53	46.2 (10.9)	75.4 (17.3)	9.3	<.001
Inactive maintainers	202	42.8 (10.3)	37.3 (11.7)	-6.0	<.001

Additional file 4, table 2. Score distribution of SDQ within a 4-band categorization in T1-T3 (n + %).

	T1 (2016)	T2 (2017)	T3 (2018)
'Close to average' (0-14)	483 (84.0)	404 (75.0)	378 (77.5)
'Slightly raised' (15-17)	48 (8.3)	66 (12.2)	65 (13.3)
'High' (18-19)	14 (2.4)	27 (5.0)	32 (6.6)
'Very high' (20-40)	30 (5.2)	42 (7.8)	13 (2.7)
Total	575 (100)	539 (100)	488 (100)



Note. Total WEMWBS score range = 14 - 70 points

Additional file 5, figure 3. Score distribution of WEMWBS in T1-T3.

Appendix I:

Questionnaire

Due to better readability of the pdf output of the online questionnaire from the 2nd data collection (2017), this version is attached. However, as Hedmark University College changed its' name to Inland Norway University of Applied Sciences this year, the new name and logo will thus appear on this output.

HØGSKOLEN i INNLANDET

INFORMASJON OM SAMTYKKE

Skole, læring og psykisk helse prosjektet

Takk for at du er positiv til å delta i undersøkelsen vår. På denne måten hjelper du oss med å få bedre kunnskap om barn og ungdom sin psykiske helse, fysiske aktivitet og skolemiljø. Ungdommer fra 11 ulike skoler skal svare på de samme spørsmålene. Svarene dine skal være hemmelige, og ingen på skolen vil få lov til å se spørreskjemaet ditt etter at du har fylt dette ut.

For å få god kunnskap om ungdommer sin psykiske helse, fysiske aktivitet og skolemiljø er det til stor hjelp for oss at du svarer så ærlig som mulig på alle spørsmålene. Om det likevel er noen spørsmål du ikke ønsker å svare på, lar du dette stå åpent og går videre til neste spørsmål. Det er heller ingen svar som er rett eller galt, svar slik du virkelig føler. Om noe er forvirrende, be om hjelp, så skal vi hjelpe deg.

Noen av spørsmålene kan virke veldig like. Det skal de også være. Det er imidlertid viktig at du leser spørsmålene grundig (godt) fordi svaralternativene til spørsmålene vil variere.

Tusen takk for hjelpen!

Professor Miranda Thurston
Prosjektleder

○ Jeg har lest teksten og ønsker å være med på undersøkelsen

	6 siffer	6 siffer
ID-nummer		

HØGSKOLEN i INNLANDET

Her kommer noen spørsmål om deg og din familie

1. Hva er fødselsdagen din

	Dag																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Jan
Velg i nedtrekklistene	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

2. Er du gutt eller jente?

- ○ Gutt
- ○ Jente

Denne undersøkelsen er produsert og tilrettelagt av Høgskolen i Innlandet

HØGSKOLEN i INNLANDET

3. Hva er den høyeste utdanningen du har tenkt til å ta? Sett bare et kryss

- ○ Universitet eller høyskoleutdanning av høyere grad (f.eks. master, lektor, advokat, sivilingeniør, lege)
- ○ Universitet eller høyskoleutdanning av lavere grad (f.eks. bachelor, lærer, politi, sykepleier, ingeniør, journalist)
- ○ Videregående skole: studiespesialisering / idrettsfag / musikk, dans og drama
- ○ Videregående skole: yrkesfag
- ○ Har ikke bestemt meg
- ○ Annet

3.1. Annet: Nevn hva

4. I hvilket land er du født?

- ○ I Norge
- ○ I Sverige, Finland, Danmark eller Island
- ○ Annet land i Europa
- ○ Annet land utenfor Europa
- ○ Vet ikke

HØGSKOLEN i INNLANDET

5.1. I hvilket land er din mor født?

- I Norge
- I Sverige, Finland, Danmark eller Island
- Annet land i Europa
- Annet land utenfor Europa
- Vet ikke

5.2. I hvilket land er din far født?

- I Norge
- I Sverige, Finland, Danmark eller Island
- Annet land i Europa
- Annet land utenfor Europa
- Vet ikke

HØGSKOLEN i INNLANDET

6. Har din far jobb?

- ○ Ja
- ○ Nei
- ○ Jeg vet ikke
- ○ Jeg har ikke eller treffer ikke min far

HØGSKOLEN i INNLANDET

6.a.1. Kan du da skrive hvor han jobber? (for eksempel sykehus, restaurant, skole)

6.a.2. Skriv ned nøyaktig hva han gjør der (for eksempel sykepleier, kelner, lærer)

6.b.1. Vet du hva din far gjør? Sett kryss ved det passer best.

- Han er syk, pensjonist eller student
- Han søker jobb
- Han er hjemme på heltid (tar seg av hus og barn)
- Jeg vet ikke

HØGSKOLEN i INNLANDET

7. Har din mor jobb?

- Ja
- Nei
- Jeg vet ikke
- Jeg har ikke eller treffer ikke min mor

HØGSKOLEN i INNLANDET

7.a.1. Kan du da skrive hvor hun jobber (for eksempel sykehus, restaurant, skole)

7.a.2. Skriv ned nøyaktig hva hun gjør der (for eksempel sykepleier, kelner, lærer)

7.b.1. Vet du hva din mor gjør? Sett kryss ved det svaret som passer best

- Hun er syk, pensjonist eller student
- Hun søker jobb
- Hun er hjemme på heltid (tar seg av hus og barn)
- Jeg vet ikke

HØGSKOLEN i INNLANDET

8. Har familien din bil?

- Nei
- Ja, en
- Ja, to eller flere

9. Har du eget soverom?

- Nei
- Ja

10. Hvor mange ganger reiste du og familien din på ferie til utlandet i fjor?

- Ingen
- En gang
- To ganger
- Mer enn to ganger

HØGSKOLEN i INNLANDET

11. Hvor mange datamaskiner og nettbrett har familien din?

- Ingen
- En
- To
- Tre
- Mer enn tre

12. Hvor mange bøker har familien din hjemme? Det er vanligvis rundt 40 bøker i hver rekke i bokhylla

- Ingen
- 1-10 bøker
- 22-50 bøker
- 51-100 bøker
- 101-250 bøker
- 251-500 bøker
- Mer enn 500 bøker

