Runar Barstad Solberg // Physical activity, physical fitness and academic performance among adolescents.

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES
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Physical activity, physical fitness and academic performance among adolescents. Intervention effects from the School in Motion study

– a cluster randomized controlled trial

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Pernille, this thesis is dedicated to you

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Runar Barstad Solberg

List of papers

Paper I

Kolle, E., Solberg, R.B., Säfvenbom, R. *et al.* The effect of a school-based intervention on physical activity, cardiorespiratory fitness and muscle strength: the School in Motion cluster randomized trial. *Int J Behav Nutr Phys Act* **17,** 154 (2020). https://doi.org/10.1186/s12966-020-01060-0

Paper II

Solberg RB, Steene-Johannessen J, Anderssen SA, Ekelund U, Säfvenbom R, Haugen T, Berntsen S, Åvitsland A, Lerum Ø, Resaland GK, Kolle E. Effects of a school-based physical activity intervention on academic performance in 14-year old adolescents: a cluster randomized controlled trial - the School in Motion study. BMC Public Health. 2021 May 6;21(1):871. doi: 10.1186/s12889-021-10901-x. PMID: 33957895; PMCID: PMC8101111.

Paper III

Solberg RB, Steene-Johannessen J, Wang Fagerland M, Anderssen SA, Berntsen S, Resaland GK, Van Sluijs MF E, Ekelund U, Kolle E. Aerobic fitness mediates the intervention effects of a school-based physical activity intervention on academic performance. The School in Motion study – a cluster randomized controlled trial. *Preventive Medicine Reports, 24, 101648* (2021). doi:https://doi.org/10.1016/j.pmedr.2021.101648

Paper IV

Solberg RB, Steene-Johannessen J, Resaland GK, Tjomsland H, Van Sluijs MF E, Haugen T, Grydeland M, Lerum Ø, Kolle E. Teacher-reported contextual factors are not associated with the intervention dose delivered: A quantitative implementation assessment of a school-based physical activity intervention. [Manuscript submitted].

Summary

Introduction: Emerging evidence suggests a favourable relationship between physical activity, aerobic fitness and academic performance. Recent data show that physical activity levels decrease through adolescence, whilst only 50% of Norwegian 15-year-olds are sufficiently active meeting physical activity guidelines of ≥ 60 minutes in moderate-to-vigorous intensity physical activity (MVPA) per day. Accordingly, there is a need to develop interventions that can effectively change behaviour, leading to increased physical activity, physical fitness and academic performance among adolescents.

Aims: This thesis is based on a school-based, physical activity cluster randomized controlled trial (RCT) titled School in Motion (ScIM). This thesis investigates the intervention effects of ScIM on adolescents' physical activity level, physical fitness and academic performance. Further, we explored whether aerobic fitness mediated the intervention effects of physical activity on academic performance. Finally, we wanted to explore the associations between teacher-reported contextualised factors and intervention dose delivered.

Methods: ScIM was a nine-month cluster RCT. In total 30 Norwegian secondary schools were randomized to one of three study arms; the physically active learning (PAL) (n = 10); the Don't worry-Be happy (DWBH) intervention (n = 10); or control (n = 10). The PAL intervention included 30 min physically active learning, 30 min physical activity and a 60 min physical education (PE) lesson per week. The DWBH intervention included a 60 min physical activity lesson and a 60 min PE lesson per week. Both components in the DWBH intervention was tailored to promote friendships and wellbeing. The control group continued as usual, including the standard amount of mandatory PE. The PAL and DWBH interventions were designed to engage the adolescents in 120 min of physical activity per week in addition to recess and mandatory physical education (PE) lessons. Parental consent was obtained from 2,084 adolescent students (76%). Physical activity (main outcome) was assessed by accelerometers; physical fitness and muscle strength were assessed by an intermittent running test and selected tests from the Eurofit test battery; whilst standardized national tests in reading and numeracy was used to assess academic performance. Teacher related contextualized factors were self-reported once by teachers after randomisation, but prior intervention start. All other measurements were conducted at baseline and at the end of the intervention.

Summary

Results: Physical activity levels decreased in all three groups throughout the intervention. We found significant mean difference in change in physical activity (counts per minute 34.7, 95% Confidence interval (CI): 4.1 to 65.3; moderate-to-vigorous intensity physical activity 4.7 min, 95% CI: 0.6 to 8.8) and aerobic fitness (19.8 m, 95% CI: 10.4 to 29.1) among adolescents in the PAL intervention compared with controls.

No evidence was found for this in the DWBH intervention. Academic performance increased among adolescents in both interventions when compared with controls. The mean difference in change in numeracy was 1.7 (95% CI: 0.9 to 2.5) and 2.0 (95% CI: 1.4 to 2.7) points in favour of students in the PAL and DWBH intervention, respectively. For reading the mean difference in change was 0.9 (95% CI 0.2 to 1.6) and 1.1 (95% CI 0.3 to 1.9) points in favour of students in the PAL and DWBH intervention, respectively. Further, aerobic fitness did mediate the effects on academic performance in the PAL intervention, but not in the DWBH intervention. Finally, we found no associations between teacher related contextualized factors and dose delivered.

Conclusion: The results from this thesis has shown that implementing two hours of extra physical activity among adolescents have several positive effects. The PAL intervention is effective in curbing the decline in physical activity observed throughout adolescents, whilst also increasing the adolescent's aerobic fitness. Furthermore, both the PAL and DWBH interventions have proven to be feasible methods to increase academic performance among adolescents. As aerobic fitness mediated the intervention effect on academic performance in the PAL intervention, physical activity of an intensity that increases aerobic fitness is one strategy to improve academic performance among adolescents.

Summary – NORWEGIAN

Introduksjon; Fysisk aktivitet er foreslått å ha gunstig påvirkning på fysisk form og akademisk skoleprestasjoner blant barn og unge. Data fra norske kartleggingsundersøkelser viser imidlertid at aktivitetsnivået reduseres gjennom ungdomstiden, og at kun 50% av norske ungdommer oppfyller anbefalingene om å være i 60 minutter moderat-til-hard fysisk aktivitet hver dag. På bakgrunn av dette er det behov for å utvikle intervensjoner som kan øke aktivitetsnivået og fysisk form, som videre kan påvirke akademiske skoleprestasjoner blant ungdommer.

Målsettinger: Dette doktorgradsarbeidet er basert multisenterstudien School in Motion (ScIM). Målsettingene i dette doktorgradsarbeidet var å evaluere effekten av ScIM på ungdommers aktivitetsnivå, fysisk form og akademiske skoleprestasjoner. Videre ønsket vi å evaluere om fysisk form virker som et mellomledd i effekten mellom økt fysisk aktivitet og akademisk skoleprestasjoner. Avslutningsvis vil vi undersøke sammenhengen mellom selvrapporterte faktorer relatert til lærerne sin opplevelse med prosjektet og intervensjonsdose levert.

Metode: ScIM var en klyngebasert randomisert kontrollert studie som ble gjennomført i løpet av 9 måneder (2017-18). Totalt ble 30 Norske ungdomsskoler tilfeldig randomisert til en av tre ulike intervensjonsarmer; fysisk aktiv læring (PAL) gruppen (n = 10), Don't worry-Be happy (DWBH) gruppen (n = 10); eller gjeldende praksis (kontrollgruppen) (n = 10). PAL gruppen gjennomførte 30 minutter fysisk aktiv læring, 30 minutter fysisk aktivitet og 60 minutter ekstra kroppsøving per uke. DWBH gruppen gjennomførte 60 minutter ekstra kroppsøving og 60 minutter fysisk aktivitet per uke som begge var utformet for å fremme vennskap i bevegelse, mens kontrollgruppen fortsatte skoleåret som normalt. Både PAL og DWBH intervensjonen var utviklet for å implementere 120 minutter ekstra fysisk aktivitet og kroppsøving per uke i tillegg til de obligatoriske timene med kroppsøving. Totalt leverte 2,084 ungdommer (76%) informert samtykke fra foresatte om å delta i prosjektet. Fysisk aktivitet (hovedutfallsmål) ble registrert med akselerometer; fysisk form og muskelstyrke ble målt med en utholdenhetstest og utvalgte styrkeøvelser fra Eurofit testbatteri; mens akademiske skoleprestasjoner i regning og lesing ble målt med nasjonale prøver. Lærerne selvrapporterte faktorer relater til prosjektet før intervensjonen startet, men etter at komponentene hadde blitt inkludert på timeplanen. Alle andre malinger ble gjennomført før intervensjonen startet og på slutten av prosjektet.

Summary - Norwegian

Resultater: Gjennom intervensjonsperioden reduserte ungdommene i alle gruppene sitt fysiske aktivitetsnivå. I løpet av intervensjonsperioden hadde ungdommene i PAL intervensjonen en økning i aktivitetsnivået (tellinger per minutt 34.7, 95% CI 4.1 til 65.3; moderat-til-fysisk hard fysisk aktivitet, 4.7 min, 95% CI 0.6 til 8.8) og fysisk form (19.8 m, 95% CI 10.4 til29.1) sammenlignet med kontrollgruppen. Det ble ikke funnet tilsvarende resultater når ungdommene i DWBH ble sammenlignet med kontroll. Akademiske skoleprestasjoner økte signifikant blant ungdommene i både PAL og DWBH sammenlignet med ungdommene i kontrollgruppen. Gjennomsnittlig endring i regning var 1.7 poeng (95% CI 0.9 til 2.5) og 2.0 poeng (95% CI 1.4 til 2.7) i favør ungdommene i PAL og DWBH intervensjonen. For regning var gjennomsnittlig endring 0.9 poeng (95% CI 0.2 til 1.6) og 1.1 poeng (95% CI 0.3 til 1.9) i favør studentene i PAL og DWBH intervensjonen. Videre viste analysene at fysisk form virket som et mellomledd i effekten mellom økt fysisk aktivitet og akademiske skoleprestasjoner i PAL intervensjonen, men ikke i DWBH intervensjonen. Vi fant ingen sammenheng mellom selvrapporterte faktorer relatert til lærerne sin opplevelse prosjektet og intervensjonsdose levert.

Konklusjon: Resultatene fra dette doktorgradsarbeidet viser at det å innføre to timer ekstra fysisk aktivitet og kroppsøving blant elever på 9.trinn kan gi flere positive effekter. Ungdommene i PAL intervensjonen reduserte nedgangen i aktivitetsnivå observert gjennom ungdomstiden, samtidig som de økte fysisk form. Videre, viste begge modellene å være effektive metoder for å øke skoleprestasjoner. Effekten på skoleprestasjoner observert i PAL intervensjonen viste seg å være delvis som et resultat av økt fysisk form, som indikerer at fysisk aktivitet som øker fysisk form er en måte å øke akademiske skoleprestasjoner.

Abbreviations

AEE	Activity-induced energy expenditure
BMI	Body mass index
BMR	Basal metabolic rate
BDFN	brain-derived neurotrophic factor
CI	Confidence interval
CPM	Counts per minute
CFIR	The Consolidated Framework for Implementation Research
DLW	Doubly labelled water
DWBH	Don’t worry – be happy intervention model
EE	Energy expenditure
ICAD	International Children’s accelerometery database
HR	Heart Rate
ICC	Intra class correlation
LPA	Light physical activity
LOA	Limits of Agreement
MET	Metabolic equivalent
MPA	Moderate physical activity
MVPA	Moderate-to-vigorous physical activity
NSD	Norwegian centre for Research data
PE	Physical education
PYD	Positive youth development
PME	Positive movement experiences
PAL	Physically Active learning intervention model
RCT	Randomised controlled trial
RDS	Relational developmental systems
SED	Sedentary time
SES	Socio-economic status
ScIM	School in Motion
SD	Standard deviation
VO2	Oxygen consumption
Vo2max	Maximum oxygen uptake
Vo2peak	Peak oxygen uptake
VPA	Vigorous physical activity
WHO	World Health Organization

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1.0 Introduction

Adolescence (10-19 years) is a period marked by rapid physical, biological, social and mental development (Gogtay et al., 2004; Lamblin, Murawski, Whittle, & Fornito, 2017; Rosen, 2004). A sufficient amount of physical activity of a reasonable intensity contributes to positive development by providing physical, biological and mental health benefits for children and adolescents (Carson et al., 2016; Poitras et al., 2016). It is concerning that physical activity and physical fitness levels are decreasing among adolescents (Tomkinson, Lang, & Tremblay, 2019; van Sluijs et al., 2021). Lower levels of physical activity have a significant impact on adolescents' physical and mental health outcomes (Lubans et al., 2016; Poitras et al., 2016) and impose a large financial burden on society (van Sluijs et al., 2021). To prevent this unfavourable development and reap the benefits associated with physical activity, stakeholders and public health authorities are examining strategies to increase physical activity levels among adolescents (van Sluijs et al., 2021).

Numerous interventions aimed at increasing physical activity levels among children and adolescents have been implemented across home, school and community settings with mixed outcomes (Brown & Summerbell, 2009; Dobbins, Husson, DeCorby, & LaRocca, 2013; Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007). Schools are considered to be ideal for physical activity promotion for two main reasons; first, because children and adolescents from all backgrounds spend a significant amount of time in this setting (van Sluijs et al., 2021), and, second, the scholar's age is key to developing healthy habits, and, in addition, young people who are physically active are more likely to be active adults (Telama et al., 2014). However, in Norway, the school system is constantly under development, and national tests are mandatory to document the academic performance of children and adolescents. Consequently, the focus on academic performance has increased and schools have to devote a significant amount of curriculum time to activities to enhance academic outcomes, which, consequently, reduces the time available for other activities, such as physical activity.

Over recent years, research has shown that physical activity is related to brain structure, morphology and functions associated with academic outcomes in humans (Donnelly et al., 2016a; Lubans et al., 2016; Marques, Santos, Hillman, & Sardinha, 2018). Hence, the interest of researchers and practitioners in physical activity as a pedagogical teaching method has increased, and studies have reported associations between physical activity, physical fitness and academic outcomes in children and adolescents (Bezold et al., 2014; Booth et al., 2014; Chomitz et al., 2009; Desai, Kurpad, Chomitz, & Thomas, 2015; Esteban-Cornejo et al., 2014; Garcia-Hermoso, Esteban-Cornejo, Olloquequi, & Ramirez-Velez, 2017; Harrington, 2013; London & Castrechini, 2011; Maher et al., 2016; Morita et al., 2016; Rauner, Walters, Avery, & Wanser, 2013; Wittberg, Northrup, & Cottrell, 2012). Consequently, increasing the time allotted to curricular physical activity may yield physical, mental and academical benefits.

The prospect of establishing effects on physical activity and academic outcomes of including physical activity in the school curriculum has resulted in numerous randomized controlled trials (RCTs). Systematic reviews and meta-analyses related to school-based physical activity interventions have reported a modest increase in the aerobic fitness, physical activity (Hartwig et al., 2021) and academic performance of children and adolescents (Alvarez-Bueno et al., 2017). However, the research includes interventions that lack sustainability, and the results are inconclusive (Donnelly et al., 2016a; Love, Adams, & Sluijs, 2019; Marques et al., 2018; Santana et al., 2017; Singh et al., 2019). The latter could be related to different ways of measuring exposure and outcome and methodological limitations. Self-reported measures of physical activity tend to be associated with academic performance in children and adolescents (Marques et al., 2018). However, self-reported measures of physical activity have limited validity (Helmerhorst, Brage, Warren, Besson, & Ekelund, 2012; Ruescas-Nicolau et al., 2021). As measurements methodologies are developed and objective device-based methods, such as accelerometers, become more frequently used, the conclusions in more recent systematic reviews and meta-analyses have become less significant (Love et al., 2019; Marques et al., 2018). Furthermore, academic performance is measured with a large variety of tools with significant discrepancies in reliably and validity (Alvarez-Bueno et al., 2017), which limits the external validity of the findings. Finally, the crowded curricula in schools require physical activity interventions to be time-efficient, easy to implement and contribute to achieving academic objectives. However, school-based physical activity interventions often consist of a variety of physical activity components, for example, physically active transport to school, physically active lessons, physical education (PE), short physically active breaks during lessons and physically active homework. Thus, physical activity interventions might be complex to implement and can be comprehensive and time-consuming, which may make them vulnerable to poor intervention adherence (Wassenaar et al., 2020).

To close the knowledge gap in the literature, school-based physical activity interventions need to be easy to implement, and there is also a need to use valid measures for exposure and outcome variables (Wassenaar et al., 2020). Furthermore, most school-based physical activity interventions are with children in elementary schools, and there is a lack of studies that include large adolescent populations (Wassenaar et al., 2020).

Introduction

The overall aim of this dissertation is to improve our understanding of the effects of increased school-based physical activity on adolescents' physical activity level, physical fitness and academic performance. Furthermore, we explored the mediating role of aerobic fitness on the effect of the intervention on academic performance, in addition to exploring factors associated with the implementation to guide future interventions.

2.0 Theoretical background

2.1 Physical activity and sedentary behavior

Physical activity is defined as *any bodily movement produced by skeletal muscles that results in energy expenditure* (Caspersen, Powell, & Christenson, 1985). It is a multidimensional behaviour which includes intensity, frequency and duration. The *intensity* refers to the rate of energy expenditure, whereas the *duration* is the amount of time spent in physical activity within a specific timeframe, and *frequency* is the number of sessions performed per time unit. The total *volume* of physical activity is the duration multiplied by frequency and intensity, which is often related to energy expenditure (Caspersen et al., 1985) commonly expressed as metabolic equivalent of tasks (METs) (Lynch et al., 2019). In adults, one MET is defined as the amount of oxygen consumed while resting, equal to 3.5 ml/0_2/kg/min (Jetté, Sidney, & Blümchen, 1990). However, children have higher basal metabolic rates (BMR) compared with adults. Consequently, use of the standard MET equivalency would underestimate BMR of children (Butte et al., 2018). To estimate the energy cost of physical activities in children, Butte et al (2018) developed the Youth Compendium of Physical Activity (Butte et al., 2018). Using measured VO_2 divided by BMR they estimated that intensities such as light physical activity (LPA) correspond to 1.5–2.9 METs, moderate physical activity (MPA) to 3.0–5.9 METs and vigorous physical activity (VPA) to ≥ 6.0 METs. Further terms related to physical activity are *sedentary time* (SED) and *physical inactivity.* When awake, behaviour at the lower intensity spectrum, while sitting, lying or reclining, is categorised as SED (≤ 1.5 METs). Physical inactivity is defined as insufficient physical activity levels to meet the current physical activity guidelines (Tremblay et al., 2017).

A comprehensive examination of the effects of physical activity on adolescents physical activity levels, physical fitness and academic performance entail a carefully consideration of measures of exposure and outcome, and the various measures reliability, validity and feasibility (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013).

Theoretical background

2.1.1 Measurement of physical activity

The *reliability* of a method refers to how consistent and stable the results are when produced, such as whether two independent assessors produce the same results (interrater reliability) or repeated administrations of a given method by a single individual agree (intrarater reliability) (Fitzner, 2007). *Validity* refers to whether a method measures what is it supposed to measure (Fitzner, 2007). More specifically, *construct validity* evaluates whether a method represents the construct it is supposed to measure. High *construct validity* is important for the overall validity as it allows inferences to be made from the results (Bannigan & Watson, 2009). Next, *content validity* refers to how representative a method is of all aspects we are interested in measuring; *face validity* considers whether a method measures what it is intended to measure; whilst *criterion validity* refers to how closely the results of one test correspond to the results of a different one (Bannigan & Watson, 2009). A method must be reliable to be valid and should be tested in the population of interest.

Several different measurement methods for physical activity exist (Warren et al., 2010). Generally, the physical activity measurement methods can be divided into three categories: measures of energy expenditure (EE) (e.g., doubly labelled water (DLW) and indirect calorimetry), self-reported methods (e.g., questionnaires, diaries and logs) and device-based methods (e.g., heart rate monitors, pedometers and accelerometers). The most suitable method depends on many factors, and each method varies in its validity, reliability, cost and feasibility. There is often an inverse relationship between the feasibility and precision of a measurement method. For example, highly valid measurement methods (e.g., measures of energy expenditure) are often too expensive to use in research including many participants, while more feasible measures (e.g., self-reported methods) have lower validity.

DLW is considered the “gold standard” of measuring energy expenditure during free-living physical activity (Westerterp, 2013). Direct observation is also considered a salient method of measuring physical activity among children and adolescents because it allows research to gather contextual information such as activity pattern and activity type (Phillips et al., 2021). However, whilst DLW is a rather complicated and expensive method, direct observation is demanding for the researcher. Hence, DLW and direct observation is often considered inappropriate for use in large-scale epidemiological research. Consequently, other measurements for physical activity are used.

Theoretical background

Self-report methods

Self-report methods in physical activity research are diaries, logs, questionnaires and surveys. These methods are cost-effective and often relatively simple to use in large studies and require either an individual or a proxy to assess and report their physical activity behaviour, levels and/or pattern. Questionnaires can obtain information on domains, dose, intensity and frequency of physical activity and is frequently used, but is limited by relatively poor reliability and validity (Helmerhorst et al., 2012; Ruescas-Nicolau et al., 2021; Sallis & Saelens, 2000; Sirard & Pate, 2001). Logs and diaries can provide more detailed and accurate physical activity measurements but are precluded in studies including children due to the high burden of use. In general, self-report methods are prone to social desirability bias, which refers to the tendency of respondents to answer in a manner that will be viewed favourably by others, as well as their reliance on individuals to accurately recall and quantify their physical activity. These are important limitations which may introduce well-known flaws in the interpretation of physical activity levels and patterns and preclude their application in studies including children (Sirard & Pate, 2001). Consequently, device-based methods have become widely used to assess physical activity in young people.

Device-based methods

Device-based methods involve the use of a wearable device to measure physical activity. Rapid advances in technology have resulted in several different devices being available, most of which are relatively cheap and validated; consequently, their use in research has increased. Two classes of commonly used devices in research are heart rate (HR) monitors and motion sensors.

Relying on the linear relationship between oxygen consumption (VO_2) and HR when exercising, HR monitors are valid at intensities such as moderate-to-vigorous physical activity (MVPA) (Leonard, 2003). However, at lower intensities, factors such as stress, caffeine and environmental temperature can influence HR (Strath et al., 2013). In order to overcome this limitation individuals can calibrate the linear relationship between VO_2 and HR to establish an HR threshold, which discriminates between resting energy expenditure and activity-induced energy expenditure (AEE) (Leonard, 2003). However, intra-individual variation using the HR threshold is present, and the time-consuming procedure limits its use in large studies (Sirard & Pate, 2001).

Theoretical background

Motion sensors include *pedometers* and *accelerometers.* Pedometers estimate number of steps by recording movement while walking (Strath et al., 2013) and show generally high accuracy when compared to direct observation (Crouter, Schneider, Karabulut, & Bassett, 2003; McNamara, Hudson, & Taylor, 2010). Although studies have reported strong correlations between pedometer-assessed steps and direct observation in children and adolescents, pedometers cannot accurately assess the intensities, frequencies or duration of physical activity (Clemes & Biddle, 2013). This limits their applicability in large studies.

Accelerometers are motion sensors that quantify acceleration over time in one or more planes (Freedson, Pober, & Janz, 2005). These accelerations are sampled at frequencies greater than once per second and filtered into lower-resolution epochs usually ranging from 5 to 60 sec (Strath et al., 2013; Warren et al., 2010). Data extracted from accelerometers are usually expressed in counts per minute (CPM), which are referred to as an individual's total physical activity level. Further, specific cut-off points are used to determine intensity of physical activity, often expressed as LPA, MVPA or VPA. Finally, SED is often characterized by zero to very low accelerometer CPM (Cain et al., 2013).

Since the accelerometer emerged in the 1980s, rapid technological development has resulted in more advanced and lighter models with better battery and memory capacities (Troiano, McClain, Brychta, & Chen, 2014). Consequently, increased feasibility and accuracy, in addition to the number of available devices, have made them easier to use in large-scale epidemiological studies. The most used accelerometers in research, accounting for over 50% of published studies by 2015, are the monitors made by Actigraph (ActiGraph LLC, Pensacola, FL) (Wijndaele et al., 2015).

Theoretical background

Studies have reported strong associations between accelerometers and criterion measures of EE. When subjects used the older models (Computer Science and Applications Activity monitor) while walking and running on a treadmill, one study reported strong associations ($r = 0.86$, $p < 0.001$) between the activity monitor and EE assessed by indirect calorimetry in 10- to 14-year-olds (Trost et al., 1998). Using the modern model, Actigraph GT3X+, good inter-instrument reliability were reported when measuring CPM (95% Limits of Agreement (LoA) 68.0) and intensity-specific physical activity in free-living conditions among adults (SED LoA ±18.2 min, MVPA LoA ± 6.7 min) (Aadland & Ylvisåker, 2015). Further, in order to achieve a reliability estimate above 0.8, a study including 6,025 individuals aged nine to 11 years old from 12 countries recommended participants to wear the GT3X+ for seven consecutive days with at least four valid days (minimum 10 hours of wear time between 0600 and 2359) (Barreira et al., 2015). A recent systematic review including 11 studies and 570 participants published from 1996 through 2018 evaluated the validity of triaxial accelerometers compared with EE using indirect calorimetry (Lynch et al., 2019). Across studies, median sensitivity ranged from 46% to 96%, and median specificity ranged from 71% to 96% (Lynch et al., 2019). As such, current evidence suggest that Actigraph models are valid in measuring physical activity in children and adolescents (aged 3–18) (Lynch et al., 2019).

However, the use of accelerometery is not without methodological challenges (Cain et al., 2013). Since accelerometers quantify acceleration of the body segment to which the monitor is attached, normally either the hip/waist or the wrist, they can assess different movements. Even though the discussion regarding placement of accelerometers is ongoing, review-level evidence suggests that the validity is greater when accelerometers are placed on the hip/waist rather than the wrist (Lynch et al., 2019). Further, accelerometers tend to underestimate activities such as swimming (as the device is removed during activities in water) bicycling and strength training, and cannot distinguish between walking up- or downhill or with or without heavy bags, which can affect EE (Ainsworth, Cahalin, Buman, & Ross, 2015). Additionally, data collection and processing criteria using accelerometers to define intensity levels, including different epoch-length, non-wear time and criteria for valid days and measurements, vary between studies (Cain et al., 2013). In a systematic review aiming to provide age-specific considerations based on existing validation studies, the authors indicated that epoch lengths ranging from 1–15 sec, more than 10 hours of valid wear time per day and more than four days with valid recordings were necessary to achieve acceptable reliability (Migueles et al., 2017) . However, there is no consensus, as other studies suggest that between two and seven days with a minimum six hours of valid wear time per day is sufficient (Bingham et al., 2016; Vanhelst, Fardy, Duhamel, & Béghin, 2014).

2.1.2 The health benefits of physical activity

It is widely accepted that physical activity has several health benefits during adolescence and play a central role in future health (Carson et al., 2016; Poitras et al., 2016). Current evidence of the benefits can be divided across four main categories.

First, the associations between physical activity and cardiometabolic risk factors among children and adolescents are well established (Andersen et al., 2006; Ekelund et al., 2012). In a systematic review and meta-analysis of 30 prospective studies, the aggregated results revealed a significant inverse relationship between time spent in MVPA and clustering of cardiometabolic risk factors in youth (Skrede, Steene-Johannessen, Anderssen, Resaland, & Ekelund, 2019). Furthermore, the analysis showed that regardless of time spent in sedentary time, higher levels of MVPA were associated with better cardiometabolic risk factors (Skrede et al., 2019).

Second, some studies have reported a favourable association between MVPA and reduced adiposity among children and adolescents (Hills, Andersen, & Byrne, 2011; Hong, Coker-Bolt, Anderson, Lee, & Velozo, 2016; Steinbeck, 2001). Although the overall evidence is inconclusive (Janssen et al., 2005), evidence suggest that VPA is more strongly associated with reduced adiposity and waist circumference when compared with lower intensities (Carson et al., 2014; Janssen & Ross, 2012; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009).

Third, studies have reported a favourable association between physical activity and bone health among adolescents (Bull et al., 2020; Carson et al., 2016; Poitras et al., 2016). Good bone health is an important factor for future health because osteoporosis, which is defined as low bone mass, can cause significant morbidity worldwide (Carter & Hinton, 2014). Finally, a recent review of reviews shows support for the relationship between regular physical activity and depression (Biddle, Ciaccioni, Thomas, & Vergeer, 2019).

The benefits of physical activity and physical fitness has culminated in evidence-based global and national physical activity guidelines. The first guidelines were developed in the late 1990s and early 2000s (Troiano, Stamatakis, & Bull, 2020). The World Health Organization's (WHO) 2020 guidelines on physical activity update previous guidelines from 2010, and recommend that children and adolescents do at least an average of 60 min of daily MVPA across the week, muscle-strengthening activities at least 3 days a week and reduce time spent being sedentary (Bull et al., 2020). One notable update from the 2010 guidelines was the change from "at least" to "an average" of 60 min of MVPA per day. Meeting the physical activity recommendations is associated with increased physical fitness, cardiometabolic health, bone health, mental health and reduced adiposity (Bull et al., 2020; Carson et al., 2016; Poitras et al., 2016; Tarp et al., 2018).

2.1.3 Physical activity levels among children and adolescents

Over the last decades many studies have examined physical activity levels in youths. Two recurrent conclusion is that physical activity levels decreased with age and that boys are more active than girls (Dalene et al., 2018; Samdal et al., 2006; Steene-Johannessen et al., 2020; van Sluijs et al., 2021). In Norway, a national surveillance system for device measured physical activity in children and adolescents was initiated in 2005, with corresponding studies in 2011 and 2018 (Steene-Johannessen et al., 2021). Based on a nationally representative sample of Norwegian children and adolescents, results shows that the physical activity levels among 15-year-olds were 53% lower than among six-year-olds (Steene-Johannessen et al., 2021). Further, 40% of girls and 51% of boys aged 15 years met the WHO physical activity guidelines of 60 min of daily MPVA (Steene-Johannessen et al., 2021). When examining temporal trends in overall physical activity levels and time spent in MVPA, only small and insignificant changes were reported between 2005, 2011 and 2018 (Steene-Johannessen et al., 2021). The only exception was among nine-year-old boys, where lower overall physical activity levels (mean difference 62 CPM, 95% CI 24 to 100) and MVPA (-9.7 min, 95% CI -14.8 to -4.7) were found in 2018 compared with 2005. This reduction in total physical activity levels and MVPA reflects the reduction in the proportion of sufficiently active (≥ 60 minutes in MVPA per day) nine-year-old boys in 2018 and 2005 (-6.0 percentage points, 95% CI -10.9 to -1.2). In 15-year-olds, the prevalence is relatively stable and does not show any clear trend, with about 55% and 45% of boys and girls, respectively, being sufficiently active (Steene-Johannessen et al., 2021).

In an attempt to reduce the comparability challenges formed by using different processing criteria, several research groups pooled their accelerometer physical activity data to create the International Children's Accelerometery Database (ICAD) (Sherar et al., 2011). The opportunity to reanalyse data using the same methodology across studies solved, to a certain extent, the previous comparability challenge. Using ICAD data on 28,000 participants (2.8–14.8 years) from 10 countries, Cooper et al. (2015) showed that after the age of five to six, physical activity levels decreased, with an average difference of 29 CPM for boys and 32 CPM for girls between each age group, for example from age five to six and from age seven to eight. This corresponds to a decrease of 4.2% each year throughout adolescence (Cooper et al., 2015). Another study utilized harmonized ActiGraph data on 47,497 individuals (2-18 years) from 18 different European countries (Steene-Johannessen et al., 2020). The results show the same pattern as in the study by Cooper et al (2015), suggesting a substantial decrease in physical activity levels across age groups with an average category-to-category difference of approximately 50 CPM, with the highest levels at age four to five and lowest at age 14–15 (Steene-Johannessen et al., 2020). The opposite was observed for time spent sedentary, which increased with age and peaked at the age of 14–15 (Steene-Johannessen et al., 2020).

2.2 Physical fitness

Physical fitness is a measure of the body's ability to perform physical activity and exercise (Caspersen et al., 1985). The term entails aerobic fitness, muscular fitness, flexibility, body composition and motor control (Marques et al., 2021). *Aerobic fitness* reflects the functioning of several organ systems (i.e. respiratory, cardiovascular and muscular), and is considered a physiological measure of the ability to deliver oxygen to mitochondria during physical activity (Ross et al., 2016). *Muscle fitness* is a multidimensional construct and reflects performance in numerous tests, including power, speed, agility, flexibility and strength. *Body composition* is a broad term and it is defined as a physiological characteristic that affects an individual's ability to carry out daily tasks with vigor (Stodden, Sacko, & Nesbitt, 2015). The term includes different anthropometric measures for example height, weight and waist circumference, and also percent of body fat, muscle mass and hydration (Stodden et al., 2015). *Flexibility* is defined as the range of motion of muscle and connective tissues at a joint or group of joints (Stodden et al., 2015). Assessing physical fitness is important for monitoring biological and physiological adaptations that are achieved through natural development or training. Hence, several different tests for assessing the various components of aerobic fitness and muscle fitness are developed.

2.2.1. Measurements of physical fitness

Aerobic fitness

The gold standard for assessing aerobic fitness is maximum oxygen uptake (VO_{2max}), usually expressed either as an absolute rate or relative to body weight. To determine VO_{2max}, an individual exercises at progressively higher intensities on the treadmill or cycle ergometer until their VO_2 plateaus (Barker, Williams, Jones, & Armstrong, 2011). However, children and adolescents do not always reach a plateau, which has gradually led to peak oxygen uptake (VO_{2peak}) being the most common measure of young people's highest VO_2 level (Welsman, Bywater, Farr, Welford, & Armstrong, 2005). The high cost of the equipment used to test VO_{2max} and VO_{2peak} directly has hindered its use in large-scale epidemiological studies.

Indirect testing, on the other hand, requires little or no expensive equipment. Several field tests have been developed to predict $V0_{2peak.}$ Field tests include distance/time runs and shuttle run tests such as the 20-metre shuttle run (Lang, Tremblay, Léger, Olds, & Tomkinson, 2018; Léger, Mercier, Gadoury, & Lambert, 1988) and the Andersen test (Andersen, Andersen, Andersen, & Anderssen, 2008). In the distance/time tests, participants run a predefined distance as fast as they can (for instance the cooper test). In the 20-metre shuttle run test, participants run back and forth over 20 metres with a running speed starting at 8.5 km/h, increasing their speed by 0.5 km/h approximately each minute with the help of pre-recorded signals. Participants have reached their maximal performance when they fail to reach the end line on two consecutive occasions before the set beat (Léger et al., 1988). In a meta-analysis, the 20-metre shuttle run test was found to have moderate criterion validity (r=0.78, 95% CI 0.72 to 0.85) for estimating aerobic fitness in children (Mayorga-Vega, Aguilar-Soto, & Viciana, 2015).

The Andersen test is a 10-minute intermittent running test where participants run back and forth over 20 metres for 15 seconds with a corresponding 15-second break. In contrast to the 20-metre shuttle run, participants are not excluded during the Andersen test. A study of 118 10-year-old children reported bias (mean change) between three Andersen tests with an increase in running distance from test 1 to test 2 (26.7 meters, 95% CI 14.8 to 38.6), whereas no difference was found between tests 2 and 3 ($p = 0.51$). The relationship between the best performance and $VO2_{peak}$ was $r = 0.73$ (Aadland, Terum, Mamen, Andersen, & Resaland, 2014). Thus, the Andersen test has been found valid and reliable in estimating $VO2_{peak}$ at group level in children.

Muscle fitness

Different test batteries are available to assess muscle fitness. Two of the most common are the FITNESSGRAM (Plowman et al., 2006) and the Eurofit Battery (Kemper & Vanmechelen, 1996; Tomkinson, Olds, & Borms, 2007). The FITNESSGRAM includes different tests for muscle strength (curl-up, push-up, flexed arm pull-up, shoulder stretch), and have proven to be valid and reliable ($r \geq 0.80$) (Morrow et al., 2013) . In the Eurofit battery, muscle strength (i.e., endurance, and isometric and explosive strength) is tested using different field tests. Upper limb strength, referred to as handgrip strength, is measured using a handheld dynamometer, which has proven to be a valid measure of musculoskeletal strength among 8- to 20-year-olds (correlation coefficient, $r = 0.7$ to 0.8, $p < 0.01$) (Wind, Takken, Helders, & Engelbert, 2010). Further, explosive strength in the lower body is measured using a standing broad jump test, and abdominal muscle endurance is tested using a sit-up test. Standing broad jump tests have been moderately correlated with 1 repetition maximum in leg press ($r = 0.39$) (Stodden et al., 2015).

Theoretical background

Body composition

When taking feasibility, reliability and validity into consideration, three tests are recommended to assess body composition in children and adolescents. First, sum of skinfolds are considered a valid and reliable tests to estimate subcutaneous fat and predict body fat (Stodden et al., 2015). Second, body mass index (BMI) is correlated with fat mass and percentage of body fat and is the most common assessment for weight status. However, BMI has several limitations and it is important to understand that two individuals with the same BMI can differ in both fat mass and percentage body fat (Stodden et al., 2015). Third, waist circumference has shown to be a valid measure of central adiposity and a good predictor of body fat distribution in youth. Waist circumference is also associated with abdominal adiposity, which provides information about different dimensions of body composition linked to health risks (Stodden et al., 2015).

2.2.2 The health benefits of physical fitness

Current evidence suggests that physical fitness is a strong and independent predictor of cardiometabolic risk among children and adolescents (Anderssen et al., 2007; Ekelund et al., 2007; Ortega, Ruiz, Castillo, & Sjöström, 2008).

Aerobic fitness has shown to be an important health factor, with lower levels being an independent modifiable risk factor for cardiovascular disease, whilst greater levels are associated with better health outcomes in young and older people (Raghuveer et al., 2020). Additionally, physical fitness have been reported to moderate the prospective associations between physical activity and clustering of cardiometabolic risk factors (Skrede et al., 2018). In a systematic review examining whether physical fitness modified the associations between physical activity and cardiometabolic health, most of the findings supported greatest benefits of physical activity on cardiometabolic health markers in youth with low physical fitness (Husøy et al., 2021).

A systematic review and meta-analysis of 110 studies reported strong evidence for an inverse association between muscular fitness and adiposity (pooled effect size, r = -0.25, 95% CI -0.41 to -0.08) and an inverse association between muscular fitness and cardiometabolic risk (Smith, Eather, et al., 2014). Further, a recent systematic review and meta-analysis of 30 prospective studies and 21,686 participants (aged 3–18 years) examined the associations between muscular fitness in childhood and adolescents and future health (follow-up ranged from 1–27 years, mean 8.6 years). The authors reported an inverse prospective association between muscular fitness and adiposity and risk factors for cardiovascular diseases later in life (García-Hermoso, Ramírez-Campillo, & Izquierdo, 2019).

2.2.3 Physical fitness levels among adolescents

Based on country-specific and age-specific aerobic fitness performance indices from fifty countries, Lang and colleagues (2018) described the 20-metre shuttle run test performance among 1,142,026 children and adolescents aged 9–17 years. The performance varied substantially across countries, with boys in the best-performing country covering a distance of approximately 1600 m, whilst those in the lowest-performing country averaged 400 m (Lang et al., 2018). Values for girls were approximately 1000 m and 300 m in the best and lowest performing country, respectively. Norwegian girls and boys girls aged 13-15 years ran approximately 900 m and 1100 m, making them the fifth best performing group (Lang et al., 2018). In a Norwegian study of 104 10-year-olds using the Andersen test, the results showed that the adolescents girls covered a distance of 909 m, whilst boys covered a distance of 974 m (Aadland et al., 2014). Examining temporal trends in physical fitness, Tomkins and colleagues (2019) included almost one million children and adolescents from 19 countries between 1981 and 2014. They found that physical fitness moderately declined overall between 1981 and 2014 (Tomkinson et al., 2019). The stratified trends showed a large and a small decline in mean physical fitness in boys and girls respectively, whilst a moderate decline in both children and adolescents was observed (Tomkinson et al., 2019).

Examining muscular fitness, a recent systematic review included approximately 2,8 million Eurofit performances in children and adolescents aged 9–17 years from 98 studies in 30 countries (Tomkinson et al., 2018). Norm values were displayed in centiles stratified by age groups, showing that muscular strength increase during normal growth and maturation in childhood throughout adolescence. Specifically, among 14-year-olds, boys performed better than girls on muscular strength tests. Among boys, handgrip strength varied from 21.6 kg in the lowest centile to 47.6 kg in the highest centile. Comparable values among girls were 18.5 kg and 35.6 kg (Tomkinson et al., 2018). Regarding the standing broad jump, values among boys ranged from 138.7 cm in the lowest centile to 223.9 cm in highest centile. Corresponding values for girls were 115.6 cm and 190.0 cm. Number of sit-ups in the lowest and highest centile among boys was 15 and 30 respectively, whilst the corresponding number among girls was 12 and 26 (Tomkinson et al., 2018). Comparable data among Norwegian 15-years-olds showed that boys and girls, on average, performed 41.3 kg and 30.5 kg in the handgrip strength test, jumped 192.0 cm and 157.3 cm in the standing broad jump and performed an average of 22 and 19 sit-ups, respectively (Steene-Johannessen, Anderssen, Kolle, Andersen, et al., 2009).

2.3 Academic performance

One of the objectives of schools is to ensure that all children and adolescents receive high-quality education. High quality education could stimulate social and cognitive skills and academic performance. Academic performance is often assessed as the performance on specific academic outcomes and represent the extent to which a student has achieved their educational goals (Stinebrickner & Stinebrickner, 2008). Hence, schools are often evaluated based on their students' academic performance.

Academic performance is a broad and complex process representing a variety of underlying factors important for school success such as brain function, brain structure, executive functions and school attitudes. Brain function refers to the neurological changes, for example increase in growth factors and neural activity, whereas brain structure is the structural changes, like increase in white and grey matter volume (Donnelly et al., 2016b; Gunnell et al., 2019). Executive functions generally refer to a set of mental processes important for learning and understanding, and include inhibition, working memory and cognitive flexibility. Inhibition is the ability to resist or override dominant or automatic responses that enable children and adolescents to resist a desire to do what seems naturally. By inhibition responses children can stay focused on the selective task (Gunnell et al., 2019) . Working memory is the ability to store information and actively manipulate this information over a relative short period of time. This ability enables children and adolescents to remember information whilst also being able to engage in other cognitive activities. Cognitive flexibility is the ability to change perspectives, being flexible to adjust to changing demands and take advantages of sudden and unexpected situations (Gunnell et al., 2019).

Academic performance is an important outcome of formal education and plays a potential vital role in life (Moore, 2019). A longitudinal study examined the relationship between mathematics and verbal scores at age 13 years and accomplishments later in life (mean age 33.6 years) (Kell, Lubinski, & Benbow, 2013). The results indicated that individuals who was identified with profound mathematical and verbal skills at age 13 not only chose prestigious occupations by the age of 38 but ended up working for impressive employers (Kell et al., 2013). Furthermore, students with better academic performance also have lower probability of dropout from school (Ramsdal, Bergvik, & Wynn, 2015; Stinebrickner & Stinebrickner, 2014). Dropout from school is a risk factor for welfare dependency and mental health problems (Lee et al., 2009; Sagatun, Wentzel-Larsen, Heyerdahl, & Lien, 2016).

2.3.1 Measurements of academic performance

Students' academic performance is rated through the assessment of their aptitude and knowledge in subjects. Academic performance is assessed differently across studies. Some studies report academic performance as unstandardized school grades in traditional subjects like language and numeracy, some use standardised performance tests, whilst others use national achievement tests.

Wechsler Individual Achievement Test

The Wechsler Individual Achievement Test assesses academic performance through a broad range of academic skills. The four basic skills are reading, mathematics, writing and speaking. Within these scales, there is a total of nine sub-tests. It takes approximately 45–90 min to administer, and the mean score is 100 with a standard deviation (SD) of 15 (Wechsler, 1992).

The Kaufman Test of Educational Achievement

The Kaufman Test of Educational Achievement is designed to assess academic achievement in individuals from the ages of four through 25. The test measures achievement in reading, writing, oral language and mathematics. Depending on age and mood, it takes between 30 and 85 min to complete the test, and the mean score is 100 with a SD of 15 (Singer, Lichtenberger, Kaufman, Kaufman, & Kaufman, 2012).

Country-specific achievement tests

Some countries have developed their own achievement tests. The *Canadian Achievement Test* is a standardised test created by the Canadian Test Centre. It is based on Canadian society and values and evaluates the effectiveness of curricula from different districts as well as the effectiveness of each curriculum across Canada (Romano, Babchishin, Pagani, & Kohen, 2010).

A similar test*, the Texas Assessment of Knowledge and Skills*, is used to assess students' attainment in reading, writing, mathematics, science and social skills in grades 3–8 and 9–11, as required under the Texas education standards. The raw score for each skill is converted into a scaled score(Keng, McClarty, & Davis, 2008) .

Theoretical background

Grades

Grades represent a grade in a specific subject, a composite score of grades in several subjects or the grade point average score across all subjects (Marques et al., 2018). In Norway, the criteria for assessing academic performance by grades are defined by The Norwegian Directorate for Education and Training (UDIR, 2019). Whilst representing a national criterion of academic outcome, this assessment is limited by the subjective assessment which is not standardized across teachers (Donnelly et al., 2016a).

National achievement tests

National achievement tests exist in most industrialised countries. Each test is based on national curricula and content standards, and they vary across countries. In Norway, mandatory national tests in reading, numeracy and English are conducted at the beginning of the 5th, 8th, and 9th school year. The tests in numeracy and reading take approximately 90 min each, while the English test takes 60 min. The score is standardised to a T-score with a mean of 50 scale points and a standard deviation of 10. Some of the items are repeated every year and function as an anchor, making the means for one year comparable to those in another (Hovdhaugen, Vibe, & Seland, 2017).

In Norway, the average score from the mandatory national tests have not changed significantly from 2014 to 2019. The results show that boys score higher in numeracy, whereas girls score higher in reading. In English, the results are more even between boys and girls (UDIR, 2021).

2.4 Physical activity, physical fitness and academic performance

Over recent years, cross-sectional and longitudinal studies have reported significant associations between physical activity, physical fitness and academic outcomes in children and adolescents (Bezold et al., 2014; Booth et al., 2014; Chomitz et al., 2009; Desai et al., 2015; Esteban-Cornejo et al., 2014; Garcia-Hermoso et al., 2017; Harrington, 2013; London & Castrechini, 2011; Maher et al., 2016; Morita et al., 2016; Rauner et al., 2013; Wittberg et al., 2012). Consequently, the evidence suggests that increasing the time allocated to curricular physical activity may yield physical, mental and academic benefits (Singh et al., 2019). If increased physical activity during school hours lead to an increase in academical- *and* health-related outcomes, school-based physical activity should be adopted as an ideal public health strategy.

2.4.1 Exploratory mechanisms

Initially, the hypothesis that suggests that physical activity could enhance executive functions, brain function and brain structure originated from animal studies (Donnelly et al., 2016a). In rodents, bouts of physical activity and exercise triggered a cascade of neurological changes in the hippocampus, linked to memory and learning (Gomez-Pinilla & Hillman, 2013; Kempermann, 2008).

As research progressed and evolved, the relationship between physical activity, aerobic fitness, executive functions, brain function and brain structure in the youth has been examined (Donnelly et al., 2016a; Gunnell et al., 2019; Lubans et al., 2016). Systematic reviews, mainly based on observational studies such as cross-sectional and acute/short-term experimental studies, have concluded that physical activity and aerobic fitness are beneficial for executive functions, brain structure and brain function in children aged 5–13 years (Donnelly et al., 2016a) and 5–18 years (Lubans et al., 2016). Recently, Gunnel et al. summarized the interventional effects of chronic and acute bouts of physical activity on cognitive functions, brain function and brain structure (Gunnell et al., 2019). Based on 84 RCTs that included more than 12,600 unique participants aged 0.8–17 years, they concluded that physical activity has favourable, or at least not detrimental, effects on cognitive function, brain function and brain structure (Gunnell et al., 2019).

Theoretical background

Several different mechanisms have been suggested in the literature regarding the relationship between physical activity, aerobic fitness and academic performance. One mechanism suggests that physical activity may lead to an increase in the thickness of the grey matter in the cortical region and the white matter tracts that support executive functions (Chaddock-Heyman et al., 2015). Furthermore, physical activity causes alterations in brain plasticity, which changes the structure of neurons and their signalling capability. Finally, it is plausible that physical activity can improve relevant factors such as attention, memory and executive functions (Moore et al., 2013). To summarize, it is suggested that, through these mechanisms, physical activity causes changes in the brain structure and cognition, which might translate into improved academic performance (Chaddock-Heyman et al., 2015).

Another hypothesis suggests that increased physical activity improves aerobic fitness, which further enhances brain structure and functions associated with learning and academic performance (Crova et al., 2014; van der Niet et al., 2016). Whilst this is not yet fully understood, studies have reported that higher aerobic fitness levels are associated with increased volume of the hippocampus and prefrontal cortex, in addition to improved cognitive performance (Weinstein et al., 2012; Wittfeld et al., 2020) These findings suggest that physical activity that increases aerobic fitness will trigger positive brain changes that are important to academic performance (Chaddock, Pontifex, Hillman, & Kramer, 2011; Hillman & Biggan, 2017). In this hypothesis, aerobic fitness acts as a mediating factor between physical activity and academic performance, emphasising that physical activity interventions must enhance aerobic fitness to impact academic performance. Whilst the evidence is principally from cross-sectional studies, a recent intervention study with 120 18-year-olds (exercise group; n = 48, control; n = 72) found that the VO2max of participants in the intervention group improved after a nine-week aerobic exercise program, compared with non-aerobic-exercise controls (Zhu et al., 2021). The improvement in VO2max was subsequently associated with improvement in executive control and changes in the frontal grey matter (Zhu et al., 2021).

The majority of the above findings are from observational studies, such as cross-sectional and acute/short-term experimental studies with or without control groups. The protocols vary across studies, but most involve individuals participating in a physical activity or exercise session and a control group, with outcome measures that include either executive functions, brain structure and brain function, or a combination. A detailed description of these studies is not within the scope of this thesis; however, there are limitations that are important to acknowledge when interpreting the above findings.

Whilst the studies mentioned in this section provide essential knowledge on the hypothetical mechanisms of the effect of physical activity on executive functions, brain structure and brain function related to academic performance, the findings cannot be directly translated into a real-life school setting. For example, the domain and intensity of the physical activity are relatively easy to control in small experimental trials, leading to conclusions such as that short-term bouts of physical activity can selectively improve executive test performance. However, during physical education, recess or in the classroom setting, it is difficult to ensure that all students achieve the same amount and intensity of physical activity (Donnelly et al., 2016b). Furthermore, physical activity incorporated into the curriculum could potentially affect other behaviours, such as sedentary time and dietary habits. It is possible that changes in other behaviours could unintentionally affect physiological or psychological factors and, thereby, confound the relationship between physical activity and academic performance.

Furthermore, the synergistic relationship between physical activity and aerobic fitness and cognition, brain function and executive functions remains unclear. For instance, we do not know how a specific change in physical activity or physical fitness affect specific aspects of executive functions, and, further, how this impacts academic performance (Donnelly et al., 2016a). Finally, we do not know whether the relationship acts in one direction, for example, that physical activity leads to increased academic performance, or if the relationship is bidirectional, causing individuals with high academic performance to indulge in more physical activity.

2.4.2 School-based physical activity interventions

The following section summarizes the literature on the effects of school-based, accelerometer-assessed physical activity interventions, physical fitness and academic performance. Furthermore, the literature included are from the apex of the evidence pyramid, with cluster RCTs and systematic reviews and meta-analyses.

2.4.2.1 Effects of physical activity and aerobic fitness

Ten cluster RCTs have contributed to our knowledge of school-based physical activity intervention effects with accelerometer-assessed physical activity in adolescents (Table 1). The sample sizes in the 10 studies ranged from 240 to 2,862, and the interventions were implemented between 2013 and 2020. The majority of the studies were *multicomponent interventions* (Hills, Dengel, & Lubans, 2015), meaning that the interventions were comprehensive physical activity programmes, consisting of several components to increase physical activity (Andrade et al., 2014; Corder et al., 2020; Dewar et al., 2013; Grydeland et al., 2013; Resaland et al., 2016; Smith, Morgan, et al., 2014; Sutherland et al., 2016; Tarp et al., 2016). All interventions incorporated programmes aimed at implementing a specific amount of additional physical activity (ranging from 120 min to 150 min in the curriculum per week), except one intervention that focused on individual or environmental strategies to encourage adolescents to be more physically (Sutherland et al., 2016). The duration of the interventions ranged from six weeks to 24 months (Table 1). Three studies observed a significant interventional effect on physical activity (Andrade et al., 2014; Riley, Lubans, Holmes, & Morgan, 2016; Sutherland et al., 2016), whilst the seven remaining studies did not (Table 1).

Four studies included various physical fitness measures as outcomes (Table 1) (Andrade et al., 2014; Smith, Morgan, et al., 2014; Stavnsbo et al., 2020; Tarp et al., 2016). Whilst just borderline significant, Andrade et al. (2014) reported that participants' aerobic fitness increased, as estimated from a speed shuttle run (intervention effect = -0.8s, 95% CI -1.58 to -0.07, P = 0.05), in those who had the physical activity intervention compared to the controls. Other school-based interventions did not affect aerobic fitness, as assessed by the Andersen test in 10-year-old (Stavnsbo et al., 2020) and 13-year-old adolescents (Tarp et al., 2016). However, the latter study showed significant effects among the girls in the intervention group compared with the controls (mean difference in change: 21 m, 95% CI 4.4 to 38.6) (Tarp et al., 2016). Smith et al. (2014) found no effects from a school-based physical activity intervention on participants' handgrip strength.

Theoretical background

Two systematic reviews recently summarized the available evidence, providing a foundation for our current understanding of the topic. First, Love et al. (2019) completed a systematic review and meta-analysis in 2019, where they evaluated the effects of school-based physical activity interventions on accelerometer-assessed daily minutes of MVPA. Based on 17 cluster RCTs including children and adolescents 6-18 years, they concluded that school-based physical activity interventions are not effective in increasing MVPA in children and adolescents across the entire day (Love et al., 2019). The results did not differ when the differential effects were examined by gender and socioeconomic status (Love et al., 2019). Second, in 2021, Hartwig et al. (2021), conducted a systematic review and meta-analysis on the effects of school-based physical activity interventions on physical activity *and* aerobic fitness in children and adolescents of 4-18 years. Twenty RCTs were included, and they observed that the interventions moderately increased the children and adolescent's MVPA and aerobic fitness (Hartwig et al., 2021). However, they did observe that the intervention effects were not equal across the subgroups. The measured effect of physical activity on MPA and VPA were the greatest among older students, and no significant differences were found between genders. For aerobic fitness, the estimated effect decreased by increasing age and were slighter among the girls (Hartwig et al., 2021).

Table 1. Randomized controlled trials investigating the effects of school-based physical activity interventions on physical activity and aerobic fitness in children and adolescents

Study	Design	Participants (% girls) age-group	Physical activity assessment	Physical fitness assessment	Intervention	Results
Dewar et al (2013)	Cluster RCT	N = 357 (Intervention n =179, (100%)) mean age = 13.2	Actigraph 7164, GT1M, GT3X+ and GT3X	N/A	12-months multicomponent intervention consisting of strategies to promote physical activity, reduce sedentary time	At 24-months follow-up, there were no intervention effect on CPM (P = 0.160), MVPA (p = 0.257) or screen time (p = 0.159)
Grydeland et al (2013)	Cluster RCT	N =1580 (Intervention n = 784 (54%)) mean age = 11.2	Actigraph 7164,	N/A	20-months multicomponent interventions targeting the promotion of overall physical activity	Increased physical activity levels from baseline to post intervention when compared to controls (50 CPM, 95% CI -0.4 to 100, p = 0.05)
Andrade et al (2014)	Cluster RCT	N = 1,440 (intervention n = 700, (66%)) mean age = 12.9	Actigraph GT1M	The Eurofit battery	28-month health promotion intervention consisting of individual- and environment-based strategies	Increased vertical jump (p = 0.01), shuttle run performance (p = 0.05). The proportion of students achieving over 60 min of daily MVPA decreased in all groups, but significantly less decrease in the intervention group (p < 0.01)
Smith et al (2014)	Cluster RCT	N = 361 (intervention n = 181, (0%)) mean age = 12.7	Actigraph GT3X	Handgrip dynamometer	20-week intervention involving provision of physical fitness equipment to school's physical activity session and researcher-led seminars	No significant intervention effect on physical activity (p > 0.05) or grip strength (p = 0.30) among students in the intervention group compared with control
Jago et al (2015)	Cluster RCT	N = 571 (Intervention n = 279 (100%)) mean age = 11.0)	Actigraph GT3X	N/A	20-week intervention consisting of two 75 min dance sessions after school	The analysis showed no intervention effects on physical activity levels in the intervention group when compared with the control (p = 0.35)
Sutherland et al (2016)	Cluster RCT	N = 1,150 (intervention n = 560, (45%)) mean age = 12.0	Actigraph GT3X+ and Actigraph GT3X	N/A	24-months intervention consisting of seven strategies to increase physical activity levels	At follow-up, there were significant effects (mean difference in change in MVPA = 7.0 min, p < 0.002) when comparing intervention group with the control

Tarp et al (2016)	Cluster RCT	N = 632 (Intervention n = 194 (48.5%), Control n = 432 (52.8%)) mean age 13.0	Actigraph GT3X+ and Actigraph GT3X	Andersen-test	20-week RCT, 1) 60 minutes of physical activity incorporated in academic lessons during school time/day 2) Scheduled physical activity during recess weekly, 3) Physical activity homework daily	No significant intervention effects were observed on aerobic fitness (p = 0.16) when intervention was compared with controls.
Riley et al (2016)	Cluster RCT	N = 240 (intervention n =142, (42%)) mean age = 11.1	Actigraph GT3X+ and Actigraph GT3X	N/A	6-weeks intervention consisting of 3 x 60 min sessions of movement-based learning	Significant intervention effects for CPM (p = 0.08) and sedentary time (p = 0.04) across the school day, in addition to CPM (p = 0.08), MVPA (p = 0.09) and sedentary time (p = 0.01) during mathematics lessons
Corder et al (2020)	Cluster RCT	N = 2,862 (intervention n = 1,543 (55%) mean age = 13.2	Axivity accelerometer	N/A	12-week intervention	No significant intervention effect on MVPA (mean difference in change -1.9 (95% CI -5.5 to 1.7))
Resaland et al (2016)/ Stavnsbo et al (2020)	Cluster RCT	N = 1,129 (Intervention n = 596 (47%), Control n = 533 (49%1%)) mean age 10.2	Actigraph wGT3X+	Andersen-test	7-month cluster RCT. 1) Physical activity lessons, 90 min/week, 2) PA physical breaks, 5 min/day, 3) PA homework, 10 min/day. In total 165 min/week more than the control group	No significant effects on physical activity, either during full day (p ≥ 0.37) or school hours (p ≥ 0.14). No significant effects on aerobic fitness (p = 0.97)

MVPA: Moderate to vigorous physical activity, RCT: Randomized controlled trial; N = numbers; N/A: Not assessed

2.4.2.2 Effects on academic performance

Nine cluster RCTs examined the effects of various forms of school-based physical activity on academic performance among children and adolescents (Table 2). These cluster RCTs were implemented between 2007 and 2018 and included sample sizes ranging from 240 to 1,597 participants (Table 2). The duration of the interventions varied from 6 weeks to 3 years, and the intervention programmes varied from 75 min to 165 min of extra physical activity per week (Table 2). Four of those interventions were successful in increasing academic performance (Donnelly et al., 2009; Lubans et al., 2018; Mullender-Wijnsma et al., 2016; Telford, Cunningham, Telford, & Abhayaratna, 2012), whilst the remainder reported no significant intervention effects (Table 2).

Several reviews including cross-sectional, longitudinal and intervention studies examining the association between, or the effects of, school-based physical activity, physical fitness and academic performance have been published over recent years (Alvarez-Bueno et al., 2017; Donnelly et al., 2016a; Fedewa & Ahn, 2011; Hillman & Biggan, 2017; Marques et al., 2018; Santana et al., 2017; Singh et al., 2019). Whilst these systematic reviews include studies of different study design and also include children, the overall conclusion is mainly the same, namely, that there is a positive association or beneficial effect of physical activity and academic performance; however, many aspects of this relationship are unclear. For example, there is a need for a universal consensus regarding assessment of outcome and exposure, and which type, length or intensity of physical activity is most beneficial to enhance academic performance (Marques et al., 2018).

Table 2. Randomized controlled trials investigating the effects of school-based physical activity interventions and academic performance in children and adolescents

Study	Design	Participants (% girls) age-group	Physical activity assessment	Academic performance assessment	Intervention	Results
Donnelly et al (2009)	Cluster RCT	N = 1579 age = 7-9	Actigraph 7163	The Wechsler Individual Achievement Test	3 years, the intervention promoted 90 min of MVPA incorporated into subjects through physically active lessons in bouts of 10 min each	Significant improvements in academic performance in reading, math, spelling and composite score ($p < 0.05$ for all) were found from baseline to follow-up when comparing intervention group with controls
Ahamed et al (2007)	Cluster RCT	N = 291 (Intervention n = 240) (50%), Control n = 73 (51%)), mean age = 10.2	PAC-C	Canadian achievement tests in mathematics, reading and language	16 months, 15 min of daily classroom-based physical activity	No significant intervention effects on academic performance when comparing intervention group with controls ($p > 0.05$)
Telford et al (2012)	Cluster RCT	N = 620 (Intervention n = 312, Control n = 308) age = 8-9	Pedometers	Literacy and numeracy tests	2-year intervention. 2 x 45 min of specialist-taught PE and 50-60 min of MVPA delivered by classroom teacher per week	The intervention group performed better in numeracy ($p < 0.03$) and writing ($p = 0.13$), but not reading ($p > 0.05$) when compared with controls
Riley et al (2015)	Cluster RCT	N = 240 (Intervention n = 142 (41.6%), Control n = 98 (39.2%)) mean age 11.1	Actigraph GT3X+	Standardized mathematics achievement test	6-week RCT, 3 x 60 minutes sessions/week over a 6-week period	No observed effect on mathematical performance after the study period ($p > 0.05$)
Donnelly et al (2016)	Cluster RCT	N = 584 (Intervention n = 316 (49.1%), Control n = 268	Actigraph GT1X	The Wechsler Individual Achievement Test	3-year cluster RCT. 1) Academic lessons (morning and afternoon), 20 min/day, plus 60 minutes of physical education per week, in total 160 minutes/week more than the control group	No group differences in any academic performance ($p > 0.05$)

		(54.1%) mean age 8.1				
Resaland et al (2016)	Cluster RCT	N = 1129 (Intervention n = 596 (47%), Control n = 533 (49%1%)) mean age 10.2	Actigraph wGT3X+	Standardised Norwegian national test in mathematics, reading and English	7-months cluster RCT. 1) Physical activity lessons, 90 min/week, 2) PA physical breaks, 5 min/day, 3) PA homework, 10 min/day. In total 165 min/week more than the control group	No effect from the intervention on academic performance ($p > 0.358$). Subgroup analysis showed a positive intervention effect in favour of the interventions in numeracy for those individuals who performed poorest at baseline ($p < 0.05$)
Tarp et al (2016)	Cluster RCT	N = 632 (Intervention n = 194 (48.5%), Control n = 432 (52.8%)) mean age 13.0	Actigraph GT3X+ and Actigraph GT3X	Custom-made grade-specific mathematics test	20-week RCT, 1) 60 minutes of physical activity in academic subjects during school time/day 2) Scheduled physical activity during recess /weekly, 3) Physical activity homework daily	No significant difference or change in mathematics skills in the intervention group compared to the control group ($p > 0.05$)
Mullender-Wijnsma et al (2016)	Cluster RCT	N = 499 (intervention n = 249 (49.9%) mean age = 8.2)	N/A	Reading, spelling and math test	2 years cluster RCT, 22 weeks of intervention per year, students participated in physical active lessons in mathematics and spelling for 20-30 min, 3 times per week	Significant change in mathematics (ES 0.5, $p < 0.01$) and spelling (ES 0.45, $p < 0.01$) performance compared with controls. No significant intervention effects found in reading
Lubans et al (2018)	Cluster RCT	N =1,173 (Intervention n = 693, Control n = 728) mean age = 12.9	Actigraph wGT3X+	National assessment program in numeracy (standardised test)	2 years, various components designed to help teachers maximize students' opportunities for MVPA.	Significant intervention effects on numeracy performance ($\beta = 0.16$, $p < 0.01$) when comparing interventions with controls

MVPA: Moderate to vigorous physical activity, RCT: Randomized controlled trial; N = numbers; N/A: Not assessed

2.4.2.3 Methodological considerations

Methodological limitations and shortcomings might explain some of the discrepancies in the results. First, the unequal intervention duration, ranging from 6 weeks to 24 months, makes direct comparison difficult. The variances in the duration imply that the baseline and follow-up measurements were not always done in the same seasons. Seasonality and weather conditions impact physical activity levels (Chan & Ryan, 2009; Turrisi et al., 2021), and, even whilst controlling for this in the analyses could account for some of the differences, the results should be interpreted with caution.