13. Hvor mange bad (rom med badekar eller dusj) er det i hjemmet ditt?

- Ingen
- Ett
- To
- Flere enn to

14. Har familien din oppvaskmaskin hjemme?

- Ja
- Nei

HØGSKOLEN i INNLANDET

15. Hvor bor du?

- I en enebolig
- I et rekkehus (ta også med to- eller firemannsbolig)
- I en leilighet

16. Har familien din hytte eller feriehus/ferieleilighet i Norge?

- Nei
- En
- To
- Flere enn to

17. Har familien din hytte eller feriehus/ferieleilighet i utlandet?

- Nei
- En
- To
- Flere enn to

HØGSKOLEN i INNLANDET

18. Hvor lett eller vanskelig er det for deg å snakke med andre om ting som virkelig plager deg?

Sett ett kryss for hver av personene som er listet opp nedenfor

	Veldig lett	Lett	Vanskelig	Veldig vanskelig	Jeg har ikke eller treffer ikke denne personen
Far	○	○	○	○	○
Stefar / mors kjæreste	○	○	○	○	○
Mor	○	○	○	○	○
Stemor / fars kjæreste	○	○	○	○	○
Eldre brødre	○	○	○	○	○
Eldre søstre	○	○	○	○	○
Beste venn	○	○	○	○	○
Venner av samme kjønn	○	○	○	○	○
Venner av motsatt kjønn	○	○	○	○	○

HØGSKOLEN i INNLANDET

19. Vi er interessert i hva du tenker om de følgende påstandene (les hver påstand nøye og kryss av for hvor enig du er i hver påstand)

a. Familien min prøver virkelig å hjelpe meg

Svært uenig						Svært enig
○	○	○	○	○	○	○
1	2	3	4	5	6	7

b. Jeg får den følelsesmessige hjelpen og støtten jeg trenger fra familien min

Svært uenig						Svært enig
○	○	○	○	○	○	○
1	2	3	4	5	6	7

c. Jeg kan prate med familien min om problemene mine

Svært uenig						Svært enig
○	○	○	○	○	○	○
1	2	3	4	5	6	7

d. Familien min ønsker å hjelpe meg i å ta beslutninger

Svært uenig						Svært enig
○	○	○	○	○	○	○
1	2	3	4	5	6	7

HØGSKOLEN i INNLANDET

20. Nedenfor følger noen påstander om familien din. Les hver påstand nøye, kryss av for hva du føler om hver påstand

	Helt enig	Enig	Verken enig eller uenig	Uenig	Helt uenig
I min familie føler jeg de viktige tingene blir snakket om	○	○	○	○	○
I min familie blir jeg hørt når jeg forteller om noe	○	○	○	○	○
I min familie stiller vi spørsmål når vi ikke forstår hverandre	○	○	○	○	○
I min familie prater vi sammen til vi har oppklart en misforståelse	○	○	○	○	○

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om følelsene og tankene dine

21. Nedenfor finner du en del utsagn om følelser og tanker. Vennligst kryss av for det som best beskriver din opplevelse for hvert utsagn de siste 2 ukene.

	Ikke i det hele tatt					Hele tiden
	0	1	2	3	4	5
Jeg har vært optimistisk med hensyn til fremtiden	○	○	○	○	○	○
Jeg har følt meg nyttig	○	○	○	○	○	○
Jeg har følt meg avslappet	○	○	○	○	○	○
Jeg har følt interesse for andre mennesker	○	○	○	○	○	○
Jeg har hatt masse energi	○	○	○	○	○	○
Jeg har løst problemer på en god måte	○	○	○	○	○	○
Jeg har tenkt klart	○	○	○	○	○	○
Jeg har vært fornøyd med meg selv	○	○	○	○	○	○
Jeg har følt nærhet til andre mennesker	○	○	○	○	○	○
Jeg har følt meg selvsikker	○	○	○	○	○	○
Jeg har vært i stand til å ta beslutninger	○	○	○	○	○	○
Jeg har følt at noen er glad i meg	○	○	○	○	○	○
Jeg har vært interessert i nye ting	○	○	○	○	○	○
Jeg har vært i godt humør	○	○	○	○	○	○

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om selvbilde

22. Nedenfor er noen spørsmål om hvordan du synes du selv er. Kryss av for det som passer best på deg

	Stemmer svært godt	Stemmer nokså godt	Stemmer nokså dårlig	Stemmer svært dårlig
Jeg synes jeg er like smart som andre på min alder	○	○	○	○
Jeg synes det er ganske vanskelig å få venner	○	○	○	○
Jeg er flink i all slags sport	○	○	○	○
Jeg er ikke fornøyd med utseende mitt	○	○	○	○
Når jeg er interessert i å bli kjæreste med en, så er det gode muligheter for at den andre vil være interessert i meg også	○	○	○	○
Jeg klarer å få virkelig nære venner	○	○	○	○
Jeg er ofte skuffet over meg selv	○	○	○	○
Jeg er ganske sein med å bli ferdig med skolearbeidet	○	○	○	○
Jeg har mange venner	○	○	○	○
Jeg tror jeg kan gjøre det bra i nesten hvilken som helst ny sport	○	○	○	○
Jeg ønsker at kroppen min var annerledes	○	○	○	○
Jeg prøver å sjekke opp de som jeg er virkelig interessert i	○	○	○	○

22. Nedenfor er noen spørsmål om hvordan du synes du selv er. Kryss av for det som passer best på deg

	Stemmer svært	Stemmer nokså	Stemmer nokså	Stemmer svært

	godt	godt	dårlig	dårlig
Jeg har en nær venn som jeg kan dele hemmeligheter med	○	○	○	○
Jeg liker ikke den måten jeg lever livet mitt på	○	○	○	○
Jeg gjør det svært godt på skolen	○	○	○	○
Andre ungdommer har vanskelig for å like meg	○	○	○	○
Jeg synes at jeg er bedre i sport enn andre på min alder	○	○	○	○
Jeg ønsker at jeg så annerledes ut	○	○	○	○
De som jeg kunne tenkt meg å bli kjæreste med, vil også kunne bli interessert i meg	○	○	○	○
Jeg har en venn som jeg kan dele ting med	○	○	○	○
Jeg er stort sett fornøyd med meg selv	○	○	○	○
Jeg har vansker med å svare riktig på skolen	○	○	○	○
Jeg er populær blant jevnaldrende	○	○	○	○
Jeg gjør det ikke så godt i nye øvelser i gymtimene	○	○	○	○