Whilst all studies used the Actigraph accelerometer to assess physical activity levels, the approaches data processing to reduce the raw data varied, which reduces the external validity. Some studies used physical activity collected in 60 sec epochs, whilst others used 15 sec, in addition to using different cut-off points for defining intensities. From a methodological perspective, these limitations and differences in data reduction could affect how accelerometer-assessed physical activity behave as exposure (Lynch et al., 2019). Specifically, if studies that include accelerometer-assessed physical activity as exposure uses longer epoch of time (i.e. 60 sec), the MVPA will probably be underestimated. When the intervention measure is prone to random measurement error, a statistical phenomenon referred to as regression dilution bias occurs. This phenomenon causes an attenuation or underestimation of the relationship with an outcome variable. In addition, a minimum wear time criterion might ensure that the physical activity data is more indicative of habitual physical activity but, at the same time, will probably reduce sample size and, consequently, statistical power. However, increasing the sample size will not affect the bias but only make the error in the estimates more precise (Hutcheon, Chiolero, & Hanley, 2010).

The limitations related to accelerometers mentioned above also affect how physical activity acts as an outcome variable. Even though the random measurement error observed with the use of accelerometers will have minimal effect on the regression coefficient, it will decrease the precision of the estimate by increasing the standard error. In practice, an increased standard error could result in an association being overlooked due to a lack of statistical significance (Hutcheon et al., 2010). Hence, using measures prone to random measurement error for the outcome can cause a study to be unable to detect a true effect of an exposure.

Theoretical background

The physical activity programs implemented in the mentioned RCTs varied greatly (Table 1 & 2), and this could explain some of the discrepancies in the results. Some interventions integrated physical activity components into academic content or activities, whilst others included additional physical activity during recess or physical education lessons not connected to other subjects. Furthermore, some studies included multiple different physical activity components in different domains (e.g. at school, during recess, with homework and after school). However, others, such as the interventions by Ahamed et al. (2007), Riley et al. (2015) and Mullender-Wijnsma et al. (2016), consisted of one specific physical activity component. There is a possibility that some activities may affect other behaviours, such as sedentary time and dietary habits, and it is possible that changes in other behaviours could unintentionally affect physiological factors and, thereby, confound the effects of physical activity on academic performance.

In addition, lack of validation and reliability in studies related to academic performance measure results in a significant variety in the assessments of academic performance, which makes direct comparison of the intervention effects difficult (Table 2). The utilisation of several different measures to assess academic performance may be problematic because some focus on specific characteristics such as processing speed and rapid decision making, whilst others are more general, focusing on specific knowledge in traditional subjects such as numeracy and reading. Even though numeracy and reading assessment is an essential part of the teaching-learning process, it is important to bear in mind that numeracy and reading performance are quite different. Numeracy performance is probably best identified by assessing recall and the application of facts and methods (Daly-Smith et al., 2018), whilst reading performance is best identified by assessing knowledge of language structure and vocabulary. Furthermore, assessment of numeracy and reading performance is challenging because most tests lack reliability and validity testing. In addition, it is often not clear whether different test versions were utilised in longitudinal or intervention studies. Consequently, academic performance may be susceptible to learning effects. No single measure of academic performance, executive function or cognition can fully account for what is occurring in the brain and in the learning processes in response to physical activity. Optimally, methods that collectively assess different aspects of brain structure, functioning *and* performance tests in traditional curriculum subjects should be combined (Donnelly et al., 2016a). All of these limitations affect the external validity of the findings in studies.

2.4.2.4 Implementation of school-based physical activity interventions

The inconsistent findings regarding the effects of physical activity, aerobic fitness and academic performance in the literature can be due to the complexity of implementing physical activity interventions in a real-life school setting (Naylor et al., 2015). Implementations can be viewed as activities designed to put an intervention into practice, and they include fidelity, adaptation, quality, responsiveness and dose delivered (Naylor et al., 2015). Fidelity is often defined as the determination of how effectively an intervention is implemented in comparison with the original programme (O'Donnell, 2008), whilst adaptation is the process of thoughtful alteration of the programme with the goal of improving its effectiveness (Wiltsey Stirman, Gamarra, Bartlett, Calloway, & Gutner, 2017). Responsiveness is a measure of how participants respond to or are engaged in the intervention (Carroll et al., 2007), whilst dose delivered refers to how much of the intervention is implemented and has been identified as a key concept of implementation (Durlak, 2016).

Previous research on school-based physical activity interventions has emphasised the importance of examining the implementation of each intervention component. Consequently, most of the described intervention studies (Table 1-2) have in some way assessed the dose delivered throughout the intervention period. Whilst one study reported poor (30%) adherence to protocol, the majority reported medium to high adherence to protocol (60–95%), depending on the intervention component (Andrade et al., 2014; Corder et al., 2020; Donnelly et al., 2009; Donnelly et al., 2017; Mullender-Wijnsma et al., 2016; Resaland et al., 2016; Riley et al., 2016; Smith, Morgan, et al., 2014; Sutherland et al., 2016; Tarp et al., 2016).

Classroom teachers usually implement school-based physical activity interventions (Russ, Webster, Beets, & Phillips, 2015), and, as such, they are closely involved with the implementation and dose of the intervention delivered. The importance of the implementor was emphasised in a systematic review by Naylor et al. (2015), in which they found that the top seven contextualised factors that influenced the implementation of physical activity interventions were related to the classroom teacher. These factors include limited time, competing demands, quality and availability of resources, school climate and the appropriateness of the intervention. Identifying whether some contextualised teacher-related factors are associated with the dose of the intervention delivered will inform the development of the interventions and may increase the effectiveness of future studies.

Theoretical background

The Consolidated Framework for Implementation Research (CFIR) was first introduced by Damschroder et al. (Damschroder et al., 2009) to help researchers to identify and understand factors that influence the implementation of an intervention. The CFIR includes 36 constructs that related to barriers and facilitating factors for implementation, grouped into five domains. Teacher-related factors can be conceptualised in three domains, namely *inner setting, characteristics of individuals* and *intervention characteristics* (Damschroder et al., 2009). *Inner setting* refers to the school- and teacher-related culture and includes the amount of time teachers are able to dedicate to planning, organising and conducting the intervention components and the extent to which they are trained for the implementation. The *characteristics of individuals* include the teacher's knowledge, beliefs and attitudes towards the intervention, whilst the *intervention characteristics* are the key attributes of the intervention. These factors are elements that are related to the implementation of an intervention and can impact its success (Campbell et al., 2015; Robbins, Pfeiffer, Wesolek, & Lo, 2014). An understanding of how these contextual factors relate to the dose delivered can inform the development of strategies to improve implementation and sustain future interventions (Shoesmith et al., 2021). For example, if teacher training is identified as a key contextual factor for implementation, future interventions could target teacher training to increase the dose delivered.

Even though many studies that had a wide range of objectives, methodologies and designs have used CFIR for useful examination of the implementations, CFIR has limitations. First, it does not provide a clear understanding of the dynamic interplay between researchers, teachers and the school context (Rojas Smith L, 2014). Second, CFIR was originally developed for highly focused research and interventions rather than for evaluations of multicomponent school-based physical activity interventions (Damschroder et al., 2009; Saluja et al., 2017). Third, there is the matter of the settings of schools. Interventions in the school context and curriculum involve more than only occurrences during school hours. Community-based organizations, parents, stakeholders and politicians are often involved in some way or another in school-based physical activity interventions and might be critical to sustaining the intervention. Hence, it might be beneficial to consider that these interventions are based on layers of organizations, rather than embedded in a single setting. However, because the context included in CFIR can vary by time, location and organizational unit, it is difficult to use the CFIR to identify these multiple layers (Saluja et al., 2017).

2.5 Research gaps

The current literature provides no consensus regarding which intervention or physical activity programs that is most effective in increasing adolescents' physical activity, aerobic fitness and academic performance (Hartwig et al., 2021; Love et al., 2019; Singh et al., 2019). Further, the specific role of physical activity components, including their duration, intensity and how the they are incorporated into academic subjects, remains poorly understood due to inconsistent intervention programs duration, dose and methodological shortcomings related to measures of exposure and outcomes (Daly-Smith et al., 2018). Greater knowledge of potential effects on physical fitness and academic performance, in addition to closer examinations of the pathways through which such interventions can affect academic performance, is critical to developing programmes that can effectively change behaviour (Lubans et al., 2016). Additionally, identifying factors related to the teachers and their implementation of the intervention components is important for future interventions to be successful (Shoesmith et al., 2021). Finally, most school-based physical activity intervention including academic performance measure are with children in elementary schools, and there is a lack of studies that include large adolescents populations (Wassenaar et al., 2020).

Thus, there is an established need for high quality, cluster RCT's including adolescents. Future studies need to include; 1) high-quality quantification of the physical activity exposure and a valid assessment of physical activity, physical fitness and academic outcomes; 2) a large sample of adolescents; 3) sufficient data on the adherence throughout the intervention and 4) explore factors related to the implementation of the intervention.

2.6 Objectives and aims of the thesis

Given these identified knowledges, this thesis investigates the intervention effects of School in Motion (ScIM) on adolescents' physical activity, physical fitness and academic performance, in addition to the associations between dose delivered and teacher-reported contextualised factors. The specific research aims across the four papers are outlined below.

I. To investigate the effect of two school-based physical activity interventions on daily physical activity levels, aerobic fitness and muscle strength among adolescents.

II. To investigate the effect of two school-based physical activity intervention on academic performance among adolescents.

III. To investigate the mediating role of aerobic fitness on intervention effects of a school-based physical activity intervention on academic performance.

IV. To investigate the associations between teacher-reported implementation contextual factors and the intervention dose implemented in the ScIM study.

3.0 Methods

3.1 Study design and participants

The ScIM study was a nine-month, three-armed cluster RCT. Four collaborating study partners with a geographical spread across Norway conducted the study (Norwegian School of Sport Sciences (NIH), Western Norway University of Applied Sciences, University of Agder and University of Stavanger). A random sample of lower secondary schools located in municipalities in the geographical area near the four study partners were invited to participate. In the selection of schools, we took population density into account and therefore included a different number of schools from each of the four geographical areas. Inclusion criteria were that schools should have at least 25 students in 9th grade and be able to participate in additional weekly physical activity and PE. We excluded schools that worked systematically with physical activity as an integrated part of the curriculum, private and designated special schools, and schools who participated in other studies with similar outcome. The study was funded by the Ministry of Education and Research and The Ministry of Health and Care Services.

A total of 103 schools were invited, of these 30 schools agreed to participate. Schools were randomized manually by a lottery in a 1:1:1 ratio to one of the following study arms: the Physically Active Learning (PAL) intervention arm, the Don't worry be happy (DWBH) intervention arm or the control arm (Figure 1). The randomization was stratified by district to ensure that schools from all four study locations were represented in each of the three study arms. The data-manager who conducted the randomization did not participate in any other aspects of the study. The randomization process took place after inclusion but prior to baseline testing. Neither participants, schools nor researchers were blinded.

After randomization, but prior to baseline testing, one school (control) withdrew from the study. In total, 2084 adolescents (76% of eligible sample) from 29 schools (20 intervention schools and 9 control schools), agreed to participate in the study and provided parental consent. Three months into the intervention, one of the schools in the DWBH-intervention arm withdrew from the study due to practical reasons.

Methods

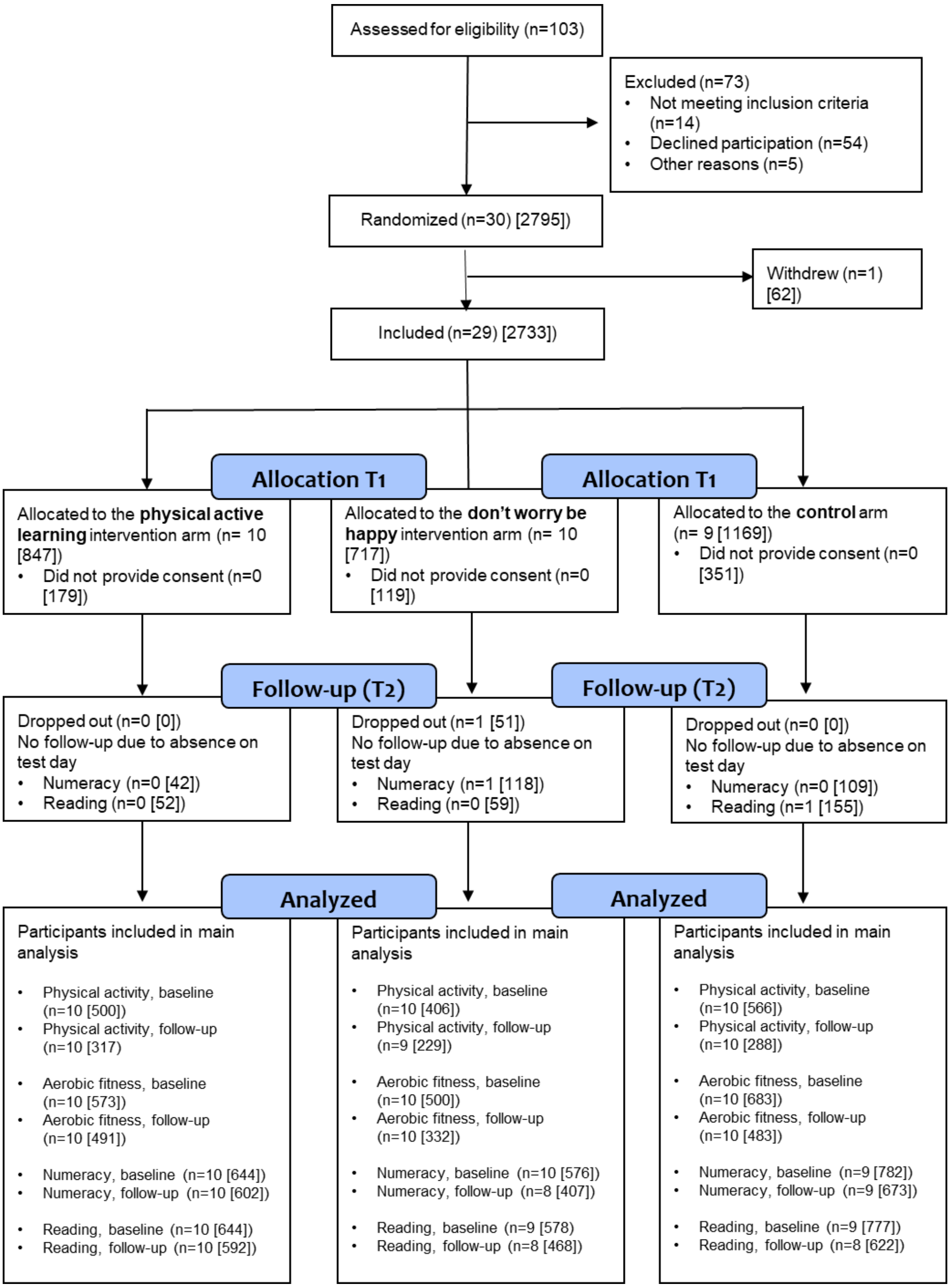


Figure 1. Flow diagram of the included students (n = schools [students]).

3.2 The ScIM interventions

The conceptualization of the ScIM study and the two intervention models commenced in the spring of 2015, when the Norwegian government, through a series of political reports, indicated that the role of physical activity in the adolescent population in schools should be examined (Omsorgsdepartementet, 2014). Based on a research proposal, NIH was granted the project that consisted of three different subprojects.

The first project was to summarize the current literature regarding the effects of physical activity on physical health, mental health and academic performance (Lillejord, 2016). The second project was to summarize the measures that lower secondary schools in Norway employ to include physical activity during school hours (Tjomsland, Odberg, & Leversen, 2016). This was done through questionnaires and phone surveys in lower secondary schools in Norway. The questionnaire was sent to teachers and rectors at every secondary schools in Norway (n=1200) and 340 schools replied. Based on the questionnaire responses, 12 schools were included in the phone survey. In brief, the report by Tjomsland et al. (2016) emphasized that four main approaches were used to incorporate physical activity was 1) expanded recess, 2) increased physical education, 3) physical activity not connected to other subjects and 4) physically active learning lessons. The third, and final part of the assignment was to design and implement a cluster RCT that included two physical activity intervention models and examined the effect of the interventions on adolescents' physical health, mental health and academic performance.

The two intervention models were developed with the use of the knowledge gathered through the two reports (Lillejord, 2016; Tjomsland et al., 2016), from previously school-based physical activity intervention, for example, the Active Smarter Kids study (Resaland et al., 2015), HEIA study (Grydeland et al., 2013) and KISS study (Kriemler et al., 2010), in addition to the knowledge of the project group. Ideas of intervention components were shared among members of the research group through workshops, brainstorming sessions and discussions before formulating the PAL and DWBH interventions. Prior to the implementation of the cluster RCT, we conducted a pilot study to evaluate the intervention models and, if necessary, to adjust the intervention models to better reach the target group. The core components of both the PAL and DWBH interventions were 120 minutes of additional physical activity per week. Schools had to reallocate 5% of the time allocated to other subjects to physical activity (60 min) and add one extra PE lesson (60 min) per week to the curriculum. All the intervention schools received financial resources from The Norwegian Directorate for Education and Training to account for expenses. The amount received (approximately €90 per student) was based on the number of students attending the school.

Methods

3.2.1 The Physically Active Learning (PAL) intervention model

The origin of the PAL intervention is influenced by previously conducted interventions (Kriemler et al., 2010; Resaland et al., 2015; Tarp et al., 2016). However, we modified the intervention model to make it more feasible for lower secondary schools in Norway.

Schools in the PAL intervention model included three additional components per week (Table 3):

- One additional lesson of PE (60 minutes). The lessons were planned and conducted by PE teacher and were in accordance with the ordinary curriculum. This lesson was included in the grounds leading to the PE mark.
- One Physical Active Learning lesson (30 minutes). During this session play-based activities were integrated in core subjects (e.g. numeracy, English, Norwegian). The aim was to increase student's physical activity levels while improving their academic performance. The component should be carried out by the teacher of the current subjects, be outside as often as possible and preferably on days without PE-lessons.
- One physical activity session (30 minutes). This component was not connected to any particular subject and students were included in choice of activities. The aim was that students experienced mastery, self-determination and joy during physical activity.

The components in the PAL intervention model were planned to be varied and enjoyable. It was emphasized that the activities should include all students and that they should experience positive feeling and attitudes toward being physically active. Consequently, teachers devoted special attention to create a positive and encouraging atmosphere when they carried out the intervention components.

The PAL intervention model are based on a socioecological framework, that understands the complex interplay between the many personal and environmental influences on behaviour (Langille & Rodgers, 2010). In short, the socioecological approach recognizes proximal individual and social factors and several distal determinants for behaviour change such as individual factors (e.g. self-esteem, attitudes), social relationships (e.g. family, friends), the physical organizational environment (e.g. schools, walkability), community levels (e.g. school board) and public policies (e.g. provincial government policies) as different levels of impact. Change at all levels is necessary to achieve lasting positive change in health behaviour (Langille & Rodgers, 2010). Furthermore, the PAL intervention builds upon three different theories. First on Harter's competence motivation theory (Harter, 1978), which centres on the idea that people are driven to engage in activities to develop or demonstrate their skills, then on bandura's social-cognitive theory (Bandura, 1986), and finally on Ryan & Deci's self-determination theory which builds on the concept that changes in the environment that simulate personal growth (Ryan, 2002), behavioural quality and general well-being will stimulate people to partake in activities to develop or demonstrate their skills. The theoretical rationale is thought to function as a mediating structure between intervention strategies and outcomes.

The additional PE lesson should follow the ordinary curriculum, but teachers could use the lesson as additional practice on elements/subjects whilst working through the curriculum. The PE teacher used these lessons to grade the students. The physically active learning component should stimulate to increased activity while also providing an opportunity to work with curriculum related topics in traditional subjects. Finally, the additional physical activity lesson was performed on the adolescents' premises in order to enhance their positive experience of being physically active.

Table 3. Intervention content and means of implementation stratified in the PAL intervention

Intervention components (minutes)	Practical organization	Providers of interventions	Implementation facilitated by and how
Physical activity in academic subjects (30 min)	Weekly	Teachers	Program tailored specific to the subject curriculum was provided by an external collaborator. Two courses for teachers during the intervention period.
Physical education (60 min)	Weekly	Physical education teachers	Follows the normal physical education curriculum
Physical activity (30 min)	Weekly	Teachers/physical education teachers	Students could choose between varied activities. Teachers were encouraged to motivate students during physical activity to stimulate their positive feelings and attitudes towards physical activity

3.2.2 The Don't Worry – be Happy intervention model (DWBH)

The DWBH intervention model is a reinvention of the traditional way of incorporating physical activity into the curriculum. Whilst teachers are the most obvious choice to do the implementation, adolescents are significant resources when provided with confidence and the right tools. Some members of the ScIM study group have experienced the social competence, self-esteem and motivation of adolescents in relation to physical activity participation (Haugen, Säfvenbom, & Ommundsen, 2011, 2013). This novel knowledge could inspire future alternative models for interventions and for implementing physical activity in the curriculum.

The DWBH model was based on an integrative relational developmental systems (RDS) approach to human development (Lerner, 2018), theories on positive youth development (PYD) (Lerner, 2015) and the concept of positive movement experiences (PME) (Agans, Safvenbom, Davis, Bowers, & Lerner, 2013).

According to RDS theories on human development, different subsystems of variables in humans are related to each other at different organizational levels (e.g. microbiology, cognitive function, family, friends and culture). Thus, when intervening in the everyday life of adolescents, these subsystems should be regarded as interpenetrating dynamic dimensions, and a physical activity intervention should be seen as mental and social in addition to physical dimensions. Moreover, diversity among the adolescents involved represents a significant issue, and the effects of a PA intervention will rely on the adolescents' relational experience of meaning and relevance in the new movement context (intervention) and not on the activity dose per se. An intervention affects as many developmental trajectories as there are participants, and every participant will experience the interaction in the intervention context differently. Therefore, such interventions cannot rely on a "one size fits all" approach.

The RDS perspective stipulates that school-based interventions should promote individual-context relationships that are mutually beneficial for everyone involved. According to Agans et al. (2013), it is possible for all individuals to have PME if the characteristics of the individual and the characteristics of the context are aligned in such a way that they produce mutually beneficial relationships among all the students and teachers involved. From the perspective of PYD, only the adolescents are able to build these mutually beneficial person-context relationships. This is because PYD theories focus on the fact that all youths have strengths, and these strengths have to be identified and acknowledged to promote healthy development. This view regards adolescents as resources to be developed, not problems to be managed (Roth, Brooks-Gunn, Murray, & Foster, 1998). The DWBH intervention model included two extra physical activity components each week

(Table 4). The primary focus of the DWBH intervention was to promote friendship through PA and vice versa.

- The Be Happy lesson (60 minutes): During this lesson, students from all 9th grade classes performed activities in self-organized groups of at least three students. The activities were developed according to the individual's activity preferences, for example, traditional sports, lifestyle sports, dancing, outdoor recreation or drama. The activities were performed inside or outside the school, and several PE teachers/other teachers were present to support students.
- The Don't Worry lesson (60 minutes): This lesson was an ordinary PE lesson conducted during regular classes. However, it was organized and led by students, and they practiced the same activity as in the "Be Happy" lesson. A PE teacher was present to support if necessary and used this lesson to grade the students.

Table 4. Intervention content and means of implementation stratified in the DWHB intervention.

Intervention components (minutes)	Practical organization	Providers of interventions	Implementation facilitated by and how
Activity class (Be Happy-class) (60 min)	Weekly	Students	Self-organized activity developed according to the adolescents' activity preferences
Physical education (Don't Worry class) (60 min)	Weekly	Students	Regular PE class led by the students. The students practiced their Be Happy activity.

During the first weeks of the school year, the students were introduced to the key features of the DWBH intervention model. They were told to think of an activity they wanted to conduct and then to form groups based on their activity of interest. When all 9th grade students participated, it was easier to find students who wanted to conduct the same activities.

Next, once the groups were established, they had to develop an "activity contract", where students had to define the following:

- three aims to govern the group
- one major aim for the next six months
- management structure
- strategy for possible conflicts
- routines for registration of attendance

The "activity contract" had to be approved by the teacher before the group could start their activity.

3.2.3 Pilot study

The two intervention models in ScIM were pilot tested during the school year 2016–2017. Seven lower secondary schools and approximately 700 14-year olds students were included. In order to tailor the interventions to better reach the target group, some adjustments were made to both intervention models after the pilot. In the pilot study, the PAL intervention model included one additional component; 5 min of physically active brain breaks per day. The PAL intervention model was simplified by removing the physically active brain brakes, as teachers found it difficult to perform on a daily basis. In the DWBH intervention, the students were given the options to change activity and group mid-intervention (January), this was not possible in the pilot study.

3.2.4 Implementation and teacher training

The recruitment of schools to the cluster RCT started in January 2017. First, County Governors were informed about the project by information posted on their web page. We then contacted school owners in the different municipalities to get permission to contact the principals of the schools that we wanted to participate. If the school owner approved, the letter of invitation was sent to the school's principal. This was followed by a phone call from the research team to give the principal and school management further information about the project and answering any questions they might have. A visit to the school was then scheduled to present the project in its entirety. Schools that wanted to participate in the study returned a signed consent form. Information meetings were held with all teachers at the intervention schools, and teachers involved in implementation of the intervention received further information regarding the intervention components.

Further, key teachers who had been assigned a particular responsibility for the intervention at their school, were invited to a one-day seminar at the NIH. At the seminar the theoretical framework that the two models were built upon were presented alongside practical training, which was deemed vital in coping with the pressure of adding more work on teachers in an already busy schedule. Additionally, the seminar focused on how to arrange the different component's in various settings both indoors and outdoors. Further, each school appointed an intervention promotor, to act as a local ambassador and participate in quarterly collaboration meetings between the researchers and intervention schools. The purpose of these meetings was to uphold the intervention through the study period, gather teachers across intervention schools and discuss and solve possible challenges.

3.3 Ethics

The project was reviewed by the Regional Committee for Medical and Health Research Ethics (REK) in Norway, who according to the Act on medical and health research (the Health Research Act 2008) concluded that the study did not require full review by REK. The Norwegian Centre for Data Research approved the ScIM study protocol (Appendix 1). Printed study information sheets were distributed, and written consent was obtained from each adolescent's parent(s) or legal guardian prior to testing (Appendix 2). This consent could be revoked by the participant or parents/guardian at any time. The trail is registered in ClinicalTrials.gov (25/01/2019), ID nr: NCT03817047, and all study procedures and methods used adhered to the World Medical Association's Declaration of Helsinki.

3.4 Measures

All participants were tested using an identical set of outcome measures at baseline and follow-up. Baseline measurements were done in April to June 2017 while students were in eighth grade. The follow-up measures were taken approximately 12 months after the baseline measures, while the participants were in the last phase of the intervention. The exception was academic performance where baseline testing was conducted in September 2017 and follow-up in May/June 2018. A team of researchers visited each school in the study and collected all data while the participants were at school. All research personnel were thoroughly trained prior to the data collection by members of the research team.

The choice of measure for the exposure and outcomes in ScIM might affect the results and the interpretation of the findings in the studies included in this thesis. To nuance their role in the results and interpreting of the findings, we have discussed this in section 5.6.

3.4.1 Anthropometrics

We measured height to the nearest 0.1 cm using a portable stadiometer (SECA 123, Hamburg, Germany). Weight was measured to the nearest 0.1 kg using a SECA 899 electronic scale (SECA 899). To account for clothing, we subtracted 0.6 kg (light clothing; gym shorts and t-shirts) or 1.5 kg (normal clothes; pants and sweaters) from the weight measurements. Body mass index (BMI) was calculated using weight in kilograms divided by the square of height in meters (kg x m^{-2}).

3.4.2 Physical activity and sedentary time

To assess physical activity in ScIM, the study group choose to use GT3X and GT3X+ accelerometers (Actigraph, LLC, Pesacola, Florida, USA). Accelerometer was chosen because it is a reliable and valid alternative to criterion measures, and more precise compared with self-report (Ruescas-Nicolau et al., 2021). Further, it is relatively simple and practical in large-scale research including a large group of participants (Lynch et al., 2019).

All adolescents were fitted with an accelerometer at school and instructed to wear the accelerometer on the right hip for seven consecutive days. The accelerometer should be worn at all times except during sleeping and water-based activities. Accelerometers were initialized to start recording at 0600 AM on the day after they were delivered, and epoch length was set to 10 s. The Actilife software was used to initialize and download the accelerometer files (version 6.13, ActiGraph, LLC, Pensacole Florida). Raw files from the accelerometer were processed and analysed using specifically developed and commercial software (StataCorp. 2015. Stata Statistical Software: Release 15. College Station, TX: StataCorp, LP).

We created a variable for “school hours” by matching the timetable provided by each school with the corresponding accelerometer files. A valid day was considered as ≥ 480 min wear time between 0600 and 0000, whereas a valid school day was defined as wear time of ≥40% of school hours. Non-wear time was defined as ≥20 min of zero counts. The present combination of non-wear time and valid days has previously shown reliable estimates of habitual physical activity amongs children (Rich et al., 2013).

We used average CPM over the whole assessment period as measure of overall physical activity. To get average minutes per day spent in SED, LPA and MVPA, we summarized and divided the total minutes registered with < 100 CPM, 100-1999 CPM and ≥2000 CPM respectively, by the number of valid days. The <100 CPM cut point have shown to provide realistic estimates of time spent sedentary in children (Fischer, Yıldırım, Salmon, & Chinapaw, 2012; Trost, Loprinzi, Moore, & Pfeiffer, 2011) (19-20), whereas the ≥2000 CPM was developed for the European Youth Hearth study and is equivalent to ≥ 4km/h for children and adolescents (Andersen et al., 2006).

Participants with at least 2 of 7 valid days were included in the main analysis of daily physical activity, whereas we included participants with at least 2 of 5 valid school days in the analysis of physical activity during school hours.

3.4.3 Aerobic fitness

Aerobic fitness was assessed by the Andersen test, an intermittent shuttle run test with the objective of cover the greatest distance possible in 10 minutes (Andersen et al., 2008). Several reasons for choosing the Andersen test exist, for example that it is practical for mass testing and do not require expensive equipment; it provides reliable and valid data on a group level when compared with results from VO2peak tests; and it does not stigmatize participant having poor aerobic fitness and does not exclude them from the test (Aadland et al., 2014). The latter is an important reason why the Andersen test were included in ScIM.