22. Nedenfor er noen spørsmål om hvordan du synes du selv er. Kryss av for det som passer best på deg

	Stemmer godt	Stemmer nokså godt	Stemmer nokså dårlig	Stemmer svært dårlig
Jeg synes jeg ser bra ut	○	○	○	○
Jeg tror at jeg er spennende og interessant for de som vil ha en kjæreste	○	○	○	○
Jeg synes det er vanskelig å få venner som jeg virkelig kan stole på	○	○	○	○
Jeg liker meg selv slik jeg er	○	○	○	○
Jeg tror jeg er ganske intelligent	○	○	○	○
Jeg føler at jevnaldrende godtar meg	○	○	○	○

Jeg synes ikke at jeg har så sterk kropp som andre på min alder	○	○	○	○
Jeg liker utseende mitt veldig godt	○	○	○	○
Jeg forsøker vanligvis ikke å få den jeg er interessert i til å bli interessert i meg	○	○	○	○
Jeg har ikke noen god venn som jeg kan dele virkelig personlige ting med	○	○	○	○
Jeg er svært fornøyd med hvordan jeg er	○	○	○	○

HØGSKOLEN i INNLANDET

Nå kommer noen spørsmål om helse og livskvalitet

23. Vil du si at din helse er..?

- Svært god
- God
- Ganske god
- Dårlig

24. I løpet av de siste 6 månedene: Hvor ofte har du hatt følgende plager? (Sett ett kryss for hver linje)

	Omtrent hver dag	Mer enn èn gang i uka	Omtrent hver uke	Omtrent hver måned	Sjelden eller aldri
Hodepine					
Vondt i magen					
Vondt i ryggen					
Følt deg nedfor (trist)					
Vært irritabel eller i dårlig humør					
Nervøs					
Vanskelig for å sovne					
Svimmel					
Vondt i nakke og skulder					
Lei og utslitt (sliten)					
Redd					

HØGSKOLEN i INNLANDET

25. Her er et bilde av en stige. Øverst på stigen (10) står for det best mulige livet for deg og nederst på stigen (1) er det verst mulige livet for deg.
Generelt sett hvor synes du at du står på stigen nå for tiden? Sett kryss i den boksen som står ved siden av nummeret som best forteller hvor du står.

○ 10	Best mulig liv
○ 9	
○ 8	
○ 7	
○ 6	
○ 5	
○ 4	
○ 3	
○ 2	
○ 1	Dårligst mulig liv

HØGSKOLEN i INNLANDET

Sterke og svake sider

26. Vennligst kryss av for hvert utsagn: Stemmer ikke, Stemmer delvis eller Stemmer helt. Prøv å svare på alt selv om du ikke er helt sikker eller synes utsagnet virker rart. Svar på grunnlag av hvordan du har hatt det de siste 6 månedene.

	Stemmer ikke	Stemmer delvis	Stemmer helt
Jeg prøver å være hyggelig mot andre. Jeg bryr meg om hva de føler	○	○	○
Jeg er rastløs. Jeg kan ikke være lenge i ro	○	○	○
Jeg har ofte hodepine, vondt i magen eller kvalme	○	○	○
Jeg deler gjerne med andre (mat, spill, andre ting)	○	○	○
Jeg blir ofte sint og har kort lunte	○	○	○
Jeg er ofte for meg selv. Jeg gjør som regel ting alene	○	○	○
Jeg gjør som regel det jeg får beskjed om	○	○	○
Jeg bekymrer meg mye	○	○	○
Jeg stiller opp hvis noen er såret, lei seg eller føler seg dårlig	○	○	○
Jeg er stadig urolig eller i bevegelse	○	○	○
Jeg har en eller flere gode venner	○	○	○
Jeg slåss mye. Jeg kan få andre til å gjøre det jeg vil	○	○	○
Jeg er ofte lei meg, nedfor eller på gråten	○	○	○
Jeg blir som regel likt av andre på min alder	○	○	○
Jeg blir lett distrahert, jeg synes det er vanskelig å konsentrere meg	○	○	○
Jeg blir nervøs i nye situasjoner. Jeg blir lett usikker	○	○	○
Jeg er snill mot de som er yngre enn meg	○	○	○

Jeg blir ofte beskyldt for å lyve eller jukse			
Andre barn eller unge plager eller mobber meg			
Jeg tilbyr meg ofte å hjelpe andre (foreldre, lærere, andre barn/unge)			
Jeg tenker meg om før jeg handler (gjør noe)			
Jeg tar ting som ikke er mine hjemme, på skolen eller andre steder			
Jeg kommer bedre overens med voksne enn de på min egen alder			
Jeg er redd for mye, jeg blir lett skremt			
Jeg fullfører oppgaver. Jeg er god til å konsentrere meg			

HØGSKOLEN i INNLANDET

Nå kommer noen spørsmål om skolen og skoledagen

27. Når står du vanligvis opp på en skoledag ?

- Før 6.30
- Mellom 6.30 og 7.00
- Mellom 7.00 og 7.30
- Mellom 7.30 og 8.00
- Etter 8.00

28. Når legger du deg vanligvis på en skoledag?

- Før 20.00
- Mellom 20.00 og 21.00
- Mellom 21.00 og 22.00
- Mellom 22.00 og 23.00
- Mellom 23.00 og 24.00
- Etter 24.00

HØGSKOLEN i INNLANDET

29. Hvordan kommer du deg vanligvis til og fra skolen på denne årstiden ?

Sett ett kryss for **Til skolen** og ett kryss for **Fra skolen**

Til skolen?

- ○ Med bil eller motorsykkel
- ○ Med buss, trikk, t-bane eller tog
- ○ Med sykkel
- ○ Går

Fra skolen?

- ○ Med bil eller motorsykkel
- ○ Med buss, trikk, t-bane eller tog
- ○ Med sykkel
- ○ Går

HØGSKOLEN i INNLANDET

30. Hvor lang tid bruker du vanligvis til og fra skolen på denne årstiden?

Sett ett kryss for **Til skolen** og ett kryss for **Fra skolen**

Til skolen?

- ○ Mindre enn 5 minutter
- ○ 6-15 minutter
- ○ 16-30 minutter
- ○ 31 minutter til 1 time
- ○ Mer enn en time

Fra skolen?

- ○ Mindre enn 5 minutter
- ○ 6-15 minutter
- ○ 16-30 minutter
- ○ 31 minutter til 1 time
- ○ Mer enn en time

HØGSKOLEN i INNLANDET

31. Hva gjør du vanligvis på i friminuttene?

(Kryss av for alle alternativ som gjelder for deg)

- [ ] Spiller ballspill
- [ ] Deltar i andre aktiviteter
- [ ] Går tur
- [ ] Snakker med vennene mine
- [ ] Holder på med telefonen min
- [ ] Annet

31.1. Annet: Nevn hva

32. Hvor stresset blir du av skolearbeidet (både arbeid du skal gjøre på skolen og lekser)?

- Ikke i det hele tatt
- Litt
- Ganske mye
- Svært mye

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om hva du synes om å gå på skolen

Du skal tenke på hvordan du har hatt det på skolen i høst.
Hvis du er helt enig i setningen setter du et kryss på stor JA
Hvis du er nesten enig setter du kryss på liten ja
Hvis du er litt uenig setter du kryss på liten nei
Hvis du er helt uenig setter du kryss på stor NEI
Du skal kun sette ett kryss for hver setning. Synes du det er vanskelig å svare, sett kryss i den ruten som er nærmest det du mener.

33. Faglig trivsel

	JA	ja	nei	NEI
Jeg liker vanligvis å gå på skolen	○	○	○	○
Jeg synes det er viktig å gå på skolen for å lære	○	○	○	○
Jeg synes ofte det er kjedelig i timene	○	○	○	○
Det er viktig for meg å gjøre det bra på skolen	○	○	○	○

34. Sosial trivsel

	JA	ja	nei	NEI
Jeg liker meg godt i klassa	○	○	○	○
Jeg liker meg godt i friminuttene	○	○	○	○
Jeg blir ofte mobbet og plaget av andre elever	○	○	○	○

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om lærerne dine

Nedenfor skal du ta stilling til en rekke setninger om læreren din. Du har sikkert flere lærere, men her skal du kun tenke på kontaktlæreren din når du svarer. Du skal sette kryss i den ruten som passer best for hvordan din kontaktlærer er overfor deg og andre elever i basisgruppa/klassa. Du kan velge mellom svaralternativene: «Helt enig», «Litt enig», «Litt uenig», «Helt uenig».

35. Relasjoner mellom lærer og elev

	Helt enig	Litt enig	Litt uenig	Helt uenig
Jeg har god kontakt med læreren	○	○	○	○
Læreren liker meg	○	○	○	○
Når jeg har problemer eller er lei meg kan jeg snakke med læreren	○	○	○	○
Læreren roser meg når jeg jobber hardt	○	○	○	○
Læreren gjør alt for å hjelpe meg til å lære mest mulig	○	○	○	○
Læreren bryr seg om hvordan jeg har det	○	○	○	○
Læreren gjør meg flau hvis jeg ikke vet svarene	○	○	○	○
Læreren bruker lite tid til å snakke med meg	○	○	○	○
Læreren oppmuntrer meg når jeg ikke får til det jeg holder på med	○	○	○	○

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om klassa og klassekammeratene dine

Her kommer det noen setninger som handler om klassa du går i og klassekameratene dine. Du skal svare ut fra hvordan du mener det vanligvis er i klassa. Du kan også her velge mellom svaralternativene: «Helt enig», «Litt enig», «Litt uenig», «Helt uenig».

36. Relasjoner mellom elever – læringskultur

	Helt enig	Litt enig	Litt uenig	Helt uenig
Det er lett å lage grupper som skal arbeide sammen i timene.	○	○	○	○
Elevene i denne klassa liker å hjelpe hverandre med oppgaver og lekser.	○	○	○	○
Elevene jobber hardt i timene.	○	○	○	○
Vi får som regel gjort det vi skal i timene.	○	○	○	○
Klassekameratene mine hjelper meg, hvis det er noe jeg ikke forstår	○	○	○	○

37. Relasjoner mellom elever – sosialt miljø

	Helt enig	Litt enig	Litt uenig	Helt uenig
Hvis noen i klassa er lei seg eller har problemer så snakker klassekameratene med han/henne.	○	○	○	○
Hvis noen blir dårlig eller urettferdig behandlet så hjelper klassekameratene han/henne.	○	○	○	○
Elevene i denne klassa kjenner hverandre godt.	○	○	○	○
Elevene i klassa er gode venner.	○	○	○	○
Det er noen elever i denne klassa som ikke går så godt sammen.	○	○	○	○
Jeg har blitt venner med mange i denne klassa.	○	○	○	○
I denne klassa blir du godtatt selv om du ikke er like flink som	○	○	○	○

eller litt annerledes enn andre.				
Klassekameratene bryr seg ikke om hvordan jeg har det				
Klassekameratene mine liker meg.				
Det er elever i klassa som jeg ikke går så godt sammen med.				

HØGSKOLEN i INNLANDET

De neste spørsmålene handler om fritid og fysisk aktivitet

38. Tenk på de siste 7 dagene: Hvor mange timer har du drevet fysisk aktivitet i form av svømming?

- 0 timer
- 1 time
- 2 timer
- 3 timer
- 4 timer
- 5 timer
- 6 timer
- 7 timer
- 8 timer
- 9 timer
- 10 timer
- 11 timer
- 12 timer
- 13 timer
- 14 timer
- Mer enn 14 timer

39. Tenk på de siste 7 dagene: Hvor mange timer har du drevet fysisk aktivitet i form av sykling?

- 0 timer

- 1 time
- 2 timer
- 3 timer
- 4 timer
- 5 timer
- 6 timer
- 7 timer
- 8 timer
- 9 timer
- 10 timer
- 11 timer
- 12 timer
- 13 timer
- 14 timer
- Mer enn 14 timer