The test was administered as per standard protocol, however, due to different sizes of available indoor facilities at the included schools, we standardized the length to 16 m instead of the original 20 m. First the adolescents were explained the test, followed by a five-minute warm up, and then the adolescents ran back and forth between two parallel lines set 16 m apart for 15 s then pausing for 15 s. Each time the adolescents turned around at the end line, they had to touch the floor with one hand. The test was conducted with groups of 6-12 individuals. Adult test personnel recorded the distance covered and subjectively judged whether the adolescents completed a valid test. We recorded the distance covered during the test in meter as a proxy for aerobic fitness.

3.4.4 Muscle strength

Muscle strength (i.e. endurance, isometric and explosive strength) was measured using reliable and validated selected tests from the Eurofit test battery (Tsigilis, Douda, & Tokmakidis, 2003). We chose tests from this test battery as they are feasible and practical for mass testing in a school setting and do not require expensive equipment. Further, the nature of the test's battery makes it possible to test a large group of adolescents at the same time. Finally, the Physical Activity in Norwegian Children study include the same measure, making it feasible to compare across studies (Steene-Johannessen, Anderssen, Kolle, & Andersen, 2009).

Abdominal muscular endurance was measured by a sit-up test. The subject started in a lying position with hands clasped behind the neck, knees bent at 45^{o} angel. Feet and heels were held flat on the floor by test-personnel. The subject had to rise to a position with the elbows pointed forward until they touched the knees. During a period of 30 sec the number of correctly performed and completed sit-up was counted by the test personnel.

Upper limb strength – handgrip strength was measured using a hand dynamometer (Baseline® Hydraulic Hand Dynamometer, Elmsford, NY, USA). The subject used the dominant hand, with the arm extended and squeezed the dynamometer with maximum isometric effect in 2-3 sec. Best results of two attempts were used.

Explosive strength in the lower body was measured using a standing broad jump test. The participants stood behind a line with feed slightly apart. They were instructed to jump as long as possible without falling backwards. The distance from the take-off line to the nearest point of contact on the back of the heels was measured. The better of two attempts was used.

3.4.5 Academic performance

Grades were considered as measure for academic performance, but the follow-up measure were conducted prior to students receiving the grades. Furthermore, grades express students' effort and contribution over the school year and represent more than just students' learning and academic performance in addition to be subjectively given by teachers without standardization (Donnelly et al., 2016b). Various tests for assessing cognitive and executive function were also considered, but due a tight timeline and limited budget these were not included. Hence, academic performance was measured using standardized computer-based national tests designed and administered by The Norwegian Directorate for Education and Training.

The numeracy test measured an individual's ability to understand numbers and measurements. The reading test measured an individual's ability in basic Norwegian reading skills, interpreting and understanding texts, and to consider its form and content. Both tests included anchor questions, which made it possible to provide baseline for an equating analysis between the two timepoints. The scores were standardized to a T-score with mean of 50 scale points with a standard deviation of 10.

3.4.6 Socioeconomic status

We linked our database to registry data collected by Statistics Norway and used the highest education level of the participants' parents as a proxy for socioeconomic status (SES). Four SES groups were computed: low (primary/lower secondary/ vocational high school), middle (secondary/high school), middle high (undergraduate degree) and high (graduate degree).

3.4.7 Adherence

Throughout the study period, intervention schoolteachers reported weekly on the number of components implemented. They reported if the intervention component was delivered, as well as the intensity and the duration of the activity. The intensity (low, moderate or high) was judged subjectively by the teacher who delivered the component. Level of intensity was reported on a group level.

3.4.8 Contextualised factors related to implementation

The contextual factors for implementation were selected from the CFIR. In the present study, one construct from the *characteristics of individuals,* two constructs from the *inner setting* domain, and one from the *intervention characteristics* were selected for the present implementation evaluation (Table 5). All constructs related to the implementation were collected from a teacher survey. The survey items were developed by reviewing relevant items from existing survey instruments as well as relevant research literature. The questionnaire was distributed to all teachers involved in the implementation and conduction of the ScIM interventions. The survey was conducted using SurveryExcact. Primarily, the survey consisted of closed-ended questions (e.g. Likert-Scale ranging from 1 to 4) and was designed to take approximately 10 minutes to complete. It was administrated in august 2017, prior to intervention start.

In the *characteristics of individuals* domain teachers reported how satisfied they were with the way in which the ScIM study had been introduced to them. Two questions assessed the *inner setting* domain: one assessed how much teachers agreed that their school supported them implementing the intervention; the other assessed whether teachers received enough time to include the intervention components in the normal curriculum. The teachers reporting to what extent they agreed with relevant statements. One question assessed *intervention characteristics by* asking whether teachers had received enough training to be able to implement the intervention. Finally, one item assessed teachers' perceived benefits of the interventions. The teachers reported to what extent they believed the intervention could influence the expected outcomes among students, such as their physical health, mental health, school climate and academic performance.

All response scales were as follows: 1 = 'to very little extent', 2 = 'to little extent', 3 = 'to some extent' and 4 = 'to great extent'. The responses are shown as mean (SD) in each domain.

Table 5. Selected constructs from the Consolidated Framework for Implementation Research

Domain	Constructs	Short description
Characteristics of individuals	Knowledge and beliefs about the ScIM trial	Teacher's individual attitudes towards ScIM and the interventions, after the project was introduced to teaching staff by the research group.
Inner setting	School culture	Teachers' expectations for support by leaders and colleagues for them to implement the intervention.
Inner setting	Available time	Amount of time the school's administration gave teachers to plan and deliver the intervention.
Intervention characteristics	Teacher training	Extent to which teachers agreed they had received sufficient training on how to deliver the intervention components before the intervention started.

3.5 Power Calculation

Power calculations were conducted to determine the required sample size for detecting changes in the primary outcome (CPM). The ScIM study was designed to detect a difference in total PA level of 7 % (49 CPM) between the participants in the intervention arms and the control arm. We assumed a standard deviation (SD) of 150 CPM, a power of 90 %, a significance of 0.05, leading to 492 individuals in each group. To allow for 20 % loss to follow-up we needed 590 individuals in each group. Further, we needed a minimum of ten clusters per study arm, consequently we aimed to recruit clusters and individuals until we had at least ten clusters and 590 individuals per study arm.

3.6 Statistics

Across papers, descriptive characteristics are presented as mean and standard deviation (SD), or as frequencies (percentages). Analyses were assessed for assumptions of normality and homogeneity of variance. Primarily, the statistical models used in the papers are linear mixed models including a random intercept to account for clustering of observation's within samples. Missing values were handled by the linear mixed models, so that participants with missing values in any of the variables were included in the analyses if they had at least one measurement of the outcome variable. All analyses were conducted using Stata (Stata Corp. 2015. Stata Statistical Software: Release 15.1 College Station, TX: StataCorp LP). A p-value of $p < 0.05$ indicated statistically significant findings.

Paper I

For the main analysis we included participants with valid data on physical activity, aerobic fitness or muscle strength at either baseline or follow-up.

Main effects of the intervention on physical activity, aerobic fitness and muscle strength were determined by fitting linear mixed models to all these outcomes with repeated measurements. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction. Based on the linear mixed models, we estimated mean group values at baseline and follow-up, and between group-difference in change from baseline to follow-up between participants in the intervention arms and the control arm with 95% confidence interval (CI). All linear mixed models were adjusted for gender and baseline values.

We thereafter tested how gender modified the intervention effect by introducing an interaction term (timepoint x group x gender). Statistically significant interaction between genders were evident in all models ($p \leq 0.03$ for all interactions). Consequently, the analyses were repeated stratified by gender.

Methods

Paper II

Participants with valid data on valid data on numeracy or reading performance at either timepoints were included in the analysis.

We fitted linear mixed models to both outcomes (numeracy and reading). Each model included fixed effects for intervention, time (baseline, follow-up) and interaction term (intervention x time). We estimated mean group values with 95% CI at baseline and follow-up. We estimated the between group difference in change from baseline to follow-up between the participants in the intervention arms and the control arm, with adjustment for sex.

We examined whether gender modified the intervention effect by introducing an interaction term (timepoint x group x gender). Statistically significant interaction between sexes was evident in all academic performance models ($p < 0.001$ for interaction), consequently we repeated the analysis stratified by this variable. We calculated a standardized mean difference score for each specific outcome (Cohen's d), which was estimated using a random effects model. Cohen's d values ranging from 0.01 to 0.20, 0.20 to 0.50 and 0.50 to 0.80 corresponds to very small, small and moderate effect size, respectively. We performed per protocol analysis including schools with above 80% adherence to protocol.

Multiple imputations were performed on academic performance variables to account for loss to follow- up data. Imputation of variables was performed using chained equations (mi imputed chained) in Stata v.16. In the sensitive analysis, mean differences in change, standard errors and 95% CI were obtained based on 20 imputed datasets. The imputation analyses are based on the assumption that data are missing at random.

Paper III

In the mediation analysis, participants with valid academic performance and aerobic fitness data were included if they had at least one measurement of the variable. We fitted linear mixed models to all available data from all continuous outcomes with repeated measurements. Each model contained fixed effects for intervention, time (from baseline to follow-up), and intervention x time interaction. As the unit of randomization was schools, we added random effects for school, in addition to class and subject ID, to accommodate for clustering within these units. Based on the linear mixed models, we estimated mean group values with 95% confidence intervals at baseline and follow-up. We estimated the between-group difference in change from baseline to follow-up between the participants in the intervention arms and the control arm. There was a differential intervention effect on academic performance by sex ($p < 0.001$ for interaction). Consequently, we repeated the analysis stratified by gender.

Mediation was assessed with the approach in Figure 2 (Lee, Herbert, & McAuley, 2019; Valeri & Vanderweele, 2013; VanderWeele, 2016)

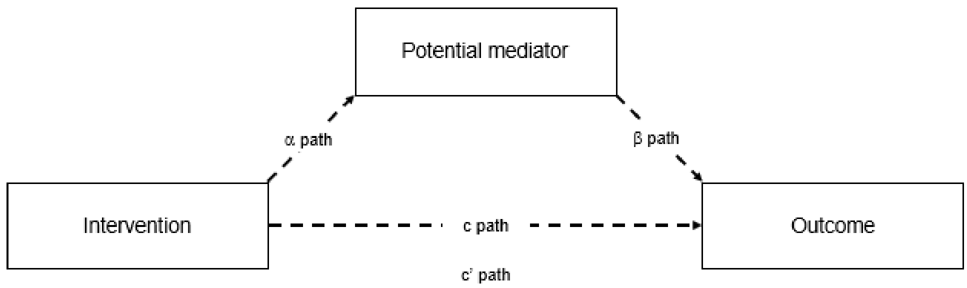


Figure 2. The hypothesized mediation model.
c path: Intervention effect (mean difference in change between intervention and control) on outcome (the total effect).
α path: Intervention effect (mean difference in change between intervention and control) on mediator of interest .
β path: Association between mediator and outcome adjusted for group allocation
c' path : The natural direct intervention effect on outcome controlling for the mediator of interest .

Methods

First, the between-group differences in change from baseline to follow-up between participants in the intervention arms compared with controls (i.e intervention effect) primary outcomes were assessed individually to generate the 'total effect' (c path). Second, the intervention effect on the hypothesized mediator was assessed (α path). Third, the association between mediators and primary outcomes adjusted for group allocation (intervention arms) was assessed individually (β path). Finally, we generated the natural direct effect by estimating the intervention effect on primary outcomes conditional on holding the mediator variable constant (c` path) and consequently generating the natural direct effect.

The natural direct effect (c` path) refers to the relationship between two variables that is mediated by a third variable on the pathway. In order to meet the criteria for mediation, paths α and β have to be significant with a confidence interval not crossing zero (Valeri & Vanderweele, 2013). If the exposure coefficient of the total effect (c path) is considerably different compared with the natural direct effect (c' path), the difference could be interpreted as mediation (VanderWeele, 2016). Partial mediation is present if the natural direct effect is significant, and full mediation is present when it is attenuated and no longer significant. The total and natural direct effects were estimated with 95% (CI) obtained by means of the bootstrap re-sampling method with 1000 replications. Results are expressed as unstandardized, baseline-adjusted coefficients for primary outcomes (points) and mediator (meters covered) with corresponding 95% CI.

Paper IV

Data from the teacher survey were imported from SurveyExcact into Stata 16.0 (StataCorp LP) for processing. Intraclass correlation coefficients (ICCs) were calculated for each implementation contextual factor; this test was used to investigate how similar teachers within a school were to one another. Higher ICC indicates higher homogeneity within a school. The dose delivered did not differ statistically between the two intervention groups (p = 0.689). Hence, these were combined for the main analysis. In the main analysis, general linear mixed models were used to examine the associations between selected implementation contextual factors and the intervention dose delivered. Each implementation contextual factor was examined in a separate model. All models included school as a random intercept to account for the nesting of teachers within schools. Next, in the stratified analysis (stratification by teachers' responses), we assessed whether the dose delivered differed between teachers reporting different responses. That is, we assessed the delivered dose for each category of teacher reported contextualized factor, with those reporting least ('to little extent') as referent. For reporting purposes, the contextual factors were grouped into three categories with response options 1 = 'to a very little extent' and 2 = 'to little extent' merged.

3.7 The role of the Ph.D. candidate

ScIM was a large project involving many people and different test centres at various locations in Norway. The project was only possible because all those involved were dedicated and put energy and hard work into it. ScIM was undoubtedly a team effort, which, in retrospect, should be viewed from the context of the ability of all the people involved to strengthen and support each other rather than shining on their own. Throughout the intervention, I functioned as the daily manager and reported to the project leader, Elin Kolle.

I started my Ph.D. in February 2017. At that point, the overall work regarding the conceptualization and design of the two intervention models and the RCT had been completed. The different outcome measures and measurement methods had also been selected. Hence, I did not participate in the developmental phase of the project. My first task was to conduct the pilot study. I recruited schools (n = 9) and adolescents (n = 700) for this quasi-experimental trial. Together with a team of researchers and research-assistants, we performed data collection at baseline and at follow-up. Thereafter, I supported the schools during the implementation of the interventions, trained the teachers and ensured that the intervention components were incorporated into the curriculum as planned. During the pilot study, I remained in contact with the teachers responsible for conducting the intervention and helped them with the various challenges with the implementation throughout the intervention.

During the preparation for the main RCT, I functioned as a group leader of a group consisting of myself and three other Ph.D. candidates, who were located at the other test centres. I developed various forms and protocols for data collection. Then I trained the other Ph.D. candidates and research assistants to ensure that the data were collected similarly by all study partners. Furthermore, I provided them with relevant information and helped them with the recruitment process. I recruited schools located near NIH and led the team of researches research assistants who gathered data in this area. After the data collection, I coordinated the transfer of the data from the study partners to NIH. Furthermore, I was responsible for data management and building the main database. Finally, I oversaw the addition of all the intervention components to the mandatory curriculum. At the end of the RCT, I organised the follow-up measures at NIH and was responsible for merging all the data files into the main database. Thereafter, under the supervision of the statistician at NIH, I conducted all the analyses for the main report and the publications I was involved in. Furthermore, I was also responsible for distributing databases to other Ph.D. candidates involved in ScIM.

4.0 Summary of results

This chapter presents the main results from each of the four papers.

4.1 Characteristics of the study sample

The characteristics of the ScIM study sample stratified by the three intervention arms at baseline and follow-up points are presented in Table 6. Dependent on the specific research objectives the analytical sample varied in each of the four papers.

Table 6. Characteristics of adolescents included in ScIM. Data is presented as mean (SD) unless other stated.

	PAL Intervention		DWBH Intervention		Control	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
N	655	655	586	525	795	781
Age (years)	13.9 (0.3)	14.9 (0.3)	14.0 (0.3)	14.9 (0.3)	14.0 (0.3)	14.9 (0.3)
Anthropometry						
Height (cm)	164.6 (8.1)	168.6 (8.3)	166.4 (7.7)	170.3 (7.9)	165 (7.7)	169.7 (7.8)
Weight (kg)	54.2 (10.8)	58.2 (10.9)	56.2 (11.0)	59.9 (10.7)	54.4 (10.5)	58.2 (11.2)
BMI	19.9 (3.1)		20.2 (3.2)		19.7 (3.1)	
Parents education levels						
Low (%)	42 (6.4)		38 (6.4)		39 (4.9)	
Middle low (%)	175 (26)		183 (31)		222 (27)	
Middle high (%)	277 (42)		229 (29)		236 (41)	
High (%)	153 (23)		141 (22)		197 (24)	
Physical activity levels full day						
Total physical activity (cpm)	510 (185)	497 (194)	531 (205)	476 (187)	537 (204)	489 (189)
Sedentary (min/day)	541 (79)	553 (87)	534 (79)	559 (94)	531 (78)	548 (84)
MVPA (min/day)	67 (23)	65 (25)	70 (26)	63 (25)	71 (28)	65 (25)
Wear time (min/day)	776 (86)	763 (92)	775 (80)	768 (100)	770 (83)	742 (92)
Physical activity levels school hours						
Total physical activity (cpm)	444 (171)	462 (213)	504 (242)	411(190)	501 (201)	433(194)
Sedentary (min/day)	227 (30)	230 (38)	217 (36)	234 (37)	220 (31)	227 (35)
MVPA (min/day)	25 (11)	25 (11)	28 (15)	24 (13)	29 (13)	24 (11)
Wear time (min/day)	322 (31)	312 (46)	321 (31)	323 (43)	320 (43)	292 (43)
Physical fitness						
Aerobic fitness (m)	894 (101)	925 (108)	909 (111)	909 (90)	928 (102)	940 (92)
Handgrip (kg)	30 (6.5)	32 (8.1)	30 (7.4)	32 (9.0)	29 (7.5)	32 (8.8)
Standing long jump (cm)	168 (27)	176 (27)	171 (26)	178 (28)	172 (24)	179 (28)
Sit-ups (n)	18 (4)	19 (4)	18 (4)	19 (4)	19 (4)	20 (4)
Academic performance						
Numeracy (points)	54 (10)	55 (9)	54 (9)	55 (9)	55 (9)	53 (9)
Reading (points)	55 (9)	54 (9)	54 (9)	55 (8)	55 (10)	54 (9)

PAL = Physical active learning; DWBH = Don't worry – Be happy"; BMI = Body Mass Index; CPM = Counts per Minute; Min/day = minutes per day; MVPA = Moderate- to vigorous intensity physical activity; M = meter

4.2 Paper I

In total 1,579 participants had valid physical activity assessment at baseline and/or follow-up and were included in the analysis. For the physical fitness data, in total 1,873 participants had valid CRF assessments and 1,976– 1,992 participants had valid muscle strength assessments at baseline and/or follow-up (handgrip: n = 1,992; standing broad jump: n = 1,976; sit-ups: n = 1,977).

At follow-up, the daily physical activity levels and time spent in MVPA decreased in all intervention groups. However, the decrease was significant smaller in the PAL intervention compared with controls. Hence, the intervention effect on total physical activity levels were in favour of students in the PAL intervention with a mean difference in change of 34.7 CPM (95% CI 4.1 to 65.3) when compared with controls (Figure 3). The PAL group had also a favourable change in MVPA with a mean difference in change of 4.7 (95% CI 0.6 to 8.8) minutes per day compared with controls. In addition to the favourable changes in physical activity levels across the whole day, students in the PAL intervention had similar effects during school hours. A mean difference in change of 86.4 CPM (95% CI 52.1 to 120.7), 5.6 min (95% CI 3.5 to 7.7) spent in MVPA and -4.0 min (95% CI -7.7 to -0.3) spent SED during school hours was found when compared with controls. Mean difference in change in CPM and MVPA when comparing students in the DWBH intervention model with controls were typically modest and not significant (Figure 3), except that they increased sedentary time during school hours (mean difference in change 10.0 minutes (95% CI 6.0 to 14.0)).

Summary of results

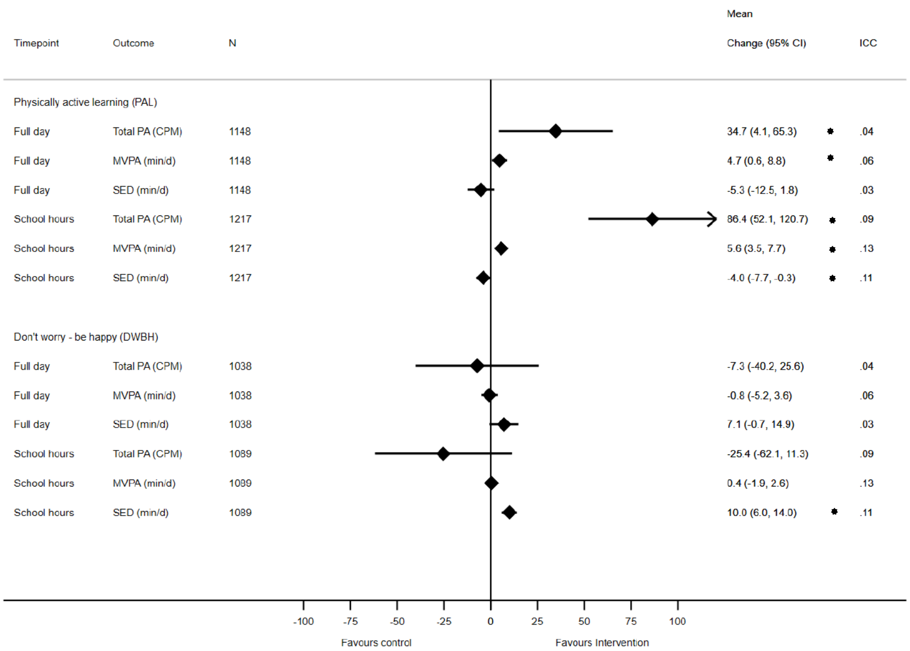


Figure 3. The intervention effect on physical activity variables during the full day and during school hours stratified by study group. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for subject ID .MVPA = moderate- to vigorous-intensity physical activity, min = minutes, CPM = counts per minute, CI = confidence interval; ICC = Intra class correlation coefficient; •indicates significant mean difference in change compared with controls

For the secondary outcomes, students in the PAL intervention model increased distance covered on the Andersen-test with 19.8 meters (95% CI 10.4 to 29.1) compared with control (Figure 4). Further, students in the PAL group had a favourable change in numbers of sit-up test, where the mean difference in change was 0.5 (95% CI 0.1 to 0.9) compared with controls (Figure 4).

Students in the DWBH group did not change the distance run in the Andersen-test during the intervention period. When we compared the change in distance between adolescents in the DWBH and controls, the mean difference in change was 11.6 m (95% CI -21.9 to 1.1) in favour of the controls (Figure 5).

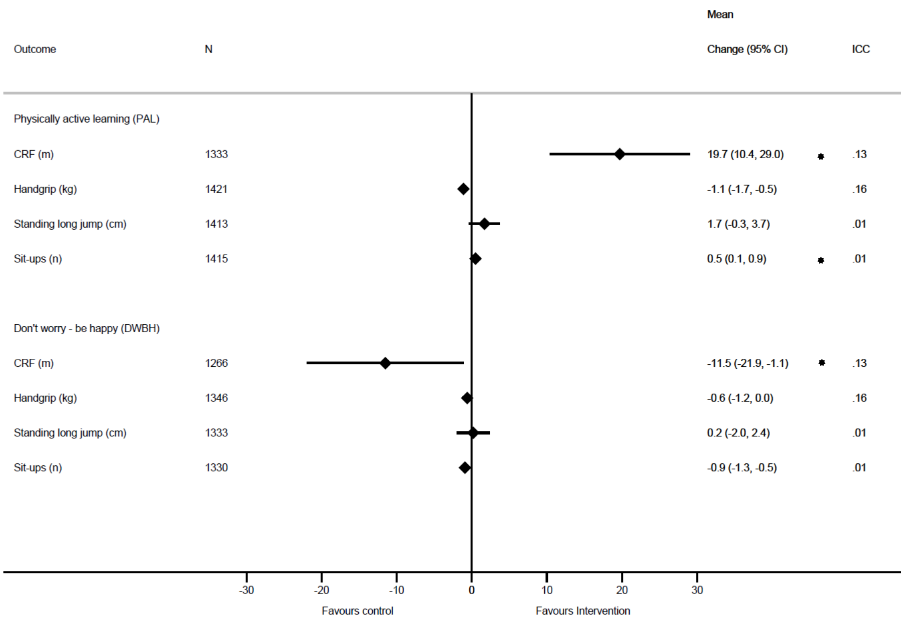


Figure 4. The intervention effect on aerobic fitness and muscle strength stratified by study group. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for subject ID, ICC = Intra class correlation coefficient,• indicates significant mean difference in change compared with controls

4.3 Paper II

In paper II, 1999 and 2002 students had valid data at baseline in reading and numeracy, respectively. A total of 1682 students had valid data in reading and numeracy at follow-up.

Significant intervention effects were present among students in both intervention models compared with controls (Figure 5). Mean difference in change in numeracy was 1.7 (95% CI 0.9 to 2.5) and 2.0 (95% CI 1.4 to 2.7) points in favour of students in the PAL and DWBH intervention model, respectively. Regarding reading performance, we found similar results, where the mean difference in change was 0.9 (95% CI 0.2 to 1.6) points in favour students in the PAL intervention, and 1.1 (95% CI 0.3 to 1.9) points in favour students in the DWBH intervention (Figure 5).

Summary of results

Stratified by gender, the intervention effect on numeracy performance were 1.0 points (95% CI: 0.3 to 1.8) and 2.4 points (95% CI: 1.5 to 3.3) in favour of girls and boys in the PAL intervention model, respectively, compared with controls (Figure 6). In the DWBH intervention model, the mean difference in change were 1.4 points (95% CI 0.5 to 1.8) and 2.7 points (95% CI 1.5 to 3.3) for girls and boys respectively (Figure 6). The intervention effect on reading were attenuated and were only significant when boys in the DWBH intervention model was compared with control (mean difference in change 1.8 points (95% CI 0.6 to 2.9) (Figure 7).

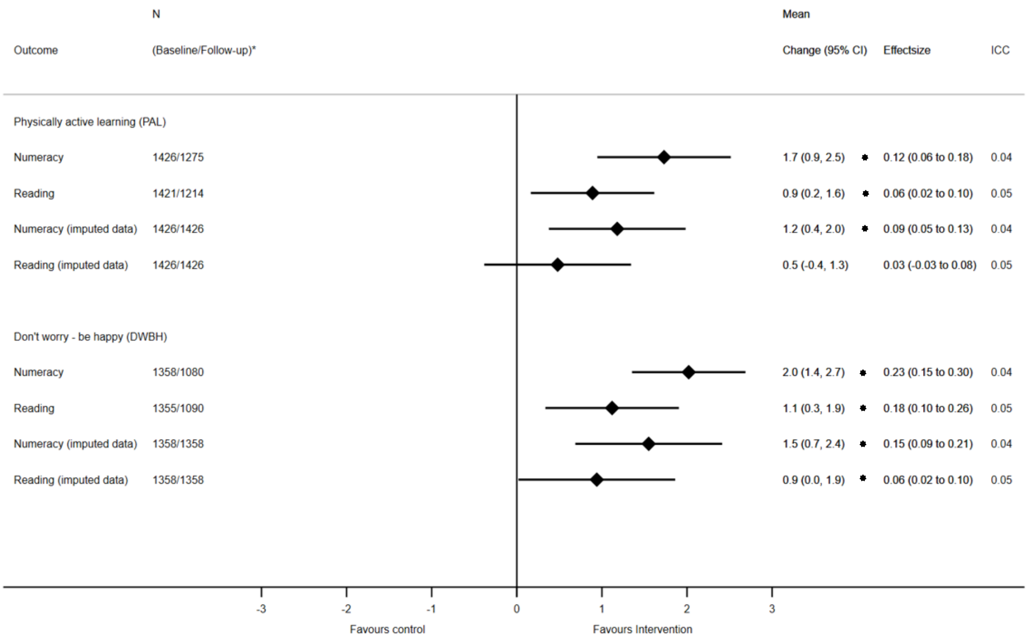


Figure 5. Intervention effect on academic performance in numeracy and reading stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group. •indicates significant mean difference in change compared with controls*

Summary of results

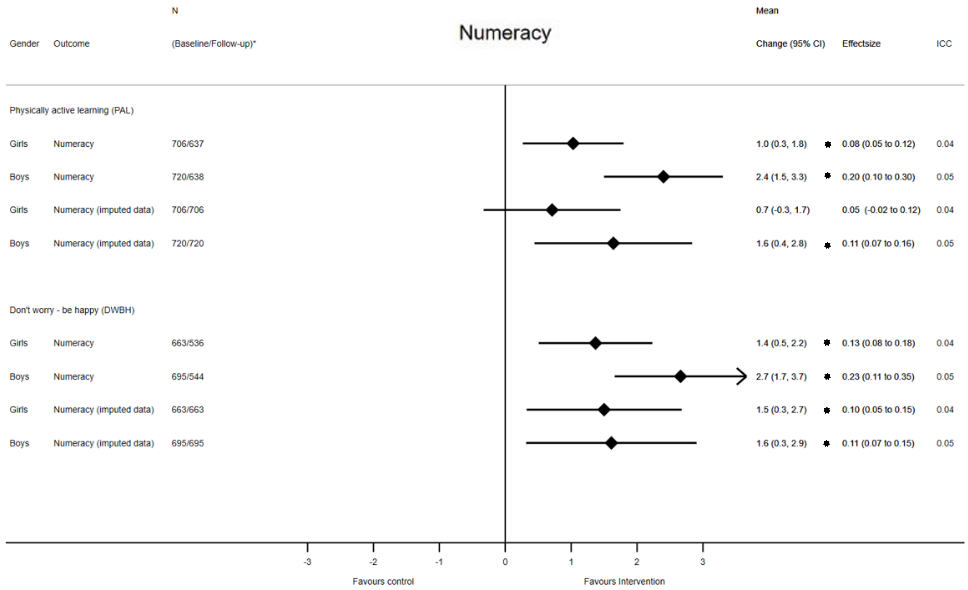


Figure 6. Intervention effect on academic performance in numeracy stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group. • indicates significant mean difference in change compared with controls*

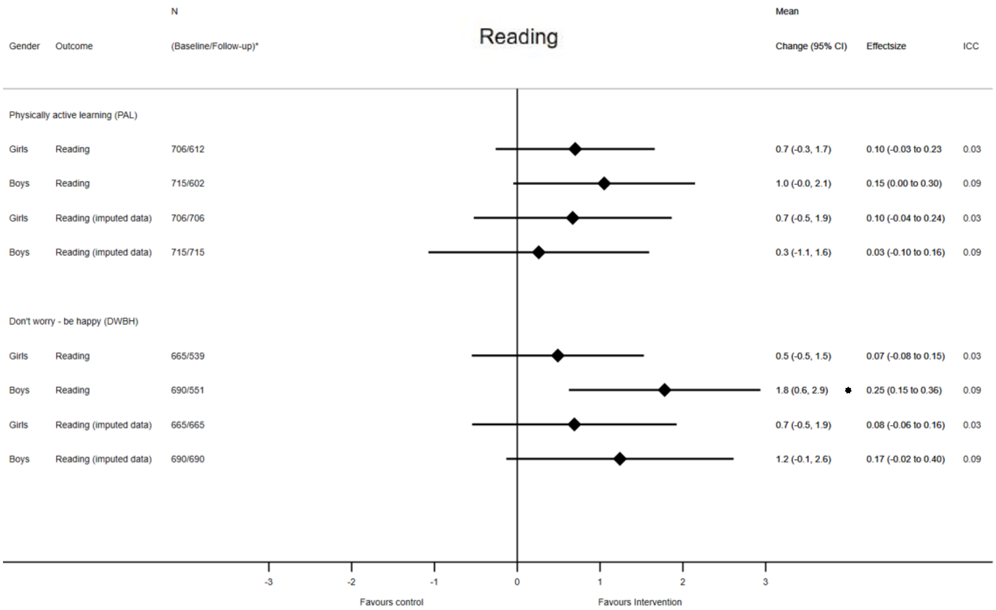


Figure 7. Intervention effect on academic performance in reading stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group. • indicates significant mean difference in change compared with controls*

4.4 Paper III

Of students with valid data on academic performance, a total of 1,873 students provided valid aerobic fitness assessment at either timepoint, and were included in the analysis in paper III.