HØGSKOLEN i INNLANDET

40. Hvor ofte har du drevet med følgende treningsaktiviteter de siste 12 månedene i snitt?

	Aldri	Under 1 gang per uke	1 gang per uke	Flere ganger per uke
Utholdenhetsidrett (f.eks. løp, langrenn, sykling, svømming, aerobic)	○	○	○	○
Lag/ballidretter (f.eks. squash, håndball, fotball, ishockey)	○	○	○	○
Estetisk idrett (f.eks. dans, turn, rytmisk gymnastikk)	○	○	○	○
Styrkeidrett (f.eks. bryting, vekttrening)	○	○	○	○
Kampsport (f.eks. judo, karate, taekwondo)	○	○	○	○
Tekniske idretter (f.eks. ridning, alpint, telemark, friidrett, snowboard, golf, skateboard, skøyter)	○	○	○	○
Risikoidrett (f.eks. elvepadling, fjellklatring, paragliding)	○	○	○	○

Annet:

HØGSKOLEN i INNLANDET

41. I løpet av en vanlig uke i sommerhalvåret: Hvilke av disse aktivitetene deltar du i på fritiden din? (kryss av alle alternativ som gjelder deg).

- [ ] Gåtur
- [ ] Jogge/løpetur
- [ ] Friidrett
- [ ] Svømming
- [ ] Sykling
- [ ] BMX-sykling
- [ ] Rulleski
- [ ] Dans (f eks. selskapsdans, ballett, Hip Hop etc.)
- [ ] Aerobics
- [ ] Turn
- [ ] Styrketrening
- [ ] Fotball
- [ ] Håndball
- [ ] Basketball
- [ ] Volleyball
- [ ] Tennis
- [ ] Squash
- [ ] Golf

- [ ] Ishockey, Bandy, Innebandy
- [ ] Kampsport
- [ ] Klatring (utendørs)
- [ ] Klatring (innendørs)
- [ ] Fjelltur
- [ ] Orientering
- [ ] Ridning
- [ ] Andre aktivteter
- [ ] Driver ikke med noen av disse aktivitetene

41.1. Andre aktiviteter (nevn hvilke)

HØGSKOLEN i INNLANDET

42. I løpet av en vanlig uke i vinterhalvåret: Hvilke av disse aktivitetene deltar du på i fritiden? (kryss av alle alternativ som gjelder deg).

- [ ] Gåtur
- [ ] Jogge/løpetur
- [ ] Friidrett
- [ ] Svømming
- [ ] Sykling
- [ ] Rulleski
- [ ] Dans (f eks. selskapsdans, ballett, Hip Hop etc.)
- [ ] Aerobics
- [ ] Turn
- [ ] Styrketrening
- [ ] Fotball
- [ ] Håndball
- [ ] Basketball
- [ ] Volleyball
- [ ] Tennis
- [ ] Squash
- [ ] Golf
- [ ] Ishockey, Bandy, Innebandy

- [ ] Kampsport
- [ ] Fjelltur
- [ ] Klatring (innendørs)
- [ ] Isklatring
- [ ] Orientering
- [ ] Ridning
- [ ] Langrenn
- [ ] Fjellski/topptur
- [ ] Alpint (Slalåm/Telemark)
- [ ] Snowboard
- [ ] Skøyter
- [ ] Andre aktiviteter
- [ ] Driver ikke med noen av disse aktivitetene

42.1 Andre aktiviteter (nevn hvilke)

43. Hvem er du som regel i fysisk aktivitet sammen med på fritiden? [Kryss av for alle alternativ som gjelder for deg]

- [ ] Foreldre
- [ ] Søsken (bror og/eller søster)
- [ ] Venner
- [ ] Lagkamerater
- [ ] Trener
- [ ] Andre

43.1. Andre (nevn hvem)

HØGSKOLEN i INNLANDET

44. Hvilke aktivitetsarenaer bruker du vanligvis? (kryss av for alle som gjelder deg)

- [ ] Fotballbane
- [ ] Idrettshall
- [ ] Svømmehall
- [ ] Treningssenter
- [ ] Skogen
- [ ] Løyper/stier
- [ ] Elv/stryk
- [ ] Fjell
- [ ] Sjø/innsjø
- [ ] Klatrefelt
- [ ] Nærmiljøanlegg
- [ ] Andre arenaer
- [ ] Bruker ikke noen av disse arenaene

44.1. Andre arenaer (nevn hvilke)

45. Hvor ofte er du engasjert med fysisk aktivitet på fritiden?

- Aldri
- Sjeldnere enn en gang hver måned
- 1-2 ganger i måneden
- Minst en gang i uka
- 2 ganger i uka eller mer
- 3-4 ganger i uka
- Nesten daglig

HØGSKOLEN i INNLANDET

46. Hvor ofte deltar du vanligvis i disse typene aktiviteter på fritiden?

	Holder ikke på med denne typen aktivitet	2-3 ganger i måneden eller sjeldnere	Omtrent 1 dag i uken	2 ganger i uken eller oftere
Musikk (spiller et instrument, synger i kor)	○	○	○	○
Kunst (f.eks tegning eller maling)	○	○	○	○
Gaming	○	○	○	○
Sjakk	○	○	○	○
Besøker museum eller kunstgalleri	○	○	○	○
Organiserte aktiviteter i grupper (f.eks kirkelige aktiviteter, speider, drama)	○	○	○	○
Annet	○	○	○	○

Organiserte aktiviteter i grupper (f.eks kirkelige aktiviteter, speider, drama). Vennligst spesifiser:

Annet. Vennligst spesifiser:

HØGSKOLEN i INNLANDET

Tusen takk for at du svarte på denne undersøkelsen!

Denne undersøkelsen er produsert og tilrettelagt av Høgskolen i Innlandet

Appendix II:

WEMWBS original Norwegian version

WEMWBS

Nedenfor finner du en del utsagn om følelser og tanker.

Vennligst kryss av for det som best beskriver din opplevelse for hvert utsagn de siste 2 ukene.

	Ikke i det hele tatt	Sjelden	En del av tiden	Ofte	Hele tiden
1. Jeg har vært optimistisk med hensyn til fremtiden	1	2	3	4	5
2. Jeg har følt meg nyttig	1	2	3	4	5
3. Jeg har følt meg avslappet	1	2	3	4	5
4. Jeg har følt interesse for andre mennesker	1	2	3	4	5
5. Jeg har hatt masse energi	1	2	3	4	5
6. Jeg har håndtert problemer godt	1	2	3	4	5
7. Jeg har tenkt klart	1	2	3	4	5
8. Jeg har vært fornøyd med meg selv	1	2	3	4	5
9. Jeg har følt nærhet til andre mennesker	1	2	3	4	5
10. Jeg har følt meg selvsikker	1	2	3	4	5
11. Jeg har vært i stand til å ta beslutninger	1	2	3	4	5
12. Jeg har følt meg elsket	1	2	3	4	5
13. Jeg har vært interessert i nye ting	1	2	3	4	5
14. Jeg har vært i godt humør	1	2	3	4	5

Translated by Smith O.R.F.[1], Alves D.E.[1], Haug E.M.M.[2], Aarø L.E.[1]

1) Division of Mental Health, Norwegian Institute of Public Health, Kalfarveien 31, 5018 Bergen, Norway
2) NLA University College, Postboks 74, Sandviken, 5812 Bergen, Norway

Appendix III:

WEMWBS Norwegian back-translations from bokmål to nynorsk

Translations from bokmål into nynorsk

Original bokmålsversjon:	Nynorsk oversetjing (Person 1)	Nynorsk oversetjing (Person 2)
Nedenfor finner du en del utsagn om følelser og tanker. Vennligst kryss av for det som best beskriver din opplevelse for hvert utsagn de siste 2 ukene. (Svarkategorier fra *«Ikke i det hele tatt»* til *«hele tiden »*)	Nedanfor finn du ein del utsegn om kjensler og tankar. Ver vennleg å kryss av for det som best skildrar di oppleving for kvar utsegn dei siste 2 vekene. (Svarkategoriar frå «Ikkje i det heile teke» til «heile tida»)	Nedanfor finn du ein del utsegn om følelsar og tankar. Vær venleg å kryss av for det som best skildrar di oppleving for kvart utsegn dei siste 2 vekene (Svarkategoriar frå «Ikkje i det heile tatt» til «heile tida »)
Jeg har vært optimistisk med hensyn til fremtiden	Eg har vore optimistisk med omsyn til framtida	Eg har vore optimistisk med omsyn til framtida
Jeg har følt meg nyttig	Eg har følt meg nyttig	Eg har følt meg nyttig
Jeg har følt meg avslappet	Eg har følt meg avslappa	Eg har følt meg avslappa
Jeg har følt interesse for andre mennesker	Eg har følt interesse for andre menneske*	Eg har følt interesse for andre menneske
Jeg har hatt masse energi	Eg har hatt masse energi	Eg har hatt mykje energi
Jeg har håndtert problemer godt	Eg har handtert problem godt**	Eg har handtert problem godt**
Jeg har tenkt klart	Eg har tenkt klårt	Eg har tenkt klart
Jeg har vært fornøyd med meg selv	Eg har vore nøgd med meg sjølv	Eg har vore nøgd med meg sjølv
Jeg har følt nærhet til andre mennesker	Eg har følt nærleik til andre menneske	Eg har følt nærleik til andre menneske
Jeg har følt meg selvsikker	Eg har følt meg sjølvsikker	Eg har følt meg sjølvsikker
Jeg har vært i stand til å ta beslutninger	Eg har vore i stand til å ta avgjersler	Eg har vore i stand til å ta avgjersler
Jeg har følt meg elsket	Eg har følt meg elska***	Eg har følt meg elska***
Jeg har vært interessert i nye ting	Eg har vore interessert i nye ting	Eg har vore interessert i nye ting
Jeg har vært i godt humør	Eg har vore i godt humør	Eg har vore i godt humør

***** Kommentar frå Person 1: «Her ville eg eigentleg ha skrive: Eg har vore interessert i andre menneske».

****** Tilbakemeldingar frå pilotundersøkjinga synte at påstanden «Eg har handtert problem godt» var vanskeleg for ein del elevar å forstå innhaldet av. Etter å ha gjennomført tilbakeoversetjingar mellom BM og NN sette ein av faglærarane opp alternativ oversetjing som han meinte var betre «Jeg har løst problemer på en god måte». Då vår vurdering er at meiningsinnhaldet frå den engelske versjonen er godt teke i vare her, har me valgt å bruka denne oversetjinga i vår bruk av WEMWBS, då me trur dette vil gjera påstanden lettare for elevane å forstå.

*******Etter analyse av pilotdata på påstand «Eg har følt meg elska» er me usikre på om alle elevar tolkar dette på måten det er meint i den engelske versjonen «I've been feeling loved». «Loved» brukast som ein samlebetegnelse for all kjærleik på engelsk, medan det blir differensiert i større grad på norsk mellom «å elske» og «å være glad i». Førstnevnte brukast i stor grad om kjærleiksforhold mellom eit par, medan sistnevnte brukast i stor grad om den kjærleiken ein har til sine familimedlemmer og nære vener. Me er usikre på om elevane som har svart 0 «ikkje i det heile tatt» kan ha mistolka denne påstanden til å handla om eit kjærleiksforhold mellom eit par. For å unngå at dette blir eit usikkerheitsmoment i tolkinga av data har me kontakta to engelsklærarar ved ein av pilotskulane med den engelske påstanden og bedt dei oversetja denne. Dei overset denne då til «*Eg har følt at noen er glad i meg*». Me vel difor leggja denne til grunn i vår bruk av WEMWBS.