The mediation pathways of aerobic fitness were examined separately in each of the intervention models when compared with controls (Figure 8 & Figure 9). When the dependent variables of interest included in the model was numeracy performance, the analysis showed that aerobic fitness partially mediated the intervention effect by 28% (total effect of 1.73 points (95% CI: 1.13 to 2.33)) to natural direct effect of 1.24 points (95% CI 0.58 to 1.91)) (Figure 8a). When analysing data with reading performance as dependent variable (Figure 8b), the analysis revealed that aerobic fitness fully mediated the intervention effect, with the total effect of 0.89 points (95% CI 0.15 to 1.62) reduced to the natural direct effect of 0.40 points (95% CI -0.48 to 1.28). In the DWBH intervention model, aerobic fitness did not satisfy the steps for mediation (Figure 9).

Summary of results

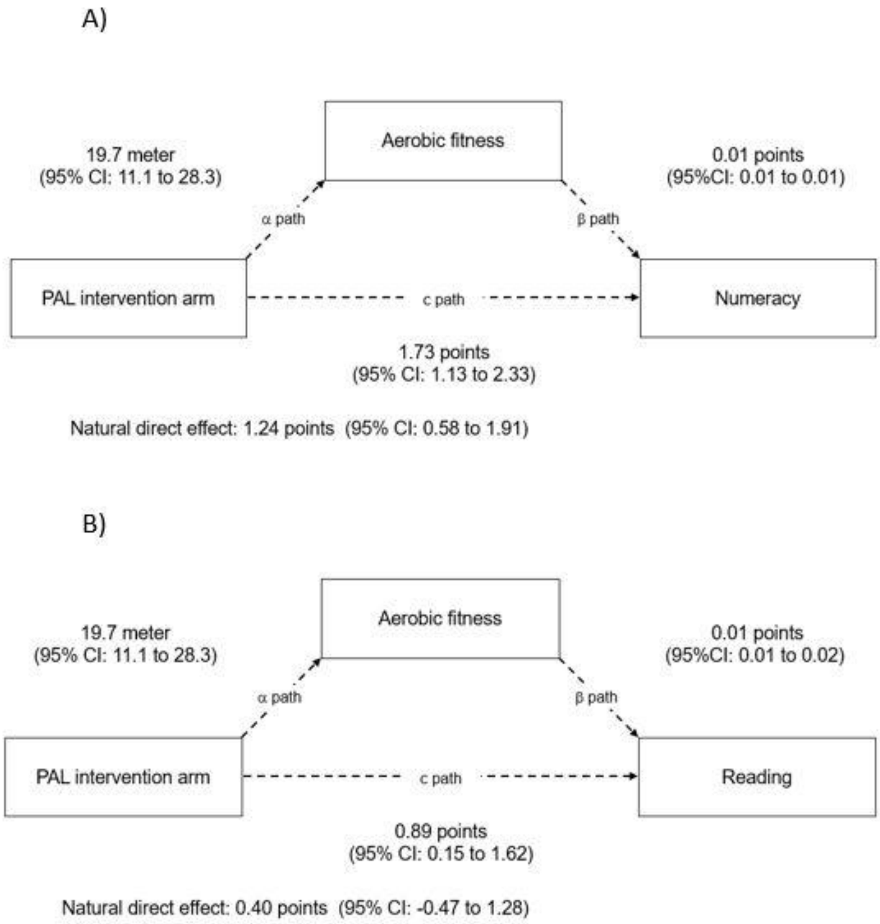
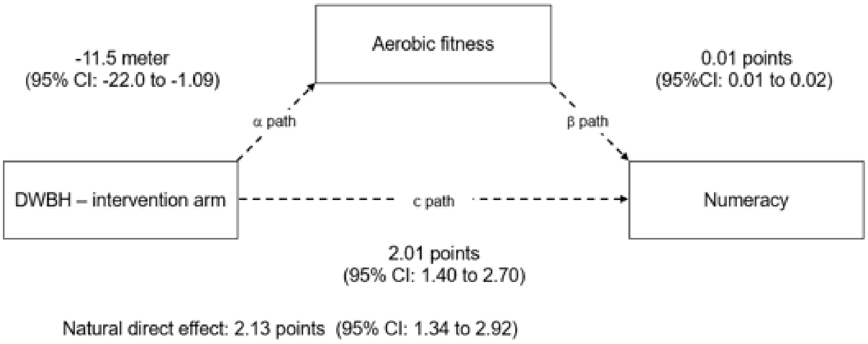


Figure 8. Models of the mediation effect of aerobic fitness on the intervention effect on A) numeracy and B) reading performance among students in the Physically Active Learning (PAL) intervention arm when compared with controls. All coefficients are unstandardized. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID. All models are adjusted for gender. CI: Confidence interval. Intra Class Correlation Coefficient for school (ICC)s: Model A: ICC: 0.04, Model B: ICC: 0.09

Summary of results

A)



B)

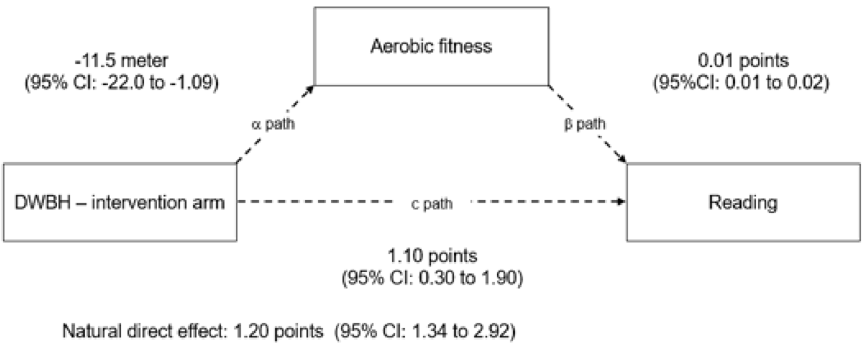


Figure 9. Models of the mediation effect of aerobic fitness on the intervention effect on A) numeracy and B) reading performance among students in the Don't worry – be happy (DWBH) intervention arm when compared with controls. All coefficients are unstandardized. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID. All models are adjusted for gender. CI: Confidence interval. Intra Class Correlation Coefficient for school (ICC)s: Model A: ICC: 0.08, Model B: ICC: 0.10.

4.5 Paper IV

In total 56 teachers from 19 intervention schools agreed to participate in the study. The majority of teachers were female (59.6%) and between 30 and 39 years of age (50.1%). The dose delivered ranged from 67% to 93% between schools. Schools in the PAL intervention reported 83% of the intended dose delivered, whilst schools in the DWBH intervention arm reported 78% of the intended dose delivered (Table 7).

Table7. Overview of total number of components and the numbers implemented through the intervention period stratified on intervention models

	Components (N)	Components delivered (N)	Percent (%)
Physically Active Learning (PAL)			
Physical Education	928	794	86
Physical Active Learning	928	776	84
Physical Activity	928	735	79
Total	2784	2305	83
Don’t worry – be happy (DWBH)			
Don’t worry – lesson	783	616	79
Be happy – lesson	783	600	77
Total	1566	1216	78

The main analysis showed no associations between teacher-reported implementation contextual factors and implementation dose delivered (Table 8).

Table 8. Associations between teacher-reported implementation contextual factors and implementation dose delivered

Implementation contextual factors	Unstandardized regression coefficients	95% Confidence interval	P-value
Knowledge and beliefs	-0.84	-4.08 to 2.38	0.608
School Culture	-1.09	-3.93 to 1.74	0.450
Time	0.60	-2.09 to 3.29	0.662
Teacher Training	0.81	-2.20 to 3.82	0.598

Mixed model containing school as cluster variable

Summary of results

When the contextualized factors were split into subgroups of teacher responses, the dose delivered did not differ between groups (Figure 10). This pattern of results was observed between different responses regarding knowledge and beliefs, school culture and available time. Finally, no association was found between dose delivered and the teachers’ satisfaction with training before the intervention started, even though a small, but not statistically significant, trend was observed towards higher delivered dose among teachers reporting that they were very satisfied with the training provided by the research group.

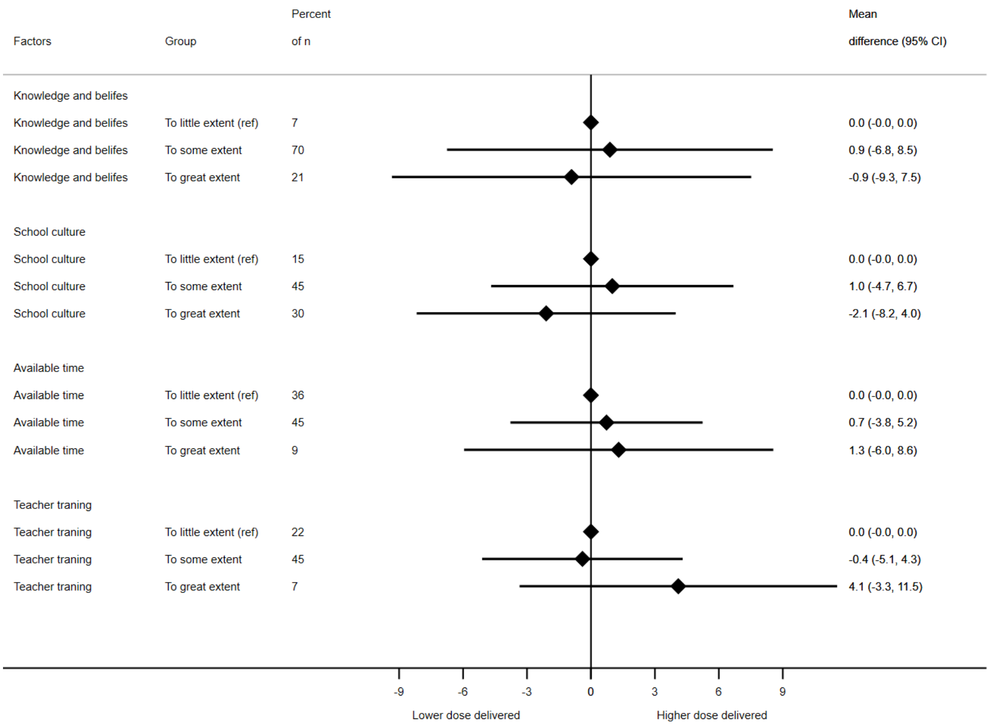


Figure 10. Stratified relationship between the teachers’ perceptions of ScIM and the dose delivered. Mixed model containing school as a cluster variable. Responses from n=56 teachers.

5.0 Overall discussion

The overall aims of this thesis were to investigate the effects of the ScIM intervention on adolescents' physical activity level, aerobic fitness and academic performance. Furthermore, we aimed to examine whether aerobic fitness mediated the physical activity effects on academic performance. Finally, we explored whether contextualized teacher-related factors were associated with the intervention dose delivered.

5.1 Summary of main findings

This thesis presents the effects of two different school-based physical activity interventions among Norwegian adolescents, and it extends current knowledge with several novel findings. **Paper I** establish that the two intervention models had different effects on the adolescents' physical activity level and aerobic fitness. All groups decreased their physical activity levels over the intervention period; however, adolescents in the PAL intervention demonstrated a favourable mean change in CPM, MVPA, SED during the full day and aerobic fitness compared with the controls, whilst no differences were found among adolescents in the DWBH intervention group.

The results of **Paper II** make a significant contribution to the field by providing evidence that two different school-based physical activity interventions can affect adolescents' academic performance. When compared with controls, adolescents in the PAL and DWBH intervention demonstrated a favourable mean difference in change in both numeracy and reading. By employing mediation analysis in **Paper III,** we were able to establish that aerobic fitness mediated the effect of physical activity on academic performance observed in the PAL intervention but not in the DWBH intervention. The findings suggest that the PAL intervention influenced academic performance through activities leading to improved aerobic fitness, whilst the intervention effect observed in the DWBH intervention might be linked to other mechanisms that were not measured.

The cross-sectional analysis described in **Paper IV** revealed no associations between teacher-reported contextualised factors (e.g., knowledge and beliefs, school culture, available time and teacher training) and intervention dose delivered. Therefore, there is a lack of understanding of which factors might have been particularly beneficial in the implementation of the ScIM study. However, the findings are insufficient to investigate associations and undertake detailed subgroup analyses, due to the homogeneous nature of the self-reported data.

5.2 Intervention effect on physical activity

By demonstrating that a school-based physical activity intervention can favourably change behaviours of adolescents that are related to important health outcomes, our findings have advanced current knowledge and provides insight into the state of the evidence base that include adolescent populations, which has been inconclusive to date (Hartwig et al., 2021; Love et al., 2019).

The fact that we observed a favourable mean difference in change in CPM and MVPA among adolescents in the PAL intervention when compared with controls, but not in the DWBH intervention is somewhat peculiar, considering that both models include a combination of components that added 120 min of additional physical activity onto the curriculum. However, the two interventions varied in the theoretical framework, content and structure, in addition to the way in which the physical activity was delivered. These variations may explain some of the discrepancies in the results.

The PAL intervention was based on theoretical frameworks that centre on the idea that people are driven to engage in activities to develop or demonstrate their skills (Harter, 1978), and a concept that changes the environment and stimulates personal growth, behavioural quality and general wellbeing will encourage engagement in activities to develop or demonstrate skills (Ryan, 2002). In the PAL intervention, PE teachers often opted to organise the additional PE lesson in such a way that adolescents could practise elements that they struggled with in the subject curriculum. Consequently, the adolescents reported that the extra PE lesson helped them to master elements of the PE curriculum. Furthermore, the physically active learning component should stimulate increased activity when students were working on curriculum-related topics in traditional subjects. Consequently, adolescents could work on subject-related topics together with classmates and solve challenges together whilst being physically active. Finally, to enhance the adolescents' positive experience of being physically active, they were involved in the decision-making process regarding the activities that would be performed in the physical activity component.

However, there are limitations in the PAL intervention framework. First, the dynamic between the person, behaviour and environment dimensions is loosely organised, and it is unclear to what extent each of these dimensions translates into changed behaviour or whether one element is more influential than others. Furthermore, it is assumed that increased physical activity incorporated into the curriculum (e.g., changes in the environment) will automatically lead to changes in adolescents' behaviours, although, this may not always be true. Finally, a "one-size-fits-all" approach such as the PAL intervention might not be suitable for all students.

Overall discussion

In contrast, the DWBH intervention was developed on theoretical frameworks that consider people as a complex system that is active, creative, self-organising and self-regulating (Agans et al., 2013; Lerner, 2015; Lerner, 2018). The DWBH intervention framework enables adolescents to pursue activities through trial and error, self-organisation and self-determination. For these self-organised activities to be sustainable, adolescents need to perceive the intervention as relevant and have positive relationships with peers within the intervention. However, although an intriguing concept, the DWBH intervention is still in a conceptual phase and should be further developed to be effective. For example, even though being speculation from some teachers in ScIM, it is possible that some students were not mature enough to cope with the freedom of the responsibility offered by the intervention. Summarised and in hindsight, the PAL framework might be the most feasible method for teachers to use in a real-life lower secondary school setting to stimulate more physical activity among adolescents.

Another perspective that should be discussed is the way in which the two interventions were delivered. For example, with the PAL intervention, teachers were encouraged to engage students in activities of at least moderate intensity, whilst the DWBH intervention promoted friendships through physical activity and PE, and the social relationships were more important than the intensity of the activity. Our expectations were that the optional physical activity and the fact that students were able to choose their activities based on their interest and preference would stimulate adolescents in the DWBH intervention to be more physically active. However, we observed a more significant decrease in CPM and MVPA among adolescents in the DWBH intervention and controls than among adolescents in the PAL intervention. Nevertheless, these findings were not unexpected, as previous data show that physical activity levels decrease during the transition from childhood to adolescence (Steene-Johannessen et al., 2021; van Sluijs et al., 2021).

Moreover, adolescents in both the DWBH intervention arm and the control arm increased sedentary time during the intervention period, but the increase was higher among those in the DWBH intervention. Thus, some may say that the components of the DWBH intervention constitute a lost opportunity to be more physically active. Some of the adolescents in the DWBH intervention performed activities that included movements of at least moderate intensity. Others chose activities that were less physically demanding, such as yoga or building a tree house, whilst some performed activities that involved upper body movements (i.e., resistance training) or cycling or swimming. A known limitations of accelerometers is the poor ability to capture and register acceleration when subjects are cycling or conducting load-bearing activities such as strength training, and, in addition, it cannot be worn during water activities (Trost et al., 2011). These limitations may explain the counterintuitive findings in the DWBH intervention.

The intervention exposure might be relevant to the potential intervention effect. The ScIM interventions consisted of components that added 120 min of physical activity to the curriculum. When comparing with the intervention exposure in comparable studies, the ScIM exposure is lower (Ahamed et al., 2007; Donnelly et al., 2009; Donnelly et al., 2017; Grydeland et al., 2013; Jago et al., 2015; Lubans et al., 2018; Mullender-Wijnsma et al., 2016; Resaland et al., 2016; Riley et al., 2016; Tarp et al., 2016; Telford et al., 2012). One could argue that the 120 min exposure is more viable and less demanding because higher exposure requires more resources and planning.

5.3 Intervention effects on physical fitness

In our study, adolescents in the PAL intervention increased their running distance during the Andersen tests relative to controls by 19.7 m, which corresponds to a 3.5% increase in the average distance covered at baseline. For muscle strength, the analysis showed that handgrip strength had increased in all groups during the intervention period, but the increase was significantly greater among the adolescents in the control group. Furthermore, we observed a favourable mean difference in change in sit-ups among adolescents in the PAL intervention compared to the control group, whilst these similar results were not demonstrated among adolescents in the DWBH intervention. Studies have reported an inverse and protective association between physical fitness in youth and several conditions that are cardiovascular risk factors (García-Hermoso et al., 2019; Högström, Nordström, & Nordström, 2014; Raghuveer et al., 2020). Hence, measures to improve physical fitness among adolescents are important and can result in important health benefits later in life (García-Hermoso et al., 2019; Raghuveer et al., 2020). Consequently, the positive findings in the PAL intervention is important in a public health perspective.

The aerobic fitness results from the PAL intervention align with the findings of the most recent systematic review and meta-analysis on the effects of overall school-based physical activity on aerobic fitness (Hartwig et al., 2021). Whilst the increase might seem modest, one cannot rule out that the percentage increase might be clinically relevant, since aerobic fitness in adolescence is of importance for cardiovascular health in adulthood (Raghuveer et al., 2020). The stratified analyses revealed improvements in running distance among boys in the PAL intervention but not among girls. A plausible reason is that gender differences in growth and pubertal status may have exacerbated this effect. Specifically, it could be attributed to factors such as lean body mass, haemoglobin concentration and testosterone (Malina, 2004). On the one hand, during puberty, boys experience increases in testosterone production and muscle mass that are greater than those seen in girls, and these factors are beneficial to aerobic fitness. Girls, on the other hand, experience increases in fat mass which often result in a stagnation in performance-related tests, such as the Andersen test, where body weight and body composition are important factors.

Even though adolescents in the PAL intervention demonstrated a favourable mean difference in the 1 sit-up change compared with controls, the change was small and most likely of little clinical relevance. However, the small effect on muscle strength overall is not a surprise given that neither of the ScIM interventions was specifically designed to affect neuromuscular adaptation to increase muscle strength. Nonetheless, some groups in the DWBH intervention performed activities that could increase muscle strength, such as yoga, resistance training and swimming, but probably not in a sufficient quantity to affect the average of the entire intervention group. Furthermore, the non-significant, or even negative, development in muscle strength indicates that school-based physical activity interventions should include components of regular muscle-strengthening activities, which is in accordance with the national and global physical activity guidelines (Bull et al., 2020).

5.4 Intervention effect on academic performance

The observed positive effects of the intervention on academic performance in the PAL and DWBH intervention when compared with controls were relatively small; however, whilst difficult to quantify the exact practical implication, they might still be impactful. Our study documented that two different approaches to integrate physical activity into the curriculum can enhance academic performance. Furthermore, both the PAL and DWBH interventions took time away from traditional subjects, and the outcome contrasts with the view that physical activity during school hours steals away time from traditional subjects and, thus, hampers adolescents' academic performance.

The effects observed in the PAL intervention suggest that an approach that combines additional physical activity and academic learning is beneficial for academic performance. Although the additional PE lesson and additional 30 min of physical activity were not related to any particular theoretical subject, it might be that the classroom behaviour of adolescents improved as a result (Alvarez-Bueno et al., 2017). Furthermore, integrating physical activity into normal lessons allowed teachers to use different didactic methods, which might have stimulated improved performance in academic subjects. Finally, increased physical activity might change the brain morphology through the development of new blood cells and vessels and affect cognitive performance (Best, 2010; Best, Miller, & Naglieri, 2011; Hillman, Erickson, & Kramer, 2008) Hence, the increased academic performance in the PAL intervention might be as a result of the increased physical activity levels.

To complicate the interpretation of the findings, whilst the physical activity levels of adolescents were unaffected by the DWBH intervention, it did affect their academic performance. Consequently, the DWBV intervention effect on academic performance must be attributed to mechanisms other than physical activity. We might speculate that, since the focus in the DWBH intervention was to promote friendships through physical activity, the self-chosen activities might have enhanced alertness, minimised fatigue and boredom, and led to higher levels of self-efficacy, which could optimise students' academic performance (Fedewa & Ahn, 2011). Furthermore, the chosen activities might have encouraged students to cooperate with classmates and employ strategies to adapt to changing task demands, which is important since studies have reported that PE enriched with social interaction decrease inhibition (Donnelly et al., 2009). Finally, one other plausible mechanism that transcends both the PAL and DWBH interventions is that varied curriculum-based physical activity enhances enjoyment of academic lessons, leading to improved motivation and engagement with theoretical materials.

In **Paper III,** we found that aerobic fitness mediated the intervention effect on academic performance in the PAL intervention but not in the DWBH intervention. To our knowledge, no study has been able to determine the specific mechanisms whereby school-based physical activity interventions affect academic performance, and, whilst different mechanisms have been suggested, evidence is sparse. The concept that aerobic fitness mediates the effects of physical activity on academic performance can be explained by several hypotheses. One is that physical activity of an intensity that increases aerobic fitness is associated with enhanced cerebral capillary growth, blood flow and stimulation of the nerve cells in the hippocampus, which, in turn, are associated with learning and memory related to academic performance (Chaddock et al., 2011; Hillman & Biggan, 2017). Furthermore, higher aerobic fitness can stimulate better communication between neurons and the integration of regions that support academic performance (Chaddock-Heyman et al., 2016). Research has also shown that physical activity and aerobic fitness enhance the synthesis of brain-derived neurotrophic factor (BDNF), which is associated with an increased volume in the hippocampus and improved memory (Cotman, Berchtold, & Christie, 2007). Consequently, the indirect impact of the intervention on academic performance via aerobic fitness might be due to the positive relationship between aerobic fitness and the morphology of the brain. Our findings regarding the intervention effects on physical activity in the PAL intervention in **Paper I** might somehow support these hypotheses, but, since we did not include any measurements of cognitive functioning, we are unable to draw conclusions on this matter.

5.5 The associations between teacher-reported implementation contextual factors and the intervention dose implemented

Whilst many school-based physical activity interventions are hampered by poor implementation and low dose delivered, the teachers involved in ScIM delivered more than 80% of the intended dose during the intervention period. However, we did not find significant associations between teacher-reported contextual factors and the intervention dose delivered.

The data suggest that that the majority of teachers involved in ScIM were satisfied with their own knowledge and beliefs related to the ScIM study, the school culture related to the implementation of the interventions, the time available to plan and organise the components and the teacher training prior to the intervention. Furthermore, teachers viewed the ScIM study positively, and their perception was that the intervention could improve students' physical health, learning environment and academic performance. The latter finding is important, because improving academic standards may be a higher priority for teachers than implementing a new physical activity component in the curriculum (Clarke, Fletcher, Lancashire, Pallan, & Adab, 2013). A motivated classroom teacher who is convinced of the relevance of an intervention to the school's main purpose, which is academic excellence, strongly facilitates the successful implementation of a school-based physical activity programme (Gadais, Caron, Ayoub, Karelis, & Nadeau, 2020).

The non-significant associations between teacher-reported contextual factors and the delivered intervention dose might be explained by the homogenous nature of the self-reported data. This presumption makes it relevant to consider the theoretical framework of the study and how it might influence contextualised factors related to the implementation.

The purpose of social ecological models is to influence different levels of factors that may change health behaviours (Langille & Rodgers, 2010), starting with policies and organisation at higher levels. The ScIM study was initiated and funded by the Ministry of Education and Research and the Ministry of Health and Care Services; hence, it was supported by high-level policies. This support, in combination with the additional resources the schools received, might have influenced the trickle-down effect from the higher to the lower levels. Despite the lack of data confirming this effect in our study, other research has demonstrated the influence of higher policy levels on the community and organisational levels (Emmons, 2000). Whilst this is only speculation, support from higher-level policies could have influenced school principals in the respective communities to support the ScIM project and recommend that the school in question should participate. This support could also have influenced school managements when they were approached by the ScIM research group.

Overall discussion

Whilst higher-level policies are important, they do not have a role in determining how programmes are implemented in each school. Therefore, it is important that governments should provide flexibility for the interventions, allowing schools consider their own circumstances. The reason for this is that each school constitutes its own environment, and school-level decisions influence the support required to implement physical activity in the curriculum. Studies have shown that the personal values of individuals regarding physical activity and health behaviours influence the decisions made in schools (Shoesmith et al., 2021). The principals involved in ScIM regarded the project positively, which may have influenced the overall school climate. In total, more than 75% of the teachers experienced their school administration and teacher colleagues as supportive. A supportive school culture have been shown to be an important factor for the implementation of additional components in the curriculum (Gadais et al., 2020; Naylor et al., 2015).

Balancing the additional physical activity required by an intervention in school time with more important priorities (e.g., improving academic performance) is often challenging for schools. A motivated classroom teacher who is convinced of the relevance of an intervention to the school's main purpose of academic excellence can strongly facilitate the successful implementation of a school-based physical activity programme (Gadais et al., 2020). In ScIM, teachers viewed the interventions positively and understood that it could improve the students' physical health, learning environment and academic performance. This point was emphasised by Naylor et al. (2015), who indicated that linking the perceived benefits of a programme to established goals (such as the teachers' goal of increasing academic performance) is important for successful implementation in schools. This importance was also emphasised in a recent study that describes how teachers and stakeholders attended a workshop on how to successfully implement physically active learning into the school day. During this workshop, teachers argued that physically active lessons provide opportunities to enhance health whilst also affecting the learning environment (Daly-Smith et al., 2020). In summary, the ScIM study followed the theoretical approach of the social ecological model. By influencing factors at all levels, from the government through to the school leaders, principals and teachers – the group most often responsible for delivering the physical activity components – the high dose delivered was maintained throughout the study period.

5.6 Methodological consideration

It is important to discuss methodological considerations in the interpretation of the results in this thesis. In the following section, the study design, study sample and assessment methods for the outcomes and statistical analyses are discussed, as well as the internal and external validity and certain additional considerations.

5.6.1 Study design

The analyses in **Papers I, II** and **III** were based on data from a cluster RCT, where the unit of randomisation was a group and outcome measurements were obtained from individuals in the different groups. The cluster RCT is the best design available when an intervention is implemented at group level with changes in the physical environment (Murphy, Esterman, & Pilotto, 2006). Furthermore, the RCT research design is ideal to evaluate causal inference, which is the strongest empirical evidence of the efficacy of a treatment. The random allocation to comparison groups prevents unmeasured or poorly measured confounding factors from affecting the interpretation of causal hypotheses and minimise allocation and selection biases. Finally, the adequate sample size in ScIM minimises the possibility of incorrectly rejecting (Type 1 error) or accepting the null hypothesis (Type 2 error). However, downsides and considerations related to RCT studies include that they are demanding and require resources. Another important point is that the results may not mimic real-life settings, due to specific inclusion and exclusion criteria and controlled settings (Banerjee, Chitnis, Jadhav, Bhawalkar, & Chaudhury, 2009)

Paper IV presents results based on cross-sectional data. Thus, we were not able to derive causal relationships. However, cross-sectional analysis is valuable because of its ability to explore the relationship between factors such as teacher-reported contextualised factors and the intervention dose delivered at one point in time. We did not conduct any power calculations for this specific paper, introducing the possibility of a Type 2 error.

5.6.2 Consideration and reflections about the ScIM intervention models

Consideration and reflections of the contrasting factors within the PAL and DWBH intervention that might influence physical activity accumulation is important. Whilst the diversity in mode and intensity of the PAL and DWBH intervention components makes it difficult to point out specific factors, there are some important differences between the two models.

First, all components in the PAL intervention were teacher led. The combination of teacher led activities and including the adolescents in the decision-making process of how activities were organized, might be important for physical activity accumulation. This might be because the PAL intervention balances the trade-off between involving adolescents in the process and making sure that the components are implemented as intended. In contrast, the DWBH intervention did not trade-off these responsibilities in the same way, which might have been a disservice in the prospect of physical activity accumulation.

Another aspect is that the PAL intervention offers three different opportunities to be physically active throughout the week, whilst the DWBH intervention offered two opportunities consistent of the same activities. Hence, the DWBH intervention might be beneficial for adolescents with a great motivation to cultivate a specific interest. However, at the same time it also creates an environment where adolescents who do not engage in regular physical activities might fall outside.

Variation is another aspect that differentiated by the PAL and DWBH intervention. Whilst adolescents in the PAL intervention were provided with a great variety of physically activities in PE lessons, academic subjects and other settings (e.g. 30 min of physical activity), the DWBH activities were chosen for around five months at a time. Additionally, students could choose the same activities as their leisure activities. In hindsight, five months doing the same activities was probably a bit too long and they should be given the option to change activities more frequently. Moreover, for some, this might produce the reverse of the desired effects, and they got bored of the activities quicker than anticipated.

5.6.3 Assessment measures

Understanding how the accuracy of the exposure and outcomes could influence the results is key to the correct interpretation of research findings. In general, imprecise exposure measures could lead to underestimation of the relationship with an outcome variable, whilst random measurement errors in the outcome will increase the standard error of the coefficient estimate (Hutcheon et al., 2010).

Physical activity and sedentary time

One asset of ScIM is the use of accelerometer-measured physical activity and sedentary time. Using accelerometers eliminates bias associated with self-reported physical activity and gives confidence in the generalizability of the results (Lynch et al., 2019). However, whilst accelerometer-measured physical activity is more comparable across populations if the same models and data-reduction protocols are used, there is no agreement on which protocol is most suitable. For example, a seven-day measurement period is often regarded as representative of adolescents' physical activity behaviour (Hansen et al., 2014). In our study, post-hoc analysis showed that physical activity did not differ between those with two valid measurement days compared with 3–7 valid days. Thus, we included all adolescents with more than two valid days in our analysis to maximise statistical power and reduce the risk of type 2 errors. Furthermore, the criteria for a valid day was defined as wear-time of ≥ 480 min per day, which is lower than the recommended criteria of ≥ 600 min per day (Rich et al., 2013). However, the use of a minimum wear time of ≥ 480 min per day has shown acceptable reliability (Rich et al., 2013). Finally, we experienced a large loss in follow-up in physical activity data, which reduced the analytical sample size and statistical power in the analysis and may have affected the validity of the physical activity measurements.

Aerobic fitness

We used the Andersen field test as a measurement of aerobic fitness. There is an ongoing debate as to whether field tests for assessing aerobic fitness provide valid measurements for $V02_{max/peak}$ (Armstrong & Welsman, 2019), and several considerations are worth mentioning regarding the interpretation of the results. Originally, the Andersen test was performed on a 20-metre track. To standardise the protocol used in ScIM, we had to reduce the length of the track to 16 metres because some schools did not have a 20-metre track available. However, because all schools performed the test similarly, this reduction probably does not affect the results.

Overall discussion

An important question is whether there is a learning effect from the Andersen test from baseline to follow-up measurements. In one study by Aadland et al. (2014), three running distances for the Andersen test were performed over a three-week period. Whilst the running distance increased significantly from test 1 to test 2, there was no difference found between tests 2 and 3 (Aadland et al., 2014). Thus, the adolescents in ScIM might learn from their first performance and allocate their capacity better at follow-up. Consequently, in an ideal world, we should conduct one test before the baseline measurements; however, we argued that, since 12 months elapsed between the two tests, the learning effect was minimal.

Another important limitation is the use of different test leaders who motivated the adolescents differently. This discrepancy in motivation could potentially have affected running distance and, thus, biased the results. However, it was mostly impossible to use a single test leader due to time constraints and the distances between the test centres. To standardise, none of the involved test personnel could cheer the participants on before 6 min had passed. Finally, since there are adolescents from different backgrounds and with different native languages in schools, some experienced difficulties in understanding the information provided by the test leaders. This could also have affected performance, in addition to the fact that the test personnel subjectively judged whether or not a test was valid.

Muscle strength

The Eurofit test battery provides valid and reliable test results for large groups of children and adolescents. Moreover, the tests are easy to complete in school settings where large groups of individuals (n = 20–30) can complete the test battery in approximately 1.5 hours. However, the way the tests are performed may lead to differences in the testing procedures and conditions. Among others, differences in climate, practice and testing surfaces can affect how tests are conducted and the individual results. In our study, the tests were performed in similar conditions, namely on a flat wooden floor indoors. Hence, the climate did not affect the test procedures in ScIM. However, one point that could affect the procedures, despite the strict criteria for the test procedures, is the subjective decision taken by the test personnel of whether or not the performance of each individual was valid. Thus, measurement error might have occurred. Due to these limitations, other tests could have been chosen; however, the Eurofit test battery has been used for children and adolescents throughout Europe, and the tests are simple, reliable and practical in a school setting.

Overall discussion

Academic performance

Assessing academic performance is complex. For Norwegian adolescents, the national tests used to measure academic performance are the only standardised indicator of learning results until their final exams. The Norwegian Directorate for Education and Training is responsible for the development and execution of the tests, in addition to aggregating the data (Hovdhaugen et al., 2017). Hence, unlike with the other assessment methods included in the ScIM study, the research group was not involved in any part of the academic performance data assessment, except for asking the schools to organise the testing of the adolescents.

The testing is done in September and October each year for all 5th, 8th and 9th graders; thus, the Norwegian Directorate for Education and Training had to develop a unique test for the follow-up in May when our participants were close to finishing the 9th grade. Because the test is presented on a t-score, detecting changes between baseline and follow-up can be challenging. To overcome this challenge, the tests to assess the academic performance included questions that are repeated every year, which made the mean of one test comparable to the mean of the others (Hovdhaugen et al., 2017). Consequently, the change in academic performance, as seen in both the PAL and DWBH intervention, was attributed to the intervention and not to coincidence related to the tests. Nevertheless, the absolute validity and reliability of the national standardized tests assessing academic performance in this thesis is unknown. Even if other studies have used corresponding measure and we consider the validity reasonable, this is a limitation. Hence the results should be interpreted accordingly.

Contextualised factors related to implementation

All implementation-related constructs were self-reported by teachers through a teacher questionnaire. This is an imprecise measure and may be subject to social desirability bias.

5.6.4 Statistical methods

We used linear mixed models, including a random intercept accounting for the cluster effect of schools, in all the papers (**Papers I–IV)**. Importantly, the linear mixed models allow for fixed and random effects, thus accounting for the hierarchical structure, as the assumptions were that characteristics within the cluster are more strongly correlated than those between clusters. A measure of the correlation of observations within clusters is ICC, which is the variance of intercept divided by total variance. Low ICC indicates low clustering. The ScIM study used a cluster RCT design, whereby clusters were randomised into interventions or control. The consequence of this was a loss in power, which had to be considered in the sample size calculation. As can be observed in the results of **Papers I** and **II,** ICC ranged between 0.01 and 0.16, depending on the outcomes, which is below the recommended ICC values of ≤ 0.20 (Koo & Li, 2016); thus, the analysis had enough power.

The mixed models used in the main analysis (**Papers I–IV)** incorporated baseline values for the outcome of interest. That is, the model incorporated values from baseline and follow-up and, in a useful sense, *adjusted* for the potential baseline differences between the groups. For example, in **Paper I,** the adolescents in the PAL intervention had lower mean physical activity levels and spent less time in MVPA than adolescents in the DWHB and control arms. Thus, the intervention potential for increased physical activity could have been higher in the PAL than the DWBH intervention for this reason. However, since we incorporated the baseline values in the linear mixed models used to analyse the intervention effects, the results were not influenced by the initial physical activity levels.

Due to a loss in follow-up on physical activity, aerobic fitness (**Paper I)** and academic performance **(Paper II)**, we performed linear mixed models, including individuals with valid data on either baseline or follow-up, thus, reducing the loss of statistical power. In **Paper II,** we performed a sensitivity analysis that followed the intention-to-treat principle. Thus, imputation of variables was performed with chained equations, with mean differences in changes with corresponding 95% CI obtained from 20 imputed datasets. This imputation method is used to produce conservative estimates of intervention effects, although no method can provide unbiased estimates of such effects. Although some of the estimates in **Paper II** were attenuated in the intention-to-treat analysis, the results are still positive.

In **Paper III**, the mediation analysis was performed according to established approaches (Lee et al., 2019; VanderWeele, 2016). However, strong assumptions have to be met when conducting mediation analyses. To demonstrate the causal pathways of the intervention effect, the intervention–outcome, intervention–mediator and mediator–outcome effects must not be confounded. Even though ScIM was a cluster RCT, and the schools were randomly assigned to one of three groups, we cannot guarantee that the intervention–outcome and intervention–mediator effects are unconfounded. Importantly, the students were not randomised to receive or not receive the mediator; thus, the mediator–outcome effects may still be confounded. Potential confounders not measured in the study include pubertal development and cognition. In addition, we cannot exclude the possibility of random measurement error affecting our results.

5.6.5 Internal validity

Internal validity refers to the extent to which a study establishes a reliable cause–effect relationship between treatment and outcome, and how free such conclusions are from confounding issues. In this thesis, study design, confounding, exposure and outcomes influence the internal validity. Most sources of bias that affect the internal validity of cluster RCTs can be classified into selection bias, attrition bias and other biases.

Selection bias

Selection bias occurs when there are systematic differences between groups (Henderson & Page, 2007). Unlike cross-sectional and cohort studies, where selection biases can occur due to the procedures used to select the study sample (e.g., eligibility criteria) and factors influencing study participants, the randomisation of schools into control and interventions in ScIM ensured that characteristics that might have affected the relationship between intervention and outcome measures were equal between the groups. Nevertheless, selection bias can occur in RCTs, which raises the question of whether the mean differences in changes between groups is solely attributable to the intervention (Henderson & Page, 2007). Consequently, it is important to assess whether randomisation was properly done by statistically comparing the groups at baseline. In ScIM, there were some baseline differences in height, weight and physical activity between groups. However, since the effect analysis in all the papers included the baseline values of the outcomes, it could be argued that the study effects can be attributed to the intervention and not selection bias.

Overall discussion

Attrition

A common scenario in all studies with multiple measurement points is loss to follow-up. The loss to follow-up might reduce statistical power in the analysis and, consequently, increase the probability of a type 2 error. In ScIM, we observed loss to follow-up on all outcome measures of interest. In addition, one school in the DWBH intervention group withdrew from the study halfway through due to practical reasons. It was decided that an analysis of all participants with valid data at either timepoint would serve as the primary analysis (Shrier et al., 2014). Another approach would have been to analyse data based on the intention-to-treat principle. The latter was done as sensitivity analysis in **paper II**, and the results of the imputation analysis showed that some estimates had been attenuated and were no longer statistically significant. However, since most estimates were statistically significant and only slightly attenuated; this suggests that loss to follow-up was not a source of bias that would affect the main interpretation of the study results.

Other bias

Publication bias occurs when authors do not report findings that support the null hypothesis because such studies are less likely to be published. Efforts to address this include publishing RCT protocols that include all the measured outcomes. This means that readers can be sure that the authors are reporting null results and even unfavourable findings. For example, in **Papers I** and **II**, we published findings on the DWBH intervention where SED had increased, and aerobic fitness decreased compared with controls.

Finally, if adherence to the study protocol is low, it might introduce bias as it creates a potential limitation on determining whether the results are due to true (lack of) effects or whether differences between intervention and controls wee large enough. In ScIM, adherence to study protocol was 83% for the PAL and 78% for the DWBH interventions. These figures are somewhat higher than figures reported in other studies, suggesting that the observed results, whether significant or not, can be attributed to the interventions.

5.6.6 External validity

External validity refers to how well the outcome of a study can be applied in other settings or samples, and this is affected by selection bias and generalisability. The inclusion criteria used in ScIM excluded special and designated schools as well as schools with fewer than 25 adolescents in the 9th grade from participation in the study. Another inclusion criterion was that schools should not work systematically with increased physical activity, as this could hamper the implementation and eliminate the differences between the interventions and controls.

Schools participating in ScIM were recruited by four collaborating study partners from different geographical areas. Of the 103 schools invited to participate, 30 assented. Regarding participants, a total of 2,084 (76%) of the eligible 2,733 adolescents were willing to participate and underwent baseline testing. This represents an acceptably high participation rate. Even though we included a sufficient number of schools and adolescents in accordance with the power calculation, we cannot exclude the possibility that schools that were already enthusiastic about physical activity chose to participate, whilst schools that might have benefited most from the intervention were likely to choose not to. Because of this, we cannot guarantee that the cohort is repressive of the original population of interest. However, due to the inclusion criteria, it is reasonable to assume that the cohort included in ScIM is representative of the original population of interest, and that the results can be generalised to Norwegian adolescents.

5.6.7 Ethical considerations

The ScIM study required that schools add 120 minutes of additional physical activity into their curriculum by reallocating 5% (i.e., 60 min) of the time allocated to ordinary subjects to physical activity and adding another 60 minutes to the timetable. Since schools and teachers already have busy schedules, it was, for ethical reasons, crucial to consider the practical implications of the intervention (Henschel, Rothenberger, & Boos, 2010). Interventions such as ScIM should only be implemented into school curricula if they improve aspects that benefit students, teachers or schools.

First, the PAL intervention affected adolescents' physical activity levels and aerobic fitness positively, which is relevant for future health. Second, both the PAL and DWBH interventions increased academic performance in reading and numeracy. Thus, participation in the intervention supported the main purpose of schools, namely improving academic performance. Furthermore, this increased ability to cope with academic tasks might stimulate adolescents to complete lower secondary school. Consequently, the allocation of time to PE and subjects including physical activity is ethically defensible.

5.7 General strengths and limitations

General strengths

This is the first large-scale cluster RCT including two separate physical activity interventions among Norwegian adolescents. In addition to the cluster RCT design, the use of accelerometers to assess physical activity and the large sample size of approximately 76% of the possible study population are the study's main strengths. The large cohort reduced the risk of sampling bias, the cluster RCT design was accounted for in the analyses, and accelerometers are considered to be optimal for assessing the amount and intensity of physical activity levels. Another strength is the pilot study conducted during the 2016–2017 school year in seven lower secondary schools to evaluate the two interventions. The feedback from the schools and teachers in this pilot study led to some adjustments in both intervention arms, which increased the feasibility of the interventions. Furthermore, the intervention was implemented by teachers or by the students themselves, which is a sustainable approach, as suggested by the high dose delivered: approximately 80%, on average, during the entire intervention period. This high dose delivered indicates that the intervention models worked well in real-life contexts and that the simplicity of both interventions would likely make it possible to adopt and implement them in other lower secondary schools in Norway.

General Limitations

A general limitation is that we performed the randomisation before the baseline measurements, which might cause the group allocation to affect performances. However, the limited time before the intervention start prevented us from obtaining the baseline measurements before randomisation. The reason for this was that the components in the ScIM interventions were mandatorily incorporated into the curriculum and timetables, and the schools needed time to plan and organise this. A limitation in **Paper I** is the loss of students' physical activity data, because fewer than half of students who initially consented to participate provided accelerometer data at follow-up. However, similar losses to follow-up have also been reported in other studies (Dewar et al., 2013; Sutherland et al., 2016). Furthermore, for school days, we defined a valid day of accelerometer wear time to be at least 40% of accelerometer data during school hours. This might seem low; however, few school-based interventions studies have used individual timetables for each school to create classifications, and the basis for comparison is minimal. Therefore, we used approximately the same wear time criteria as for a full day, where a valid day was defined as at least 8 h, which corresponds to 44% of awake time (6 am to midnight).

We did not include measurements of cognition or biological pathways in **Paper II**. Such methods could provide knowledge on how physical activity influences academic performance. Although several studies have used national tests to measure academic performance, this may be a limitation because there have been no validation studies for the academic performance tests.

Among others, the limitations in **Paper III** include the possibility of random measurement error affecting the results. For example, although the Andersen test is valid to measure aerobic fitness in this age group, students were meant to run to voluntary exhaustion, and whether the students worked hard enough to achieve a valid test was subjectively judged by trained test personnel. A more sensitive measure would probably been direct measures of $VO2_{peak}$, but such measurements require more resources and might not have been feasible.

Paper IV is limited by the cross-sectional study design. Exposure and outcomes were measured within the same timeframe, precluding causality. Furthermore, a limitation of the study was the method used to assess teacher-reported implementation contextual factors. It would have been beneficial to use a more comprehensive process evaluation with a mixed-methods approach (Jong et al., 2020). The survey data was collected before the intervention but after the schools had integrated the components into their timetables. Hence, schools and teachers had arranged for additional resources to comply with the study protocol. Furthermore, because the distribution of the questionnaire was managed by appointed classroom teachers, we lacked information on how many eligible teachers received the questionnaire. Thus, selection bias might have occurred, and it is possible that only the most interested, engaged and outspoken teachers responded. Furthermore, the dependent variables, namely, "implementation contextual factors", relied on teacher self-reports, an imprecise measure that may be subject to social desirability bias. Moreover, fidelity was not systematically measured throughout the intervention period. Therefore, the research team lacked knowledge of whether the intervention models had been implemented as intended. Finally, the study used the CFIR (Damschroder et al., 2009) as a framework to evaluate the implementations; however, other unmeasured contextual factors might also be important to explain the implementation.

5.8 Implications of the findings

The findings presented in this thesis have multiple practical implications for various public health stakeholders. Given the rising prevalence of adolescent obesity, public health authorities should focus on promoting healthy behaviours (van Sluijs et al., 2021). With several national governments and international organisations promoting physical activity in children and adolescents, the findings of this thesis provide a strategy to increase physical activity and aerobic fitness and, thus, should be applicable for policy makers.

In **paper I**, the differences in effects by the PAL and DWBH intervention suggest that more work should be done to how physical activity are implemented into the curriculum. While, additional research is needed to establish best practice for implementing curricula physical activity, our analysis revealed that the PAL intervention resulted in a favourable mean difference in change in physical activity levels when compared with controls, and thus deserve attention moving forward. More specifically, the PAL intervention favourably affected MVPA, with 4.7 min/day compared with the control group. At first glance, this mean difference in change seems small. However, on a population level, estimates from the national survey on physical activity suggest that an increase of 2–3 min/day (14–21 min/week) in MVPA on average is enough to achieve the WHO's goal of a 10% reduction in physical inactivity by 2025 (Steene-Johannessen et al., 2021). Thus, the ScIM results are timely and provides a strategy to increase physical activity levels among adolescents.

Furthermore, **in paper II,** the demonstration of the intervention effects on numeracy and reading is of direct policy relevance for schools, educators, teachers and parents given the widespread focus of increasing children and adolescents academic performance. The findings are important because they show that schools can implement more physical activity into their curriculum whilst improving the students' academic standards. Moreover, the findings in **paper I** documenting increased aerobic fitness in the PAL intervention**,** and how aerobic fitness mediated the intervention effect on academic performance in **paper III,** is encouraging from a public health perspective. Low aerobic fitness in adolescence is associated with increased risk of type 2 diabetes and cardiovascular disease in adulthood (Crump, Sundquist, Winkleby, & Sundquist, 2017; Henriksson et al., 2019). Hence, our findings provide a solution to the escalating trend of lower physical fitness levels of children and adolescents (Tomkinson et al., 2019).

Finally, the findings in **paper IV** recommend that we continue to develop and evaluate school-based physical activity interventions, however, with even more focus on the assessment measures and how to increase intervention fidelity.

5.9 Recommendations for future research

Future research should focus primarily on the most important challenge, namely, developing more effective and sustainable interventions that increases physical activity levels among adolescents. To do so, interventions should include teachers and adolescents and involve them in the developmental phase of the intervention. This is likely to introduce unconventional intervention strategies that can be combined with the ones already known. For example, the rapid digital evolution has an extensive reach and should be utilized by involving mobiles, apps and the internet in the teachers and adolescents' premise to engage in physical activity behaviours (Shin, Kim, & Lee, 2019).

The PAL intervention, despite being at the lower end of the exposure spectrum compared with other cluster RCTs, was still successful in increasing physical activity levels. Therefore, future research that investigates what determines "the ideal exposure" together with what determines a clinically meaningful change in physical activity and aerobic fitness should provide essential knowledge. Thereafter, the meaningfulness of the changes in physical activity and aerobic fitness needs to be determined in the context of their potential impact on cardiovascular health and academic performance. This could be done in future studies by including measures for risk factors for cardiovascular disease (e.g., blood pressure, waist circumference, triglycerides and cholesterol), and measures of executive function, brain imaging and academic performance. Future research should also aim to understand in more detail the mechanisms through which physical activity can influence academic performance. Studies that include measurements of cognition, biomarkers such as BDNF and other variables (e.g. MRI and structural image analysis for the brain morphology) with the aim of increasing our knowledge on specific mechanisms will close this knowledge gap.

There is a need for more insight into the different components of physical activity incorporated into the curriculum and their individual effects on physical activity, physical fitness and academic performance. In our study, we cannot disentangle the effects of each component; thus, we do not know whether it was one specific component or a combination of all components that led to the result. Experiments designed to explore the effects of single components will increase our knowledge of which components are effective or ineffective and provide important knowledge for future interventions and practice. Mixed methods evaluation is necessary to enable the design of an optimal physical activity intervention. Comprehensive process evaluation can provide detailed information about how the intervention is delivered, with the aim of contextualising and interpreting the findings, which will also provide greater insight into how the findings can be applied in other contexts or with other populations. This information is necessary to be able to design and develop effective interventions in the future.

6.0 Conclusion

In the ScIM study, we found differential intervention effects on physical activity, aerobic fitness and muscle strength in the PAL and DWBH intervention. The PAL intervention resulted in favourable mean difference in change in adolescents' physical activity levels, time spent in MVPA and increased aerobic fitness compared with controls. Similar effects were not found among adolescents in the DWBH intervention, and neither intervention increased muscle strength. Thus, our results indicate that the PAL intervention is effective in curbing the decline in physical activity and aerobic fitness observed among adolescents.

We found significant intervention effects on academic performance, and numeracy and reading performance increased among adolescents with both interventions when compared with controls. Despite small estimates and the fact that some were attenuated and no longer statistically significant in the intention-to-treat analysis, our results are still positive and suggest that school-based physical activity interventions are viable models to improve academic performance among Norwegian adolescents. Furthermore, as aerobic fitness mediated the intervention effect on academic performance in the PAL intervention but not in the DWBH intervention, physical activity of an intensity that increases aerobic fitness is one strategy to improve academic performance among adolescents.

Finally, neither of the teacher-reported contextual factors were associated with the intervention dose delivered, although the homogeneity of the responses may limit the possibility of identifying associations. Hence, adapting for a positive culture in schools and among teachers early in the intervention whilst providing sufficient resources and teacher training may be relevant to dose delivered.

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Paper I-IV

Papers I-IV

Paper I

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The effect of a school-based intervention on physical activity, cardiorespiratory fitness and muscle strength: the School in Motion cluster randomized trial

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Abstract

Background: Physical activity (PA) declines throughout adolescence, therefore PA promotion during this period is important. We analyzed the effect of two school-based PA interventions on daily PA levels, cardiorespiratory fitness (CRF) and muscle strength among adolescents.

Methods: For the nine-month School in Motion intervention study (ScIM), we cluster-randomized 30 Norwegian secondary schools (*N* = 2084, mean age [SD] = 14 [0.3] years) to one of three study arms. The physically active learning (PAL) intervention included 30 min physically active learning, 30 min PA and a 60 min physical education (PE) lesson per week. The Don't worry-Be happy (DWBH) intervention included a 60 min PA lesson and a 60 min PE lesson per week, both tailored to promote friendships and wellbeing. Both intervention arms were designed to engage the adolescents in 120 min of PA per week in addition to recess and mandatory PE lessons. The control group continued as per usual, including the standard amount of mandatory PE. PA (main outcome) was assessed by accelerometers, CRF and muscle strength (secondary outcomes) were assessed by an intermittent running test and selected tests from the Eurofit test battery.

Results: Daily PA and time spent in moderate- to vigorous-intensity PA (MVPA) decreased in all groups throughout the intervention. The mean difference in PA level and MVPA for participants in the PAL-intervention arm was 34.7 cpm (95% CI: 4.1, 65.3) and 4.7 min/day (95% CI: 0.6, 8.8) higher, respectively, compared to the control arm. There were no significant intervention effects on daily PA level, MVPA or time spent sedentary for adolescents in the DWBH-intervention arm. Adolescents in the PAL-intervention arm increased distance covered in the running test compared to controls (19.8 m, 95% CI: 10.4, 29.1), whilst a negative intervention effect was observed among adolescents in the DWBH-intervention arm (− 11.6 m, 95% CI: − 22.0, − 1.1).

Conclusion: The PAL-intervention resulted in a significantly smaller decrease in daily PA level, time spent in MVPA, and increased CRF compared to controls. Our results indicate that a teacher-led intervention, including three unique intervention components, is effective in curbing the decline in PA observed across our cohort and improving CRF.

Trial registration: ClinicalTrials.gov ID nr: NCT03817047. Registered 01/25/2019 'retrospectively registered'.

Keywords: Physical activity, Fitness, Adolescents, Randomized controlled trial

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Introduction

Throughout adolescence, physical activity (PA) levels are known to decline corresponding with an increase in time spent sedentary [1, 2]. Accelerometer-assessed PA data from a national cohort in Norway showed that 50% of 15-year-olds met the recommended level of 60 min of moderate- to vigorous-intensity PA (MVPA) per day [3]. At the same time, the adolescents spent approximately 70% of their awake time sedentary, and were thereby more sedentary than the retired population [4]. This is of concern as participation in regular MVPA during adolescence is associated with improved physiological and psychological health [5]. Strong inverse associations have also been reported between cardiorespiratory fitness (CRF) and clustering of cardiovascular risk factors in children and youth [6], and lower physical fitness is detrimentally associated with obesity in childhood [7]. Further, positive associations have been reported between both PA, CRF and academic performance [8, 9]. PA levels during childhood have also been found to predict PA levels in adulthood, which support the idea that enhancement of PA in children and adolescents is of importance for the promotion of public health [10, 11]. Hence, there is a need to develop and evaluate interventions focusing on PA and fitness in the young population.

Comprehensive school-based PA interventions have been endorsed by both health and education authorities as a strategy for promoting PA [12, 13], yet the effects these interventions have on young people's PA and fitness levels are uncertain. In a recently published meta-analysis, it was concluded that current school-based efforts do not positively impact young people's accelerometer assessed daily PA level [14]. Most school-based PA interventions are implemented among children in primary school. Fewer PA interventions have been carried out among adolescents in lower secondary schools, and the generalizability of these studies are limited, for instance only examining girls [15, 16] or boys [17], or being implemented among adolescents in a middle-income country [18] or low-income or disadvantaged communities [15, 17, 19]. Further, the intervention components vary markedly making comparisons between studies difficult.

Due to the limited evidence but great potential of school-based PA interventions, we conducted a cluster randomized trial titled School in Motion (ScIM), which included two PA intervention arms. Both interventions aimed at increasing PA among adolescents in lower secondary schools receiving two additional hours of PA per week compared to a non-intervention control arm. The primary aim of this paper was to assess the effectiveness of these interventions on adolescents' daily mean PA levels (main outcome). The secondary aims were to assess the effect of the interventions on PA levels during school hours, CRF and muscle strength.

Methods

Study design

ScIM was a multicenter, school-based, three-arm cluster randomized controlled trial (RCT) recruiting ninth graders from lower secondary schools. The study was conducted by four collaborating study partners with a geographical spread across Norway (Norwegian School of Sport Sciences, Western Norway University of Applied Sciences, University of Agder, and University of Stavanger). A random sample of lower secondary schools located in municipalities near the four study partners were included. We excluded private schools, designated special schools, schools with less than 25 adolescents in ninth grade, and schools that worked systematically with PA as an integrated part of the school day.

Schools were randomized manually by a lottery to one of the following three study arms: the intervention arm "Physically Active Learning" (PAL) ($n = 10$), the intervention arm "Don't worry-Be happy" (DWBH) ($n = 10$) or the control arm ($n = 10$) in a 1:1:1 ratio. The randomization was stratified by district (study center) to ensure that schools from all four study locations were represented in each of the three study arms. The data-manager who conducted the randomization did not participate in any other aspects of the study. The randomization process took place after inclusion but prior to baseline testing. Neither participants, schools nor researchers were blinded.

The project was reviewed by the Regional Committee for Medical and Health Research Ethics (REK) in Norway, who according to the Act on medical and health research (the Health Research Act 2008) concluded that the study did not require full review by REK. The study was approved by the Norwegian Centre for Research Data. The design, conduct, and reporting of this trial adhere to the CONSORT statement. The CONSORT checklist can be found in Additional file 1 [20], and the TIDieR checklist can be found in Additional file 2.

Interventions

The ScIM intervention arms were designed to engage the adolescents in 120 min of PA per week in addition to their mandatory physical education (PE) lessons (approximately 120–180 min per week) and recess periods. Schools in the two intervention arms added 60 min of PA and 60 min of PE to the class schedule per week. This was achieved by redistributing 5 % of lesson time to PA from other subjects in the curriculum (corresponding to 60 min of PA per week), while the other 60 min were added to the weekly lesson schedule. Thus, for students in the intervention schools, the school week increased by 60 min. All intervention schools received financial resources from The Norwegian Directorate for Education and Training to account for increased expenses. The amount received was based on the number of students attending the school (approximately $90 per student). For all ninth-grade students attending an intervention school, participation in the intervention components was mandatory. The interventions were delivered from September 2017 to June 2018.

The PAL-intervention included three components: 1) An additional lesson of PE per week (60 min), including activities according to the curriculum, planned and taught by a PE teacher. The PE teacher used these lessons to grade the students; 2) a 30 min/week lesson of physically active learning where play-based activities were integrated into other curriculum subjects (i.e. math, English, Norwegian). The aim was to increase PA levels among students while improving their academic performance. The classroom teacher for the subject planned and taught the lesson; and 3) a 30 min/week lesson of PA that included a variety of activities, preferably of at least moderate intensity, and it should be enjoyable. A classroom teacher or a PE teacher planned and taught this lesson. In the PAL-intervention, the 60 min PE lessons included time for teachers to organize activities and for the adolescents to change clothes and shower.

The DWBH-intervention arm included two components; a "Be happy" lesson and a "Don't worry" lesson (each lesson was 60 min/week). At the start of the intervention, the adolescents formed groups of 3–8 students based on their hobbies. The groups could comprise students from different school classes. Examples of activities chosen were traditional sports (e.g., football or handball), lifestyle sports (e.g., parkour or BMX cycling), dancing, and outdoor recreation. The groups were expected to perform the chosen activity in the "Be happy" lesson throughout the intervention period. In the "Don't worry" lesson, the students returned to their normal classes and either continued or introduced their class peers to their "Be happy" activity. If the students had been doing group activities in the "Don't worry" lesson, such as handball or football, they instead practiced relevant skills in the "Don't worry" lesson. For example, throw technique, endurance and/or strength training for a handball player. Consequently, for the "Don't worry" lesson the gym would be full of students performing different activities. The "Don't worry" lesson was conducted as an ordinary PE lesson such that the standard PE curriculum was applied, and the PE teacher used these lessons to grade the students. "Be happy" lessons were mandatory though not graded. In DWBH, both intervention components were planned and led by the students while the teacher(s) was (were) present for support if needed. Depending on the chosen activity, both intervention components included time for the students to organize the activities, change clothes and shower.

Theory

When planning and developing the interventions, we applied the socio-ecological framework modelled by McLeroy [21]. In order to change behavior, we can approach the individual at different levels: some structures are close to the individual (e.g., individual preferences and social relationships with family and friends), and some structures are more distal, such as community infrastructure and legislation. These factors are all potential domains for effecting behavior change, and positive changes in facilitators on all levels will in theory promote actual behavior change. In the interventions we targeted all levels, though we could influence some levels more than others: individual; (promote motivation for PA through mastery and enjoyment of the activities); interpersonal (promote PA among friends); organizational (promotion of PA through the school as a structure, however we made no physical changes of the school yard to promote PA due to lack of budget); community level (no specific intervention); public policy (adding extra PE in the government set school curriculum). Hence, changes at all levels can promote positive and lasting change in health behavior. In terms of individual and social factors, the PAL-intervention builds on Harter's competence motivation theory [22], Bandura's social-cognitive theory [23] and Ryan & Deci's self-determination theory [24]. The rationale is thought to function as a mediating structure between intervention strategies and outcomes.

The DWBH-intervention arm was anchored to an integrative relational developmental systems (RDS) approach to human development [25], theories on Positive Youth Development (PYD) [26] and the concept of Positive Movement Experiences (PME) [27]. By letting the adolescents choose their own activity, the intention was for them to engage in an activity that was meaningful for them with friends. According to the theories on PYD all youths have strengths. Therefore, in the DWBH-intervention arm the adolescents were responsible for conducting the intervention. They had to form activity groups, determine group aims for the activities, develop a management structure, a strategy for impending conflicts and routines to register attendance.

The schools in the control arm continued current practice including the usual amount of mandatory PE that was part of the curriculum.

Delivery

Each week teachers in the intervention schools documented the extent to which the intervention dose was delivered as intended using an online form. They reported if the intervention component was delivered, as well as the intensity and the duration of the activity. The intensity was judged subjectively by the teacher who delivered the component. The information from this subjective assessment of intensity is on a group level and is therefore limited as it cannot be used when analyzing the results. However, it provided an indication of the general intensity of the activities.

Assessment and measures

All participants were tested using an identical set of outcome measures at baseline and follow-up. Baseline measurements (both accelerometers and physical fitness tests) were done in April to June 2017 while students were in eighth grade. The follow-up measures were taken approximately 12 months after the baseline measures, while the participants were in the last phase of the intervention. A team of researchers visited each school in the study and collected all data while the participants were at school. All research personnel were thoroughly trained prior to the data collection by members of the research team.

Physical activity level (primary outcome)

PA was assessed by triaxial accelerometry (ActiGraph GT3X+, LLC, Pensacola, Florida, USA). The adolescents were instructed to wear the accelerometer on the right hip during all waking hours (except during swimming/bathing) for seven consecutive days. Accelerometers were initialized to start recording at 6.00 AM on the day after they were distributed. The epoch length was set to 10 s. We used the ActiLife software to initialize and download the accelerometer files (version 6.13, ActiGraph, LLC, Pensacola, Florida, USA). All raw accelerometer files were processed and analyzed using specifically developed and commercially available software (StataCorp. 2015. Stata Statistical Software: Release 15. College Station, TX: StataCorp LP). A variable for "school hours" was created by matching the timetable provided by each individual school with the accelerometer file. A valid day was defined as wear time of ≥480 min/day accumulated between 06:00 and 24:00, whereas a valid school day was defined as wear time of ≥40% of school hours. Non-wear time was defined as at least 20 consecutive minutes of zero counts [28]. Participants with at least 2 of 7 valid days and at least 2 of 5 valid school days of activity recordings were included in the analysis on daily PA and school day, respectively. The outcome variables were daily mean activity counts per minute (cpm), as well as time spent sedentary and in MVPA. We defined sedentary time as all activity below 100 cpm, and MVPA as all activity > 2000 cpm. The latter cut-point was developed for the European Youth Heart Study and is equivalent to a walking speed of adolescents of > 4 km/h [2]. Time spent in MVPA or being sedentary was determined by summing total minutes, where the count met the criterion for that intensity divided by the number of valid days of recording, giving an average (min/day) across the assessment period.