Back-translations from nynorsk into bokmål

Nynorskversjon (Person 1):	**Bokmålsoversetjing (Person 3)**	**Bokmålsoversetjing (Person 4)**
Nedanfor finn du ein del utsegn om kjensler og tankar. Ver vennleg å kryss av for det som best skildrar di oppleving for kvar utsegn dei siste 2 vekene. (Svarkategoriar frå «Ikkje i det heile teke» til «heile tida»)		Under finner du en del uttalelser om følelser og tanker. Vær vennlig å krysse av for det som best beskriver din opplevelse for hver uttalelse de siste to ukene. (Svarkategorier fra «ikke i det hele» til «hele tiden»)
Eg har vore optimistisk med omsyn til framtida	Jeg har vært optimistisk med tanke på framtida.	Jeg har vært optimistisk med hensyn til fremtiden.
Eg har følt meg nyttig	Jeg har følt meg nyttig.	Jeg har følt meg nyttig.
Eg har følt meg avslappa	Jeg har følt meg avslappa.	Jeg har følt meg avslappet.
Eg har følt interesse for andre menneske	Jeg har følt interesse for andre mennesker.	Jeg har følt interesse for andre mennesker.
Eg har hatt masse energi	Jeg har hatt mye energi.	Jeg har hatt masse energi.
Eg har handtert problem godt**	Jeg har løst problemer på en god måte.**	Jeg har håndtert problem godt.**
Eg har tenkt klårt	Jeg har tenkt klart.	Jeg har tenkt klart.
Eg har vore nøgd med meg sjølv	Jeg har vært fornøyd med meg selv.	Jeg har vært fornøyd med meg selv.
Eg har følt nærleik til andre menneske	Jeg har følt nærhet til andre mennesker.	Jeg har følt nærhet til andre mennesker.
Eg har følt meg sjølvsikker	Jeg har følt meg selvsikker.	Jeg har følt meg selvsikker.
Eg har vore i stand til å ta avgjersler	Jeg har vært i stand til å ta egne avgjørelser.	Jeg har vært i stand til å ta avgjørelser.
Eg har følt meg elska	Jeg har følt meg elsket.***	Jeg har følt meg elsket.***
Eg har vore interessert i nye ting	Jeg har vært interessert i nye ting.	Jeg har vært interessert i nye ting.
Eg har vore i godt humør	Jeg har vært i godt humør.	Jeg har vært i godt humør.

Appendix IV:

Study approval from the Norwegian Centre for Research data (NSD)

Ingeborg Barth Vedøy
Institutt for idrett og aktiv livsstil Høgskolen i Hedmark, campus Elverum
Postboks 400
2418 ELVERUM

Vår dato: 24.06.2016 Vår ref: 48192 / 3 / HIT Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 04.04.2016. All nødvendig informasjon om prosjektet forelå i sin helhet 23.06.2016. Meldingen gjelder prosjektet:

48192	*Skoler, læring og psykisk helse: en studie av faktorer og prosesser i skolemiljøet.*
Behandlingsansvarlig	*Høgskolen i Hedmark, ved institusjonens øverste leder*
Daglig ansvarlig	*Ingeborg Barth Vedøy*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 31.12.2019, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Hildur Thorarensen

Kontaktperson: Hildur Thorarensen tlf: 55 58 26 54
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 48192

BAKGRUNN OG FORMÅL
Formålet er å gjennomføre en prospektiv kohortstudie som skal innhente spørreskjemadata, objektivt fysisk aktivitetsnivå (gjennom bruk av aktivitetsmålere) og karakterutskrift hos elever alle tre årene de går på ungdomsskolen. Formålet er å øke kunnskap om hvilke individuelle- og skolefaktorer som påvirker ungdommers psykiske helse i denne perioden av livet. Man er primært opptatt av å undersøke faktorer som styrker den psykiske helsen, og vil derfor ikke undersøke prevalens av psykiske lidelser. Ungdommene sitt fysisk aktivitetsnivå, aktivitetsmønster og utvikling av dette, er tillagt en særskilt vekt i dette prosjektet. Forholdet mellom fysisk aktivitet, akademiske prestasjoner og psykisk helse vil derfor være en sentral del av dette prosjektet.

Data innhentes i form av spørreskjema, registrering av aktivitetsnivå, vekt, høyde, midjemål og karakterer.

Prosjektleder oppgir at prosjektgruppen har vært i kontakt med REK, og kommet frem til at prosjektet faller utenfor helseforskningsloven.

INFORMASJON OG SAMTYKKE
Utvalget informeres skriftlig om prosjektet og samtykker til deltakelse. Foreldre samtykker for sine barn. Informasjonsskrivet mottatt 23.06.2016 er godt utformet.

Merk at når barn skal delta aktivt, er deltagelsen alltid frivillig for barnet, selv om de foresatte samtykker. Barnet bør få alderstilpasset informasjon om prosjektet, og det må sørges for at de forstår at deltakelse er frivillig og at de når som helst kan trekke seg dersom de ønsker det.

INFORMASJONSSIKKERHET
Det behandles sensitive personopplysninger om helseforhold.

Personvernombudet legger til grunn at forsker etterfølger Høgskolen i Hedmark sine interne rutiner for datasikkerhet.

Høgskolen i Lillehammer er databehandler for prosjektet. Høgskolen i Hedmark skal inngå skriftlig avtale med Høgskolen i Lillehammer om hvordan personopplysninger skal behandles, jf. personopplysningsloven § 15. For råd om hva databehandleravtalen bør inneholde, se Datatilsynets veileder: http://www.datatilsynet.no/Sikkerhet-internkontroll/Databehandleravtale/.

PROSJEKTSLUTT OG ANONYMISERING
Forventet prosjektslutt er 31.12.2019. Ifølge prosjektmeldingen skal innsamlede opplysninger da anonymiseres. Anonymisering innebærer å bearbeide datamaterialet slik at ingen enkeltpersoner kan gjenkjennes. Det gjøres

ved å:
- slette direkte personopplysninger (som navn/koblingsnøkkel)
- slette/omskrive indirekte personopplysninger (identifiserende sammenstilling av bakgrunnsopplysninger som f.eks. bosted/arbeidssted, alder og kjønn)

Vi gjør oppmerksom på at også databehandler (Høyskolen i Lillehammer) må slette personopplysninger tilknyttet prosjektet i sine systemer. Dette inkluderer eventuelle logger og koblinger mellom IP-/epostadresser og besvarelser.

Appendix V:

Study information and informed consent

Høgskolen i **Hedmark**
Campus Elverum

INFORMASJON OM SKOLE, LÆRING OG PSYKISK HELSE PROSJEKTET

Kjære elev og foreldre/foresatt,

Høgskolen i Hedmark, Avdeling for folkehelsefag ønsker å undersøke hvordan ungdom har det på skolen og i fritiden, og hvordan deres psykiske helse og læring påvirkes av hvordan de trives på skolen sammen med andre elever. Målet med studien er å få mer kunnskap om hvilke faktorer som fremmer og hemmer ungdommers psykiske helse og læring. Vi inviterer derfor ditt barn til å delta i en spørreundersøkelse på skolen høsten 2016, 2017 og 2018. Undersøkelsen gjennomføres på PC sammen med de andre elevene i klassen. Undersøkelsen vil foregå i en skoletime, og de vil bruke ca. 40 - 45 minutter på å svare på spørsmålene.