Cardiorespiratory fitness (secondary outcome)

We used the Andersen test to assess the participants' CRF [29]. The Andersen test is an intermittent running field test lasting for 10 min. The reproducibility of the Andersen test is considered good ($r = 0.84$), and the association between running distance in the Andersen test and VO_2max measured on the treadmill have shown a correlation coefficient of 0.60 among 14-year-old elite football players [29]. We administered the Andersen test as per standard procedures indoors on a wooden or rubber floor, however, due to different sizes of available indoor facilities we standardized the length to 16 m (original protocol 20 m). All adolescents were tested in groups of 6–12 individuals. The test required the participants to run back and forth between two lines 16 m apart for a total of 10 min, with 15 s work periods and 15 s breaks standing still. Each time the adolescents turned around at the end line, they had to touch the floor with one hand. The aim of the test was to cover the longest possible distance during the 10-min run, and the participants were meant to run to voluntary exhaustion. Adult test assistants, who subjectively judged whether the child completed a valid test (judging whether the students worked hard enough), recorded the distance covered. The distance covered (in meters) was used as a proxy for cardiorespiratory fitness.

Muscle strength (secondary outcome)

Muscle strength (i.e., endurance, isometric and explosive strength) was measured using reliable and validated tests selected from the Eurofit test battery [30]: 1) Upper limb strength – handgrip strength was measured using a handheld dynamometer (Baseline® Hydraulic Hand Dynamometer, Elmsford, NY, USA) (measured in kg, best of result of two attempts was used); 2) Explosive strength in the lower body was measured using a standing broad jump test (measured in cm, the best result of two attempts was used); and 3) Abdominal muscle endurance was tested using a sit-up test (number of correctly performed sit-ups within 30 s).

Height and weight

The adolescents wore light clothing with footwear removed. Weight was measured to the nearest 0.1 kg with a digital scale (Seca 889, SECA GmbH, Hamburg, Germany). We subtracted 0.6 kg (light clothing) or 1.5 kg (more heavy clothing) from each person's weight to account for clothing. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, SECA GmbH, Hamburg, Germany) with the individual standing upright facing forward. Body mass index (BMI) was calculated as weight (kg) divided by the height squared (m^2).

Socioeconomic status

We used the highest education level of each participant's parents (whichever was the higher) as a proxy for socioeconomic status (SES). Data regarding parent's education level came from registry data collected by Statistics Norway. Four SES groups were computed: low (primary school, lower secondary school, vocational high school), middle (secondary school/high school), middle high (undergraduate degree) and high (graduate degree).

Sample size calculation

Power calculations were conducted to determine the required sample size for detecting changes in the primary outcome (daily mean PA level [cpm]). The ScIM study was designed to detect a difference in mean PA level of 7 % (49 cpm) between the participants in the intervention arms and the control arm. We assumed a standard deviation (SD) of 150 cpm, a power of 90%, a significance level of 0.05, which lead to 492 individuals in each group. To allow for 20% loss to follow-up we needed 590 individuals in each group. We required a minimum of ten clusters per study arm and consequently we aimed to recruit clusters and individuals until we had at least ten clusters and 590 individuals in each arm.

Statistical analyses

Participants with valid data on PA, CRF or muscle strength at either baseline or follow-up were included in the analysis. To examine whether missing data were missing at random, or completely at random, we conducted the missing at random including covariates test in Stata (mcartest) with main outcome (cpm) and intervention model, with gender, height and weight as covariates (in order to test for covariate-dependent missing). The test supports the missing at random assumption ($p = 0.096$), although the evidence against missing at random is not very strong. Analyses were assessed for assumptions of normality and homogeneity of variance. Descriptive data are presented as means and SDs. Baseline differences between participants in the three study arms were investigated using linear regressions adjusted for gender. We fitted linear mixed models to all continuous outcomes with repeated measurements. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction. As the units of randomization were schools, we added random effects for school, class and subject ID to accommodate the clustering of participants within these units. Based on the linear mixed models, we estimated mean group values with 95% CI at baseline and follow-up. We estimated the between group difference in change from baseline to follow-up between the participants in the intervention arms and the control arm, with adjustment for gender. A value of $p < 0.05$ was considered statistically significant. We examined whether gender modified the intervention effect by introducing an interaction term (timepoint x group x gender). Statistically significant interactions between genders were evident in all PA, CRF and muscle strength models ($p \leq 0.003$ for all interactions), consequently we repeated the analyses stratified by gender. Data were analyzed using Stata (StataCorp. 2015. Stata Statistical Software: Release 15.1. College Station, TX: StataCorp LP).

Results

Thirty out of 103 invited lower secondary schools agreed to participate (Fig. 1). One of the included schools in the control arm withdrew from the study after the randomization procedure but prior to baseline testing, leaving nine schools in the control arm. A total of 2084 adolescents (intervention arms: $n = 1266$), which represented 76% of those eligible, provided parental consent, and completed baseline testing. Three months into the intervention period, one school in the DWBH-intervention arm withdrew from the study due to practical reasons. A total of 1579 of the included participants had valid PA assessments at baseline and/or follow-up and were included in the analyses for the primary outcome. For the secondary outcomes a total of 1873 participants had valid CRF assessments and 1976–1992 participants had valid muscle strength assessments at baseline and/or follow-up (handgrip: $n = 1992$; standing broad jump: $n = 1976$; sit-ups: $n = 1977$). Participants included in the analyses were comparable to those excluded in terms of all variables of interest (data not shown).

Baseline characteristics of the participants who were assessed are outlined in Table 1. Students in the PAL-intervention arm were on average 1.1 cm shorter ($p = 0.005$), and students in the DWBH-intervention arm were on average 1.8 kg heavier ($p = 0.003$) compared to students in the control arm. Table 2 shows the participants' PA levels at baseline. Both during the full day and during school hours students in the PAL-intervention had a significantly lower mean PA level, spent more time sedentary and less time in MVPA than students in the control arm ($p \leq 0.002$). Further, students in both intervention arms had significantly lower CRF and completed fewer sit-ups within 30 s at baseline than their peers in the control arm ($p \leq 0.001$) (Table 3). For the standing broad jump test, students in control group jumped 4 cm longer than the students in the PAL-intervention ($p = 0.003$).

During the intervention period, 83 and 78% of the intervention dose was delivered in the PAL-arm and the DWBH-arm, respectively. This means that the schools in the PAL-intervention arm delivered an average of 100 min/week of additional PA lessons, whereas the schools in the DWBH-intervention arm delivered an average of 94 min/week of additional PA lessons.

Primary outcome - physical activity level

Daily PA

We found significant between group differences in daily PA level and time spent in MVPA for adolescents in the PAL-intervention arm compared to adolescents in the control arm. The mean difference in change in PA level

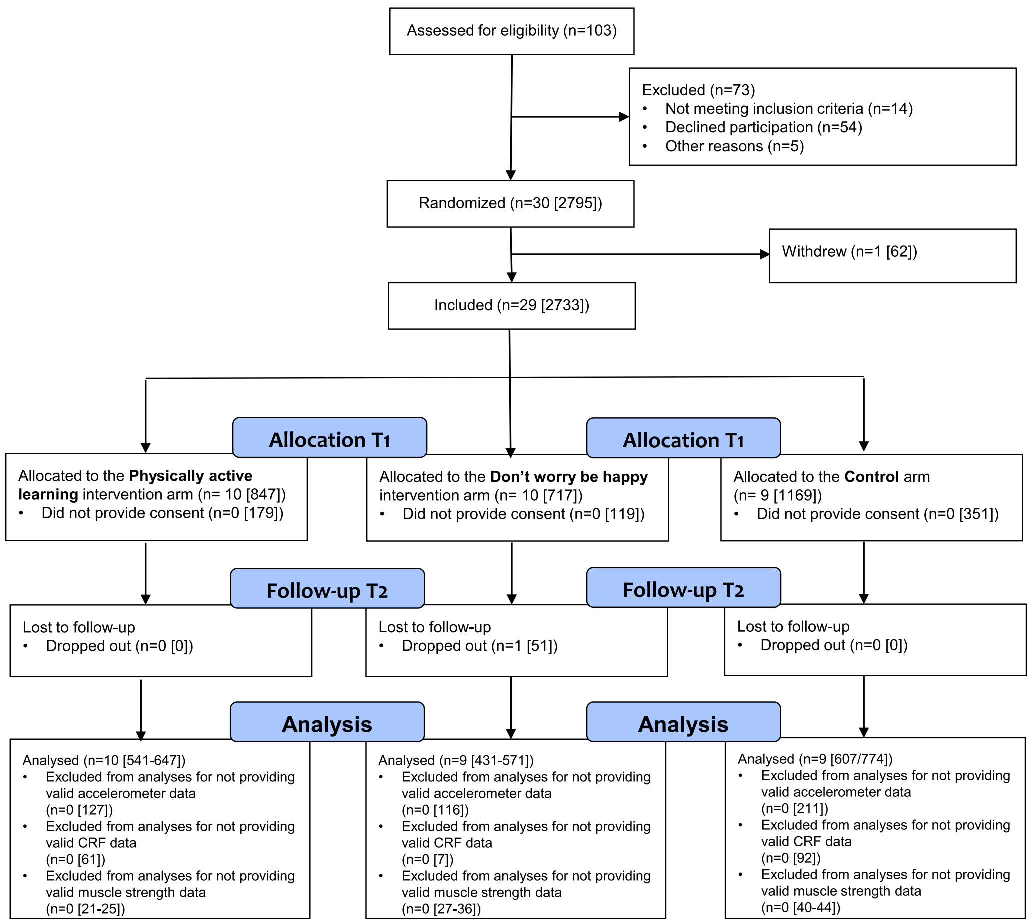

Fig. 1 Flow of schools and participants through the study. All numbers are schools [participants]. T1 = baseline; T2 = follow-up

between participants in the PAL-intervention arm and the control arm was 34.7 cpm (95% CI: 4.1, 65.3) (Fig. 2). We observed a reduction in mean PA level during the intervention period among adolescents in both the intervention arms and control arm, however, the reduction was larger among controls (a reduction of 13 and 48 cpm, respectively). The mean difference in change in MVPA between participants in the PAL-intervention arm and the control arm was 4.7 min/day (95% CI: 0.6, 8.8). During the intervention period, time spent in MVPA decreased by 2.0 min/day for adolescents in the PAL-intervention, and by 6.7 min/day among adolescents in the control arm (Table 2 and Fig. 2). When the analyses were repeated stratified by gender, the intervention effect on both total PA level and time spent in MVPA was attenuated and no longer reached statistical significance (Table 4 and Additional file 3).

We found no significant effect of the intervention on daily PA level, time spent in MVPA or sedentary time among adolescents in the DWBH-intervention arm compared with adolescents in the control arm (Fig. 2).

PA during school hours

During school hours, we found significant between group differences in PA level, MVPA and sedentary time among adolescents in the PAL-intervention arm compared to adolescents in the control arm (Fig. 2). The mean difference in change in PA level was 86.4 cpm (95% CI: 52.1, 120.7), 5.6 min/day of MVPA (95% CI: 3.5, 7.7) and – 4.0 min/day of sedentary time (95% CI: –

Table 1 Participant characteristics at baseline by study arm (*N* = 1981). Results are presented as mean (SD) unless otherwise stated

	PAL-group	DWBH-group	Control
N	647	577	757
Age (years)	13.9 (0.3)	14.0 (0.3)	14.0 (0.3)
Sex (% girls/boys)	50/50	49/51	49/50
Height (cm)	164.6 (8.1)	166.4 (7.7)	165.8 (7.7)
Weight (kg)	54.2 (10.8)	56.2 (11.0)	54.4 (10.5)
BMI (kg/m^2)	19.9 (3.1)	20.2 (3.2)	19.7 (3.1)
Socioeconomic status[a]			
Primary school (%)	6.5	6.5	5.0
Upper Secondary school (%)	27.1	31.5	28.3
University < 4 years (%)	42.8	39.4	41.6
University > 4 years (%)	23.6	22.5	25.1

PAL Physically active learning; *DWBH* Don't Worry – Be Happy, *BMI* Body mass index
[a]Based on parental education

7.7, − 0.3). When the analyses were stratified by gender, we found similar significant effects in favor of the adolescents in the PAL-intervention arm, however, the favorable reduction in sedentary time was significant only among girls (Table 5 and Additional file 3).

When comparing adolescents in the DWBH-intervention arm with adolescents in the control arm, we found significant between group differences in sedentary time (Fig. 2). Both adolescents in the DWBH-intervention arm and in the control arm increased time spent sedentary during school hours throughout the intervention period, however, the increase was larger among adolescents in the DWBH-arm than among controls (mean difference 10.0 min/day, 95% CI: 6.0, 14.0). When we stratified the analyses by gender, we found similar significant effects on sedentary time in favor of the control arm in both girls and boys (Table 5 and Additional file 3).

Secondary outcome – CRF and muscle strength

We found significant between group differences in CRF among adolescents in both intervention arms compared with adolescents in the control arm (Fig. 3). Both adolescents in the PAL-intervention arm and in the control arm increased distance run in the Andersen test during the intervention period. The mean difference in change was 19.8 m (95% CI: 10.4, 29.1) in favor of adolescents in the PAL-intervention arm compared to adolescents in the control arm. In the stratified analyses we observed significant effects on CRF among PAL-intervention boys but not among the girls when comparing with boys and girls in the control arm (Additional file 4).

During the intervention period, we found no change in the distance run in the Andersen test for the adolescents in the DWBH-intervention arm (Table 3). When comparing the change in distance run between the adolescents the DWBH intervention arm and the control arm, we found that the mean difference in change was 11.6 m (95% CI: − 22.0, − 1.1) in favor of the control arm (Fig. 3). The stratified analyses revealed that this unfavorable effect on CRF was observed among DWBH girls only (Table 6, Additional file 4).

We found significant between group differences in handgrip strength for adolescents in the PAL-intervention arm and adolescents in the DWBH-intervention arm compared to adolescents in the control arm (Fig. 3). All groups increased handgrip strength from baseline to follow-up;

Table 2 Mean (95% confidence interval) physical activity level among participants stratified by study arm at baseline and follow-up

	PAL-intervention		DWBH-intervention		Control	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Physical activity levels full day						
N	500	317	406	229	566	288
Wear time (min/day)	776 (765, 787)	763 (751, 776)	775 (763, 787)	768 (754, 782)	770 (759, 781)	742 (729, 754)
Average PA (cpm)	510 (479, 541)	497 (464, 531)	531 (497, 565)	476 (439, 513)	537 (505, 569)	489 (455, 524)
MVPA (min/day)	67 (63, 72)	65 (60, 70)	70 (65, 75)	63 (57, 68)	71 (66, 76)	65 (60, 70)
Sedentary time (min/day)	541 (533, 548)	553 (545, 561)	534 (526, 542)	559 (550, 567)	531 (523, 538)	548 (540, 557)
Physical activity school hours						
N	536	375	427	284	583	353
Wear time (min/day)	322 (313332)	312 (303, 322)	321 (311, 331)	323 (312, 333)	314 (304, 324)	292 (282, 302)
Average PA (cpm)	444 (398, 489)	462 (415, 508)	504 (456, 553)	411 (361, 461)	501 (455, 547)	433 (385, 481)
MVPA (min/day)	25 (21, 28)	25 (22, 28)	28 (25, 32)	24 (20, 28)	29 (25, 32)	24 (20, 27)
Sedentary time (min/day)	227 (221, 232)	230 (228, 240)	217 (211, 223)	234 (228, 240)	220 (215, 225)	227 (222, 233)

PAL Physically active learning; *DWBH* Don't Worry – Be Happy, *cpm* Counts per minute; *MVPA* Moderate- to vigorous-intensity physical activity. All analyses are adjusted for gender, wear time (except cpm), school cluster, class cluster and subject ID as random effect

Table 3 Mean (95% confidence interval) for cardiorespiratory fitness and muscle strength among participants stratified by study arm at baseline and follow-up.

	PAL-intervention		**DWBH-intervention**	**Control**		
	Baseline	**Follow-up**	**Baseline**	**Follow-up**	**Baseline**	**Follow-up**
Cardiorespiratory fitness (m)	894 (869, 919)	925 (900, 950)	909 (883, 934)	909 (883, 935)	928 (903, 954)	940 (915, 966)
Handgrip (kg)	30 (28, 32)	32 (30, 34)	30 (28, 30)	32 (30, 34)	29 (27, 31)	32 (30, 34)
Standing broad jump (cm)	168 (166, 171)	176 (173, 179)	171 (169, 174)	178 (175, 181)	172 (170, 175)	179 (176, 181)
Sit, ups (n)	18.3 (17.4, 19.2)	19.6 (18.7, 20.5)	18.3 (17.4, 19.2)	18.9 (218.0, 19.9)	19.4 (18.5, 20.3)	20.1 (19.2, 21.1)

PAL Physically active learning; *DWBH* Don't Worry – Be Happy. All analyses are adjusted for gender, school cluster, class cluster and subject ID as random effect

however, the increase was larger among adolescents in the control arm compared to adolescents in both intervention arms (mean difference PAL-intervention vs control: − 1.1 kg (95% CI: − 1.7, − 0.5) and mean difference DWBH-intervention vs control: − 0.6 kg (95% CI: − 1.3, 0.0) (Table 3).

We found significant between group differences in number of sit-ups performed for adolescents in the PAL-intervention arm compared to adolescents in the control arm (Fig. 3). The mean difference in change in sit-ups was 0.5 (95% CI: 0.1, 0.9) in favor of the students in the PAL-intervention arm. The intervention effect on the muscle strength tests stratified by gender is presented in Table 6 and Additional file 4.

Discussion

This study assessed the effectiveness of two different school-based PA interventions on adolescents' PA levels, cardiorespiratory fitness and muscle strength. After the

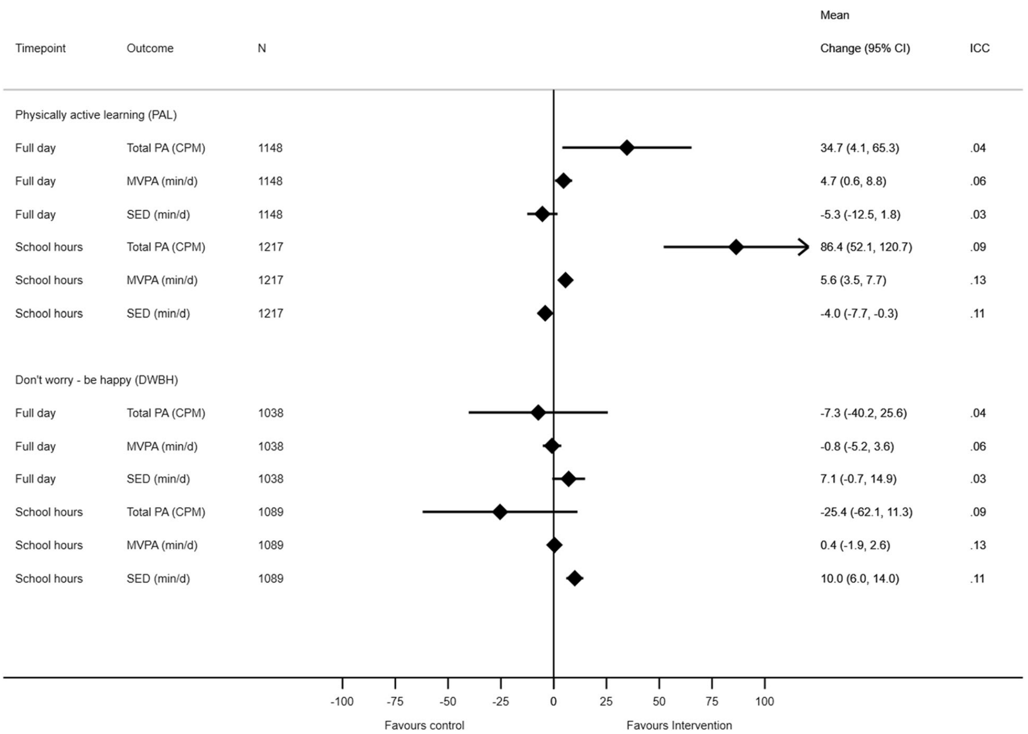

Fig. 2 The intervention effect on physical activity variables during the *full day* and during school hours stratified by study group. MVPA = moderate- to vigorous-intensity physical activity, min = minutes, cpm = counts per minute, CI = confidence interval; ICC = intraclass correlation coefficient (for school). Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID

Table 4 The intervention effect on physical activity variables during the *full day* stratified by study arm and gender. The results are presented as mean differences in change (intervention arms vs controls) with 95% CI, *P*-values and ICC for school

	n	Mean difference in change (95% CI)[a]	*P*	ICC
Girls				
PAL-intervention				
Average PA (cpm)	624	27.6 (−6.8, 62.0)	0.116	0.05
MVPA (min/day)	624	4.7 (−0.5, 9.5)	0.052	0.06
Sedentary (min/day)	624	−5.6 (− 14.0, 2.7)	0.189	0.02
DWBH-intervention				
Average PA (cpm)	559	−11.8 (−49.4, 25.7)	0.537	0.05
MVPA (min/day)	559	1.7 (−6.9, 3.4)	0.510	0.06
Sedentary (min/day)	559	8.5 (−0.6, 17.7)	0.068	0.02
Boys				
PAL-intervention				
Average PA (cpm)	524	44.0 (−11.5, 100.8)	0.119	0.03
MVPA (min/day)	524	4.0 (−3.1, 11.2)	0.268	0.05
Sedentary (min/day)	524	−3.9 (−16.5, 8.7)	0.546	0.04
DWBH-intervention				
Average PA (cpm)	479	−3.3 (−62.7, 56.1)	0.913	0.03
MVPA (min/day)	479	0.1 (−7.5, 7.7)	0.981	0.05
Sedentary (min/day)	479	5.9 (−7.4, 19.3)	0.384	0.04

PAL Physically active learning; *DWBH* Don't worry – Be happy, *PA* Physical activity, *MVPA* Moderate- to vigorous-intensity physical activity, *min* Minutes, *cpm* Counts per minute, *CI* Confidence interval, *ICC* Intraclass correlation coefficient
[a]Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID

Table 5 The intervention effect on physical activity variables during *school hours* stratified by study group and gender. The results are presented as mean differences in change (intervention arms vs controls) with 95% CI, *P*-values and ICC for school

	n	Mean difference in change (95% CI)[a]	*P*	ICC
Girls				
PAL-intervention				
Average PA (cpm)	643	92.3 (52.2, 132.5)	**< 0.001**	0.10
MVPA (min/day)	643	6.3 (3.8, 8.8)	**< 0.001**	0.13
Sedentary (min/day)	643	−7.4 (−11.9, −2.8)	**0.001**	0.08
DWBH-intervention				
Average PA (cpm)	568	−9.4 (−53–0, 34.0)	0.670	0.10
MVPA (min/day)	568	1.0 (−1.6, 3.7)	0.462	0.13
Sedentary (min/day)	568	6.7 (1.8, 11.6)	**0.007**	0.08
Boys				
PAL-intervention				
Average PA (cpm)	574	76.6 (18.8, 134)	**0.009**	0.09
MVPA (min/day)	574	5.1 (1.5, 8.6)	**0.005**	0.13
Sedentary (min/day)	574	−0.5 (−6.6, 5.6)	0.878	0.12
DWBH-intervention				
Average PA (cpm)	521	−49.9 (− 110.5, 10.5)	0.106	0.09
MVPA (min/day)	521	−0.4 (−4.1, 3.3)	0.842	0.13
Sedentary (min/day)	521	13.2 (6.7, 19.8)	**< 0.001**	0.12

PAL Physically active learning; *DWBH* Don't worry – Be happy; *PA* Physical activity; *MVPA* Moderate-to-vigorous physical activity, *min* Minutes, *cpm* Counts per minute, *CI* Confidence interval; *ICC* Intraclass correlation coefficient
[a]Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID

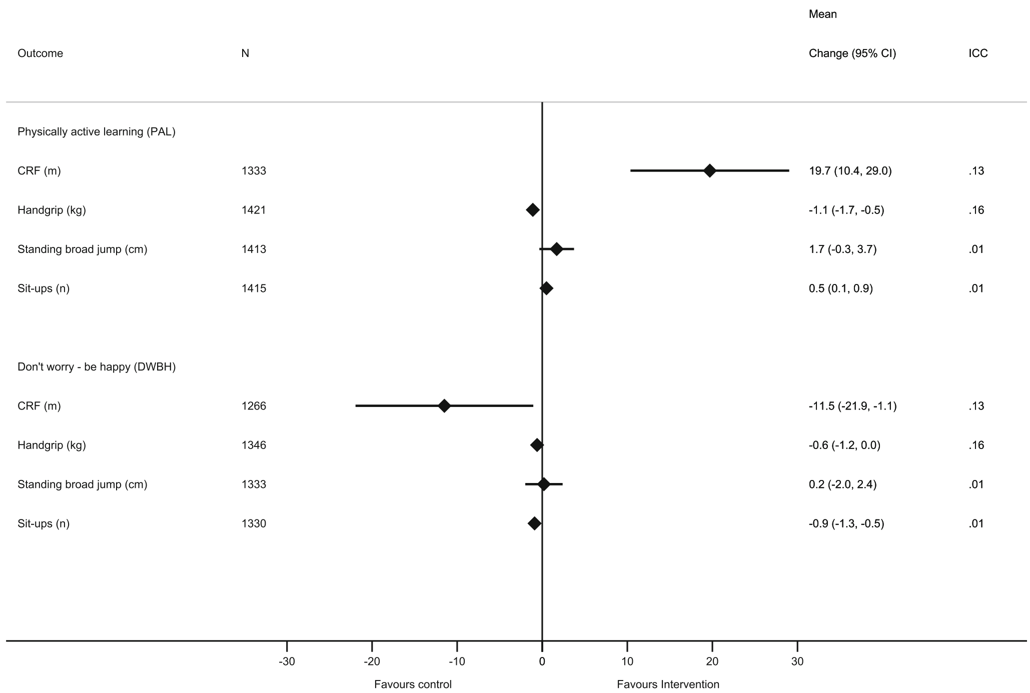

Fig. 3 The intervention effect on cardiorespiratory fitness and muscle strength stratified by study group. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID

intervention period, daily PA level and time spent in MVPA decreased in all groups, however the reduction was significantly smaller in the PAL-intervention group compared to the control group. The intervention was also effective in increasing CRF, where adolescents in the PAL-intervention arm increased significantly more than adolescents in the control arm. No intervention effects were observed on daily PA level, time spent in MVPA, or time spent sedentary among adolescents in the DWBH-intervention arm compared to adolescents in the control arm.

The PAL-intervention effect on the adolescents' daily PA level agrees with some previous studies that have used accelerometers to assess PA, though there are conflicting results within the literature. Two multicomponent, school-based obesity prevention interventions that included adolescents from low-income areas found no effect on PA level after 20 weeks [17] and 12 months interventions [15]. Further, a 20-week after-school dance program for girls [16] and a six-week intervention study [31] did not increase 11–12-year-olds PA levels. A cohort of 12–13-year-old adolescents ($n = 1440$) in Ecuador completed a 28-month intervention on PA and physical fitness [18]. In a subsample ($n = 226$) it was observed that whilst more than 90% of the cohort achieved more than 60 min of MVPA per day at baseline, the proportion decreased during the intervention period. Yet, the decrease was significantly lower in the intervention group compared to the control arm (6 vs 18 percentage points) [18]. Similar results were also reported among Australian 14-year-olds ($n = 1150$) after the completion of a 24-month school-based PA-intervention [19]. The intervention was effective in increasing daily MVPA in the intervention group compared with a decrease in the control group. Even though the results from the two latter studies have comparable findings as ours, it should be mentioned that the adolescents in these studies came from a middle-income country or disadvantaged communities and are therefore not directly comparable to the adolescents in our study. Further, both studies which reported positive results were long lasting interventions with durations of almost 2 years, including comprehensive approaches to promote an active lifestyle. Our intervention lasted 9 months and targeted the adolescents' PA levels during school hours only. We therefore speculate that had we implemented the intervention over two school years and also targeted leisure time activities in the home and neighborhood environment the intervention effect could have been stronger [32]. When stratifying the analyses by gender, the positive

Table 6 The intervention effect on cardiorespiratory fitness and muscle strength stratified by study arm and gender. The results are presented as mean differences in change (intervention arms vs controls) with 95% CI, *P*-values and ICC for school

	n	Mean difference in change (95% CI)[a]	*P*	ICC
Girls				
PAL-intervention				
Cardiorespiratory fitness (m)	656	3.2 (−10.3, 16.8)	0.643	0.16
Handgrip (kg)	698	**−1.8 (−2.5, − 1.1)**	**< 0.001**	0.24
Standing broad jump (cm)	693	**2.5 (0.1, 4.8)**	**0.036**	0.04
Sit-ups (n)	695	0.4 (−0.1, 1.0)	0.071	0.01
DWBH-intervention				
Cardiorespiratory fitness (m)	612	−24.6 (−39.8, −9.3)	**0.002**	0.16
Handgrip (kg)	648	**−0.8 (−1.5, − 0.1)**	**0.039**	**0.24**
Standing broad jump (cm)	644	−1.1 (−3.7, 1.4)	0.380	0.04
Sit-ups (n)	641	−0.2 (0.8, 0.3)	0.459	0.01
Boys				
PAL-intervention				
Cardiorespiratory fitness (m)	677	36.7 (24.0, 49.3)	**< 0.001**	0.09
Handgrip (kg)	723	−0.1 (−1.0, 0.7)	0.778	0.11
Standing broad jump (cm)	720	1.3 (−1.7, 4.4)	0.401	< 0.01
Sit-ups (n)	720	**0.6 (0.1, 1.2)**	**0.040**	0.07
DWBH-intervention				
Cardiorespiratory fitness (m)	654	1.4 (−12.6, 15.5)	0.842	0.09
Handgrip (kg)	697	−0.5 (−1.4, 0.3)	0.236	0.11
Standing broad jump (cm)	689	1.2 (−2.0, 4.4)	0.464	< 0.01
Sit-ups (n)	689	0.1 (−0.6, 0.6)	0.913	0.07

PAL Physically active learning; *DWBH* Don't worry – Be happy; *ICC* Intraclass correlation coefficient,
[a]Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention x time interaction, in addition to random effects for school, class and subject ID.,

intervention effect on both total PA level and time spent in MVPA during the full day remained positive but were no longer statistically significant as the study was not powered for stratified analyses. The mean PA level in our cohort is quite high compared to similar age groups in other European countries [2]. However, relatively large reductions in mean PA level are observed when going from childhood through adolescence [4], hence it is important to implement PA interventions which aim to curb this decline. In the PAL-intervention, the decreases in both mean PA and time spent in MVPA were significantly smaller. On average, MVPA in the PAL-intervention group decreased by 2 min/day, whilst in the control arm MVPA decreased by 6 min/day. Though this between-group difference seems small, it translates to 28 min/week more MVPA in the PAL-intervention group. Hence, the PAL-intervention can be considered as one approach to curb the decline in MVPA.