Vi ønsker også å kartlegge ditt barns aktivitetsnivå. Dette gjør vi ved hjelp av en aktivitetsmåler som de skal bære i et belte rundt livet i sju påfølgende dager. Aktivitetsmåleren er på størrelse med en fyrstikkeske, og den blir levert ut på skolen. Registreringen vil ikke påvirke deres hverdag. Samtidig ønsker vi å måle høyde, vekt og midjemål.

I tillegg til dette ønsker vi å få tilgang til ditt barns halvtårskarakterer i januar alle de tre årene som undersøkelsen varer. Vi ønsker å samle inn informasjon om dette for å kunne undersøke om hvordan ungdom har det påvirker læring og skoleprestasjon.

Vi kommer til å besøke ditt barn i skoletiden ved to anledninger med en ukes mellomrom. Den første dagen vi kommer vil vi informere om undersøkelsen, dele ut aktivitetsmålerne og måle høyde, vekt og midjemål. Ved neste skolebesøk vil vi samle inn aktivitetsmålerne og gjennomføre spørreundersøkelsen.

Ditt barns deltakelse i studien er frivillig, og all informasjon de gir vil bli behandlet konfidensielt. Dette betyr at verken foreldre/foresatte, lærere eller noen andre ungdommen kjenner vil få vite hva de har svart i spørreundersøkelsen eller noe om de andre målingene de har gjennomført. Selv om det hjelper prosjektet at de gjennomfører disse målingene, er de ikke forpliktet til å besvare alle spørsmålene i spørreskjemaet eller gjennomføre alle de andre tilhørende målingene

Dersom ditt barn deltar i studien, men på et senere tidspunkt ikke ønsker å delta lenger, kan du/ditt barn informere oss direkte eller via barnets lærer slik at vi kan slette den informasjonen som ditt barn allerede har gitt til undersøkelsen.

Innsamlede opplysninger om ditt barn oppbevares slik at navn er erstattet med en kode som viser til en atskilt navneliste. Denne listen ligger på en passordsikret server som kun prosjektansvarlig, Miranda Thurston, og stipendiat, Ingeborg Barth Vedøy, har tilgang til. Det vil ikke være mulig å identifisere ditt barn i resultatene av undersøkelsen når disse publiseres. Etter prosjektslutt 31.12.2019, vil alle personopplysninger bli anonymisert. Høgskolen i Lillehammer vil behandle data fra spørreskjemaene for prosjektet.

Dersom du har spørsmål angående prosjektet, ta kontakt med Ingeborg Barth Vedøy på tlf. 62430345/91534951 eller Hege Eikeland Tjomsland på tlf. 62430118/48510865.

Ditt barns deltakelse i studien er høyt verdsatt, og vi ser fram til å treffe ham/henne!

Vennlig hilsen
Miranda Thurston

Professor, Høgskolen i Hedmark

ELEVENES SAMTYKKEERKLÆRING

Studie: Skole, læring og psykisk helse - SL&MH-prosjektet

Prosjektansvarlig: Miranda Thurston

Jeg, _____ har lest informasjonsarket, og jeg forstår hensikten med prosjektet. Undersøkelsen har blitt forklart for meg, og jeg forstår at all informasjon jeg gir fra meg vil bli behandlet konfidensielt. Jeg vet at jeg når som helst kan trekke meg fra studien uten å oppgi noen grunn og uten at dette får noen konsekvenser, ved å informere lederen av studien eller læreren min.

Signatur: _____

Dato: _____

FORELDRENES SAMTYKKEERKLÆRING

Studie: Skole, læring og psykisk helse - SL&MH-prosjektet

Prosjektansvarlig: Miranda Thurston

Jeg, _____ har lest informasjonsarket, og jeg forstår hensikten med prosjektet. Undersøkelsen har blitt forklart for meg, og jeg forstår at all informasjon min sønn / datter gir fra seg vil bli behandlet konfidensielt. Jeg vet at min sønn / datter når som helst kan trekke seg fra studien uten å oppgi noen grunn og uten at dette får noen konsekvenser, ved å informere lederen av studien eller læreren hans / hennes.

Signatur: _____

Dato: _____

Appendix VI:

Time spent cycling and/or swimming in T1 to T3

Time spent cycling in T1 to T3, n (%).

Time spent cycling	T1 (2016)	T2 (2017)	T3 (2018)
0 hours	295 (51.7)	251 (46.7)	245 (48.0)
1 hour	95 (16.6)	101 (18.8)	92 (18.0)
2 hours	72 (12.6)	65 (12.1)	68 (13.3)
3-5 hours	77 (13.6)	86 (15.9)	83 (16.3)
≥ 6 hours	27 (5.0)	34 (6.3)	22 (4.4)

Time spent swimming in T1 to T3, n (%).

Time spent swimming	T1 (2016)	T2 (2017)	T3 (2018)
0 hours	332 (57.8)	404 (76.4)	408 (80.5)
1 hour	92 (16.0)	39 (7.4)	49 (9.7)
2 hours	75 (13.1)	30 (5.7)	19 (3.7)
3-5 hours	40 (7.0)	20 (3.8)	18 (3.6)
≥ 6 hours	35 (6.2)	36 (6.8)	13 (2.6)

Appendix VII:

Adherence to PA measurements in T1 to T3

Adherence to accelerometer measurements in T1 to T3, (%)

Time point	Valid measurements (≥2 days)
T1 (2016)[1]	572 (95.5)
T2 (2017)[1]	500 (87.1)
T3 (2018)[2]	461 (87.6)

[1] As participants with 2 and 3 days of measurement did not differ significantly from participants adhering to ≥4 valid wear days, they were included in PA analyses in T1 and T2

[2] As participants with 1, 2 and 3 days of measurement did not differ significantly from participants adhering to ≥4 valid wear days, they where included in PA analyses in T3