Positive and stronger intervention effects on PA-level were observed during school hours. Adolescents in the PAL-intervention arm increased their mean PA level while time spent in MVPA was stable. A decrease in both mean PA and time spent in MVPA was observed among adolescents in the DWBH-intervention arm and the control arm. The latter finding is not a surprise, as PA levels are expected to decrease through adolescence [1, 3]. The fact that the adolescents in the PAL-intervention arm maintained and even increased their PA-level during school hours must therefore be considered a strong and positive result of the intervention. Further, this indicates that the positive intervention effect observed on PA levels depend on how the additional PA was implemented. In the PAL-intervention, we encouraged the teachers to engage the students in activities of at least moderate intensity, however, this was not the focus in the DWBH-intervention. In the DWBH-intervention we promoted friendships through PA and PE, and we considered the social relationships more important than the intensity of the activity. However, as the students were able to choose their activities based on their interest and preference, our expectation was that this would stimulate more PA. Some of the adolescents in the DWBH-intervention arm performed activities like football, walking, or bicycling that includes movements of some intensity, but other groups chose activities that were less physically demanding (for instance yoga or building tree houses in the woods). Further, although accelerometers have been shown to provide valid and reliable estimates of PA level in children and adolescents, they have some limitations including the ability to detect certain activities and upper body movements [33]. Consequently, some activities in the DWBH-intervention arm, such as cycling or resistance training, may have been underestimated. In the DWBH-intervention the students themselves led and organized the activities, whilst the PAL-intervention was led and taught by teachers. We speculate that students tend to engage in lower intensity activities if they themselves can choose the intensity, although the intensity will also be highly dependent on the chosen activity and the individual. It should also be mentioned that at baseline adolescents in the PAL-intervention arm were less physically active than adolescents in the control arm, thus, it could be that the intervention potential was higher in this group. However, the linear mixed models used to analyze the intervention effects incorporated baseline values, therefore, baseline differences cannot explain the positive results. Lastly, both adolescents in the DWBH-intervention arm and the control arm increased time spent sedentary during the intervention period, but the increase was significantly higher in the DWBH-intervention arm. We attribute this counterintuitive finding to the fact that our intervention promoted PA and did not target sedentary time specifically.

The positive effect on CRF observed among adolescents in the PAL-intervention arm is in keeping with some results from previous school-based interventions, even though most of these were carried out among elementary school children [34]. The PAL-intervention resulted in an improvement of running distance of 3.5% compared to baseline values, whereas the DWBH-intervention resulted in no change in running distance compared to baseline values. Even though the observed PAL-intervention effect on CRF is modest, it is relevant as high CRF in adolescence is of importance for future health [35]. The stratified analyses revealed greater improvements in running distance among PAL-intervention boys than among PAL-intervention girls compared to controls. Sex differences in CRF among adolescents are attributed to a number of factors like lean body mass, hemoglobin concentration and testosterone among others [36]. During puberty, boys experience increases in testosterone production and muscle mass that is higher than in girls and these factors are beneficial for CRF. Girls on the other hand experience increases in fat mass which often results in a stagnation in performance-related tests, such as the Andersen test, where body weight and body composition are of importance.

All groups increased their hand grip strength during the intervention period; however, the increase was greater among the adolescents in the control group. Furthermore, a positive intervention effect was observed on sit-ups among adolescents in the PAL-intervention compared to the control group. Even though both mentioned intervention effects were significant, they were small and of little relevance. Mixed intervention effects on muscle strength were also observed in the study including adolescents in Ecuador [18]. The intervention increased vertical jump, however, the adolescents in the control group needed less attempts to keep their balance for 1 min in Flamingo balance test compared to intervention group. The finding of small intervention effects on muscle strength is not a surprise. The PAL-intervention did not target strength training in particular. In the DWBH-intervention, some of the groups performed activities that could theoretically improve muscle strength (like groups doing resistance training or yoga), however, no effect was observed on group level.

This study has several strengths, including use of a cluster RCT design, use of accelerometers to assess PA, the implementation of two separate PA interventions aimed at increasing PA levels and a large cohort. Approximately 76% of the study population consented to participate which reduced the risk of sampling bias. Also, randomization occurred on the school level to reduce risk of contamination, and the cluster RCT design was accounted for in the analyses. The two intervention arms were pilot tested during the school year 2016–17 in seven lower secondary schools (including approximately 700 students). Based on the pilot study, some adjustments were made to both intervention arms. These adjustments tailored the intervention to better reach the target group. Further, both intervention arms were designed to require only modest changes in already existing school structures, and none of the intervention components required expensive equipment. The intervention was delivered by teachers or the students themselves, which is a sustainable approach. Also, the intervention delivery was approximately 80% on average during the intervention period and indicates that the intervention models work well in real life contexts. The simplicity of both interventions would likely make it possible to adopt and implement in other lower secondary schools in Norway.

A limitation of the study is the loss of students with PA-assessments at follow-up, with less than half of students that initially consented providing accelerometer data at follow-up, a finding consistent with previous studies [15, 19]. The loss to follow-up was greater for accelerometer data than for the physical fitness data. As the adolescents were asked to wear the accelerometer for 7 days, they might have experienced this a burden and therefore chose not to wear it. Compliance may be improved by the provision of compensation strategies such as monetary incentives for wearing the accelerometer or for correct wear [37]. In the analyses, we used statistical methods (mixed models) that considered the loss to follow-up, consequently, all students who had valid accelerometer data at one time point were included in the analyses to reduce the loss of statistical power. Also, both intervention arms were designed to engage the adolescents in an additional 120 min of PA per week. However, for some of the components this included time to organize activities and for the adolescents to change clothes and shower, consequently, the intervention dose is probably somewhat lower than 120 min. Lastly, during school days we defined a valid day of accelerometer wear time as at least 40% of accelerometer data during school hours. This might seem low; however, few school-based intervention studies have used individual timetables for each school to create classifications and the basis for comparison is minimal. Therefore, we used approximately the same wear time criteria as during a full day, where a valid day was defined as at least 8 h, which corresponds to 44% of the awake time (6 AM to midnight).

Conclusions

During the nine-month intervention period, we observed a smaller decrease in daily PA level, time spent in MVPA, as well as improvement in CRF among adolescents in the PAL-intervention arm compared to adolescents in the control arm. During school hours, we observed increased PA levels and reduced sedentary time among adolescents in the PAL-intervention arm compared to adolescents in the control arm. We found no intervention effect on daily PA levels among adolescents in the DWBH-intervention arm compared to controls. We did, however, observe unfavorable intervention effects on time spent sedentary during school hours as well as CRF in the DWBH-intervention arm compared to controls. The PAL-intervention model was teacher-led focusing on the dose and intensity of PA, whereas the DWBH-intervention arm was a social intervention, being student-led and emphasizing the social aspects of PA. Our results indicate that a teacher-led intervention including three unique intervention components, where activities of at least moderate intensity was encouraged, is effective in curbing a decline in PA and improving CRF compared to controls.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12966-020-01060-0.

Additional file 1:. CONSORT 2010 checklist of information to include when reporting a randomised trial*.

Additional file 2:. The TIDieR (Template for Intervention Description and Replication) Checklist*.

Additional file 3: Table 2a. Mean (95% confidence interval) physical activity levels among girls stratified by study arm at baseline and follow-up. **Table 2b.** Mean (95% confidence interval) physical activity levels among boys stratified by study arm at baseline and follow-up.

Additional file 4: Table 3. Mean (95% confidence interval) for cardiorespiratory fitness and muscle strength among participants stratified by study arm and gender at baseline and follow-up.

Abbreviations

DWBH: Don't worry – be happy; MVPA: Moderate-to-vigorous intensity physical activity; PA: Physical activity; PAL: Physically active learning; PE: Physical education; RCT: Randomized controlled trial; ScIM: School in motion

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Authors' contributions

Each author has contributed to the conception and design of the work. All authors participated in writing of the paper and approved the final version.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available as publications are planned but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The project was reviewed by the Regional Committee for Medical and Health Research Ethics (REK) in Norway, who according to the Act on medical and health research (the Health Research Act 2008) concluded that the study did not require full review by REK. The study was approved by the Norwegian Centre for Research Data. The trial's protocol was retrospectively registered at ClinicalTrials.gov on 01/25/2019 (NCT03817047). Written informed consent from the participants and their parents or caretakers was obtained prior to the data collection.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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RESEARCH Open Access

Effects of a school-based physical activity intervention on academic performance in 14-year old adolescents: a cluster randomized controlled trial – the School in Motion study

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Abstract

Background: School-based physical activity interventions evaluating the effect on academic performance usually includes children. We aimed to investigate the effect of a nine-month, school-based physical activity intervention titled School in Motion (ScIM) on academic performance in adolescents.

Methods: Thirty secondary schools in Norway were cluster-randomized into three groups: the Physically active learning (PAL) group ($n = 10$), the Don't worry – Be Happy (DWBH) group ($n = 10$) or control ($n = 10$). Target dose in both intervention groups was 120 min/week of additional PA during school hours. Parental consent was obtained from 2084 adolescent students (76%). Standardized national tests in reading and numeracy was conducted at baseline and at the end of the intervention. We used linear mixed model to test intervention effects. We found significant intervention effects in numeracy and reading among students in both interventions when compared with controls.

Results: The mean difference in change in numeracy was 1.7 (95% CI: 0.9 to 2.5; Cohen's d = 0.12) and 2.0 (95% CI: 1.4 to 2.7; Cohen's d = 0.23) points in favour of students in the PAL and DWBH intervention, respectively. Similar results were found for reading, where the mean difference in change was 0.9 (95% CI 0.2 to 1.6; Cohen's d = 0.06) and 1.1 (95% CI 0.3 to 1.9; Cohen's d = 0.18) points in favour of students in the PAL and DWBH intervention, respectively. When conducting intention to treat analysis with imputed data the estimates were attenuated and some no longer significant.

(Continued on next page)

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Conclusion: The ScIM study demonstrates that two different school-based PA interventions providing approximately 120 min of additional PA weekly over nine months, significantly improved numeracy and reading performance in 14-year old students compared with controls. However, the results should be interpreted with caution as the effect sizes reported were very small or small and the estimates were attenuated when conducting intention to treat analysis. Despite this, our results are still positive and suggest that PA interventions are viable models to increase academic performance among adolescents.

Trial registration: Retrospectively registered (25/01/2019): NCT03817047.

Keywords: Physical activity, Cluster RCT, Adolescents, Academic performance

Background

Schools have received widespread attention owing to the inescapable pressure to educate students to meet accepted academic standards. Therefore, new effective teaching methods must be developed. Physical activity (PA) might be such a method because evidence has emerged concerning the positive association between PA and academic performance [1–6].

A randomized controlled trial (RCT) called Physical Activity Across the Curriculum, found improved performance in reading, numeracy, and spelling in a sub sample comparing children who received physically active lessons daily for three years with children who followed the regular curriculum [7]. Similarly, in the Fit & Vaardig op School study, weekly physically numeracy and language lessons over two years improved numeracy and spelling performance among elementary school children [8]. These results also correspond with the Activity and Motivation in Physical Education trail findings, where the authors reported significant intervention effects on numeracy performance [9].

Despite this, the literature is ambiguous as other school-based RCTs shows no intervention effect of multicomponent PA interventions on academic performance on whole group data among children [10, 11] and adolescents [12]. Finally, a recent systematic review on the effects of PA interventions on academic performance in 3–16 years olds concluded that strong evidence exist of the beneficial effects of PA on numeracy performance, but the evidence is inconclusive for overall academic performance [13].

Most studies investigating the effects of school-based PA interventions on academic performance are implemented among primary school children [7, 8, 10, 11]. Studies with adolescents have focused only on PE lessons [9] or have relatively short intervention period [12]. Consequently, few large, multicomponent PA interventions that include adolescents have been implemented over longer intervention periods in lower secondary school. Therefore, we conducted a school-based cluster RCT titled School in Motion (ScIM), consisting of two multicomponent PA interventions powered to compare changes in the mean PA level among secondary schools adolescents who received two extra hours of PA per week and a control group. We recently reported a favourable effect on the daily PA level and the time spent in moderate-to-vigorous intensity physical activity (MVPA) among adolescents in one of the intervention arms compared with controls [14]. In this paper, we investigated the intervention effect of the two PA interventions on academic performance in reading and numeracy.

Methods

Study design

The ScIM study was a nine-month school-based three-arm cluster RCT with schools as the cluster unit for randomization. The inclusion criteria were; > 25 students in ninth grade. We excluded schools that worked systematically with curriculum-prescribed PA and private and special schools. When a school agreed to attend, all students in the ninth grade were invited to participate. Four collaborating partners (Norwegian School of Sport Sciences, Western Norway University of Applied Sciences, University of Agder, and University of Stavanger) conducted the study during the 2017/2018 school year.

The ScIM study was reviewed and approved by the Norwegian Centre for Research Data and adhered to the Helsinki Declaration (2008). Parents or/guardians gave written informed consent allowing their child/ward to participate. The parents or adolescents could revoke this consent at any time. ScIM is registered in ClinicalTrials.gov (25/01/2019), ID nr: NCT03817047. The design, conduct, and reporting of this trial follow the recommendations of the CONSORT statement [15]. The CONSORT checklist is in related File 1.

Randomization and blinding

Thirty schools were randomized manually by a lottery in a 1:1:1 ratio to either Physically active learning (PAL) intervention ($n = 10$), Don't worry – Be Happy (DWBH) intervention ($n = 10$) or control ($n = 10$). One school withdrew after randomization but prior to baseline testing, leaving nine schools in the control group. The professional who performed the randomization did not partake in other parts of the study. Neither participants, schools, the testing personnel that performed the data collection in the schools nor researchers were blinded.

The ScIM interventions

Both interventions aimed to provide approximately 120 min of additional PA in addition to the mandatory 120 to 180 min PE lessons per week. This goal was achieved by redistributing 5% of the other subjects to PA (60 min per week) and adding 60 min of PE to the curriculum. All intervention schools received $90 per student to account for the increased expenses.

The PAL-intervention focused on increasing student PA levels and consisted of three components (Table 1). We constructed an online toolkit of activities based on student and teacher feedback, and the existing pedagogical material that teachers could use. The PAL intervention was based on a socio-ecological theoretical framework that recognizes the complex interplay between personal and environmental influences on behaviour [16]. Teachers conducting the PAL intervention were encouraged to provide activities that would be enjoyable for all students.

The focus of the DWBH-intervention was to promote friendship through PA, and it consisted of two components (Table 1): 60 min of a PE lesson called 'Don't worry' (DW), and 60 min of a lesson called 'Be happy' (BH). First, students across different classes formed groups based on their interests. The groups performed the chosen activity in the BH lesson throughout the intervention period. The DW lessons were similar to an ordinary PE lesson, and the activities were either the same as in the BH lesson or were led by students representing one of the other activity groups in the BH lessons. The students developed the aims, management structure, strategies for impending conflicts, and routines for registration of attendance. This intervention was anchored to an integrative relational developmental system approach to human development, promoting mutually beneficial relationships for everyone involved [17].

At least one teacher from each intervention school attended a one-day course on how to deliver the intervention. The course consisted of theoretical and practical exercises by educators with experience in integrating PA into the curriculum. Control schools continued the current practice and did not implement additional curriculum-prescribed PA.

Treatment group involvement

Teachers and students at the intervention schools were involved in the development of the two interventions in ScIM. Teachers and students were not involved designing the research questions, outcome measures, or analyses. The results of the study will be disseminated to all included schools.

Delivery

All intervention components were mandatory. Adherence to intervention components was reported in an online platform. Each week, teachers at the intervention schools self-reported components performed or not performed, and the component intensity and minutes.

Measurements

All measurements were obtained twice, first at baseline (April to August 2017) and second in the last phase of the intervention (April to June 2018). The test procedures were identical at both time points. The data were collected in the classroom and gymnasium. The research team trained all testing personnel, and all tests were conducted following the relevant guidelines.

Table 1 Intervention content and means of implementation stratified by intervention group.

Intervention components (min)	Practical organization	Providers of interventions	Implementation facilitation and method
Physically Active Learning (PAL)			
Physical activity in academic subjects (30 min)	Weekly	Teachers	An external collaborator provided a program tailored specifically to the subject curriculum. Teachers attended two courses during the intervention period.
Physical education (60 min)	Weekly	Physical education teachers	Follows the normal physical education curriculum
Physical activity (30 min)	Weekly	Teachers/physical education teachers	Students could choose between varied activities. Teachers were encouraged to motivate students during physical activity to stimulate their positive feelings and attitudes towards physical activity
Don't Worry – Be Happy (DWBH)			
Activity class (Be happy class) (60 min)	Weekly	Teachers/physical education teachers	Self-organized activity developed according to the adolescent's activity preferences.
Physical education (Don't worry class) (60 min)	Weekly	Teachers/physical education teachers	Pupils led the regular PE class. Pupils practiced their Be Happy activity.

Academic performance

Academic performance was measured using standardized computer-based national tests designed and administered by The Norwegian Directorate for Education and Training. The numeracy test measured an individual's ability to understand numbers and measurements. The reading test measured an individual's basic Norwegian reading skills, interpreting and understanding texts, and considering the form and content. Both tests included anchor questions, making it possible to provide a baseline for an equating analysis between the two timepoints. The scores were standardized to a T-score with a mean of 50 scale points with a standard deviation (SD) of 10.

Anthropometry

We measured the weight to the nearest 0.1 kg using a Seca 899 weight and measured the height to the nearest 0.1 cm using a SECA 123 Portable Stadiometer (SECA, Hamburg, Germany). We subtracted 0.6 kg (light clothing; gym shorts and t-shirt) or 1.5 kg (normal clothes; pants and sweater) from the weight measurements to account for clothing.

Physical activity

We assessed PA using ActiGraph accelerometers, models GT3X and GT3X+ (ActiGraph, LLC, Pensacola, Florida, USA). Students were instructed to wear the accelerometer on their right hip over seven consecutive days, except when sleeping, showering and bathing. ActiLife software (ActiGraph, LLC, Pensacola, Florida, USA) was used to initialize and download the accelerometer files. Raw files were processed and analysed using STATA (Stata Statistical Software, StataCorp LP), and the epoch was 10 s. The data were recorded between 00:00 and 06:00, and all intervals of ≥20 consecutive min with no accelerations were excluded. Days with ≥480 min of active recording were considered valid. As a measure of the overall PA, we used average counts·min^{-1} (CPM) over the entire assessment period. To investigate the average minutes per day spent sedentary or in MVPA, we divided time registered with < 100 CPM and > 1999 CPM by the valid assessment days, respectively.

Socioeconomic status

We linked our database to the registry data collected by Statistics Norway and used the highest education level of the participants' parents as a proxy for socioeconomic status (SES). Four SES groups were computed low (primary/lower secondary/vocational high school), middle (secondary/high school), middle high (undergraduate degree), and high (graduate degree).

Sample size

The ScIM study was powered to detect changes in the primary outcome (CPM) of 7% (49 CPM) between groups. The α level was 0.05 for all calculations. To detect a 49 ± 150 (mean ± SD) difference in CPM between the intervention groups and control group with a power of 0.9, expecting a dropout rate of 20%, we require at least 590 participants in each intervention arm.

Statistics

In the main analysis, we included participants with a valid baseline or follow-up measures for academic performance. The data were assessed for normality and homogeneity of variance. The descriptive data are presented as the mean and SD unless otherwise stated. We fitted linear mixed models to both outcomes (numeracy and reading). Each model included fixed effects for the intervention, time (baseline and follow-up), and interaction term (intervention x time). As the units of randomization were schools, a "random effect" for school was included in the model, in addition to the class and subject ID to accommodate the clustering of students within these units.

We estimated the mean group values with a 95% confidence interval (CI) at the baseline and follow-up. We estimated the between group difference in change from the baseline to the follow-up between the participants in the intervention arms and control arm, adjusting for sex. Further, we examined whether sex modified the intervention effect by introducing an interaction term (timepoint x group x sex). A statistically significant interaction between sexes was evident in all academic performance models ($p < 0.001$ for interaction). Consequently, we repeated the analysis stratified by this variable.

We calculated a standardized mean difference score for each specific outcome (Cohen's d), which was estimated using a random effects model. Cohen's d values ranging from 0.01 to 0.20, 0.20 to 0.50 and 0.50 to 0.80 corresponds to very small, small and moderate effect size, respectively. We performed a per protocol analysis including schools with above 80% adherence to the protocol. Multiple imputations were performed on the academic performance variables as a sensitivity analysis to account for loss for the follow-up data. Imputation of variables was performed using chained equations (mi imputed chained) in Stata v.16. Mean differences in change, standard errors and 95% CI were obtained based on 20 imputed datasets. The imputation analyses assume that data are missing at random. All statistical analyses were performed using Stata (StataCorp LP).

Results

The flow of the schools and participants is presented in Fig. 1. Among 2733 eligible students from 29 participating schools at baseline, parental consent was obtained from

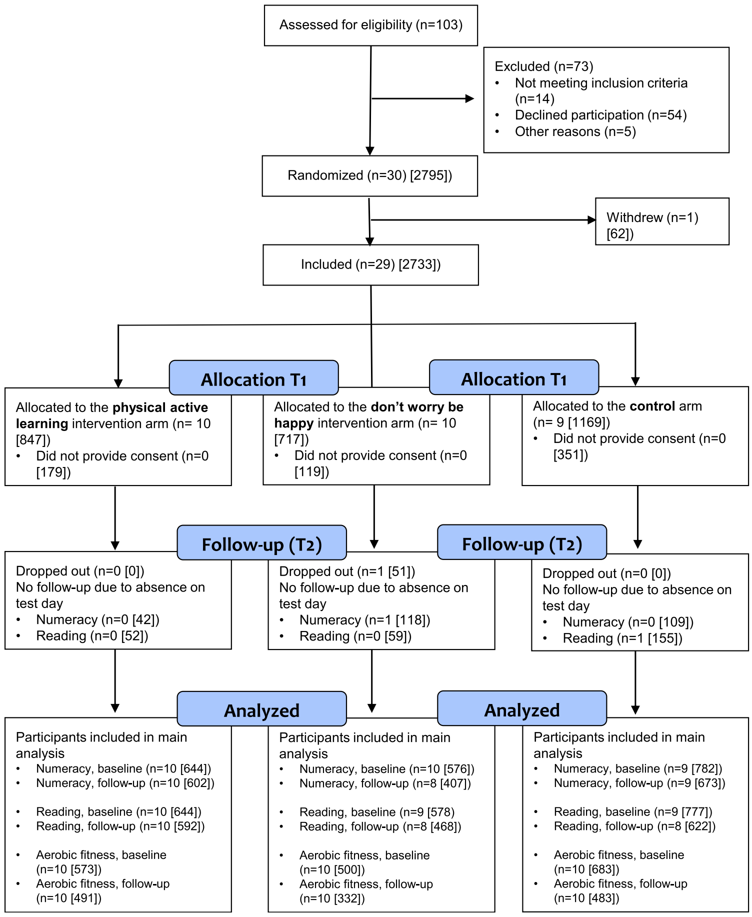

Fig. 1 Flow of schools and students through the study. All numbers are schools [students]

2084 students (76%). One DWBH school withdrew from the trial after three months for practical reasons. At follow-up, one DWBH school was unable to complete the national test in numeracy and one control school were unable to complete the reading test. At baseline, 1999 and 2002 students had valid data on reading and numeracy respectively. A total of 1682 students had valid data in reading and numeracy at follow-up. The reason for the loss of follow-up data on academic performance was absences during the post-test (reading: $n = 269$; numeracy $n = 266$). The characteristics of all students by intervention group are presented in Table 2.

Effects on academic performance

We found significant intervention effects on numeracy and reading among students in both interventions compared with the control group (Fig. 2). The mean difference in change in numeracy was 1.7 (95% CI: 0.9 to 2.5; Cohen's d = 0.12) and 2.0 (95% CI: 1.4 to 2.7; Cohen's d = 0.23) points in favour of students in the PAL and DWBH interventions, respectively. Similar results were found for reading, where the mean difference in change was 0.9 (95% CI 0.2 to 1.6; Cohen's d = 0.06) and 1.1 (95% CI: 0.3 to 1.9; Cohen's d = 0.18) points in favour of students in the PAL and DWBH interventions, respectively.

Stratified by sex, the mean differences in change for numeracy in the PAL intervention were 1.0 points (95% CI: 0.3 to 1.8) and 2.4 points (95% CI: 1.5 to 3.3) for girls and boys respectively (Fig. 3). Similar findings were observed in the DWBH intervention, where the mean differences in change were 1.4 points (95% CI: 0.5 to 2.2)

Table 2 Participant characteristics by group allocation at baseline. Mean (SD) unless other stated.

	PAL Intervention (n = 536–655)		DWBH Intervention (n = 427–586)		Control (n = 583–795)	
	Girls	Boys	Girls	Boys	Girls	Boys
N	328	327	286	300	387	408
Age (year)	13.9 (0.3)	13.9 (0.3)	13.9 (0.3)	14.0 (0.3)	14.0 (0.3)	14.0 (0.3)
Parents education levels						
Low (%)	5.8	7.0	5.2	7.6	2.5	7.1
Middle (%)	26.5	27.0	30.0	32.3	26.8	29.0
Middle high (%)	42.4	42.2	43.7	34.7	43.2	39.0
High (%)	23.8	22.9	20.2	24.3	26.1	23.5
Anthropometry						
Height (cm)	162.9 (6.2)	166.3 (9.4)	164.1 (6.1)	168.6 (8.4)	163.9 (6.5)	167.6 (8.3)
Weight (kg)	54.3 (9.6)	54.1 (11.8)	55.9 (10.2)	56.5 (11.7)	54.2 (9.3)	54.6 (11.5)
Physical activity levels full day						
Total PA (cpm)	473.2 (157.3)	552.1 (207.0)	512.8 (204.5)	563.7 (204.7)	510.5 (174.7)	590.1 (227.1)
MVPA (min/day)	64.5 (21.8)	71.6 (25.8)	69.6 (25.0)	73.3 (28.0)	69.7 (25.5)	77.8 (30.3)
Sedentary (min/day)	560.0 (69.9)	530.3 (86.7)	551.3 (75.4)	521.7 (80.6)	545.9 (72.0)	513.9 (82.9)
Academic performance						
Numeracy (points)	53.5 (9.8)	56.4 (9.8)	54.2 (9.3)	55.3 (9.4)	56.1 (9.9)	55.2 (10.1)
Reading (points)	56.5 (9.7)	54.2 (9.7)	55.8 (9.6)	53.0 (10.2)	57.5 (9.7)	52.7 (10.3)

PAL = Physical active learning; DWBH = Don't worry – Be happy". PA = physical activity; MVPA = moderate-to-vigorous intensity physical activity

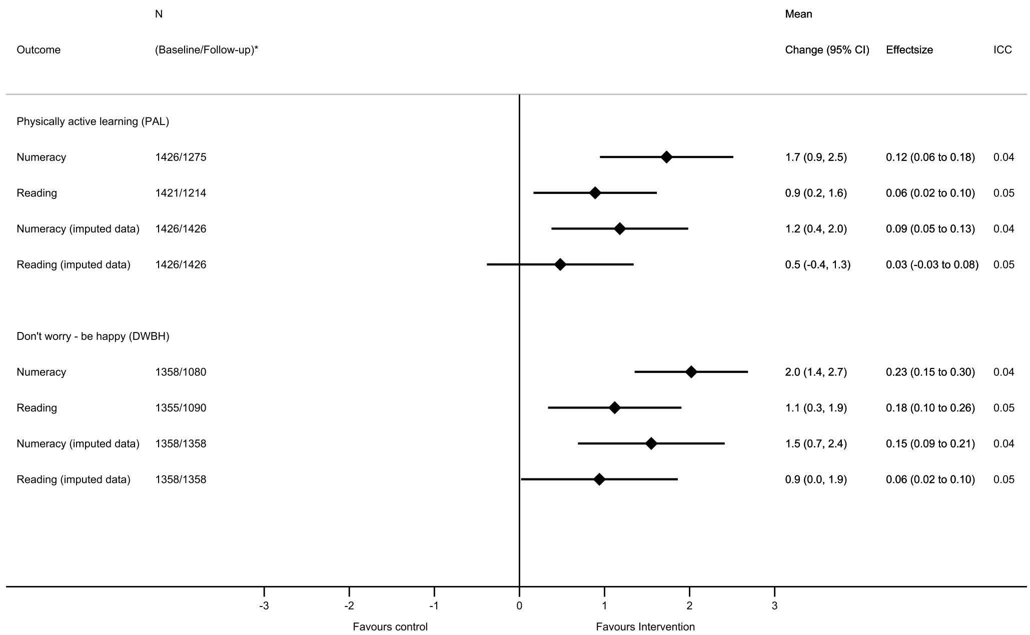

Fig. 2 Intervention effect on academic performance in numeracy and reading stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N* indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group

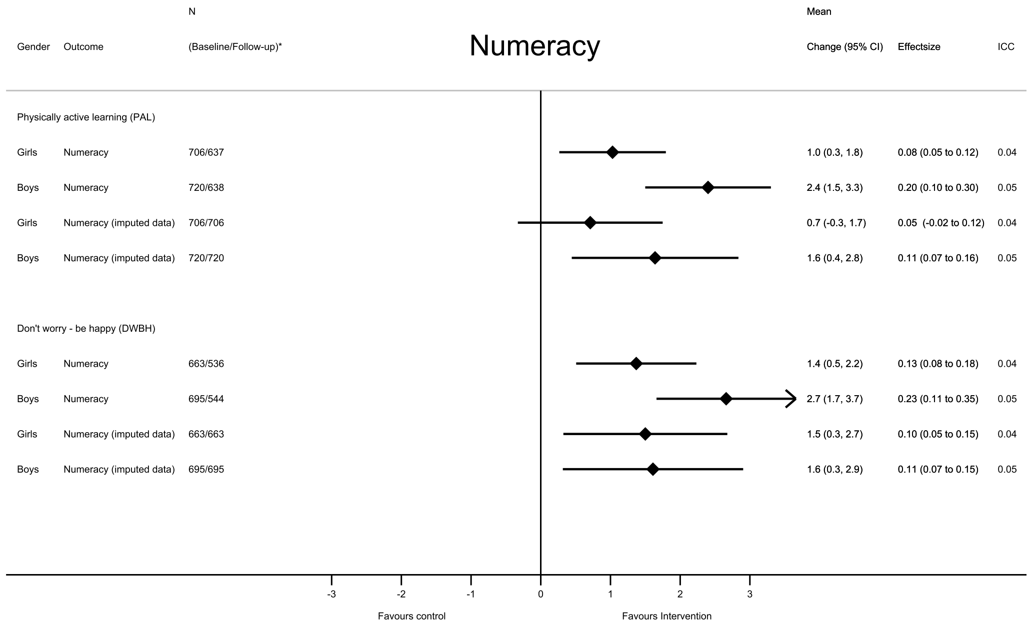

Fig. 3 Intervention effect on academic performance in numeracy stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N* indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group

for girls and 2.7 points (95% CI: 1.7 to 3.7) for boys (Fig. 3). The mean difference in change in reading was attenuated when compared with the overall estimates. The only significant effect when the analysis was stratified by sex was among boys in the DWBH intervention compared with control group (Fig. 4).

Sensitivity and per-protocol analysis

The sensitivity analysis from the imputed dataset followed the intention to treat (ITT) principle. Among students in the PAL-intervention, the mean difference in change in reading was attenuated to 0.5 points (95% CI: – 0.4 to 1.3; Cohen's d = 0.03) (Fig. 2) and was no longer significant in the ITT-analysis. In the sex specific analysis, we found a similar pattern for numeracy among girls in the PAL intervention and for reading among boys in the DWBH intervention, where the estimates were attenuated and no longer significant when conducting the ITT-analysis (Figs. 3 and 4). The per-protocol analysis, including schools with a delivery rate of above 80%, did not differ from the main analysis (data not shown), except that the intervention did not show an intervention effect on numeracy performance among girls in the DWBH group when compared with control group (mean difference in change: 0.9, 95%CI: – 0.2 to 2.0).

Intervention adherence

The adherence to the intervention protocol was 83 and 78% for PAL and DWBH interventions, respectively. Thus, the PAL-group delivered an average of 100 min/week of additional PA, and the DWBH-group delivered an average of 94 min/week of additional PA. The adherence varied between schools, ranging from 67 to 95%. Ten of the 19 intervention schools had a delivery rate of above 80%.

Discussion

This paper aimed to evaluate the effect of two school-based PA interventions on academic performance among Norwegian adolescents. Both ScIM interventions resulted in better development over time in student academic performance in reading and numeracy than the control group.

Our findings are in line with recent intervention results suggesting a beneficial intervention effect of school-based PA on academic performance [7–9]. Although our results align with some studies, other studies do not support our findings [10–12]. The LCoMotion

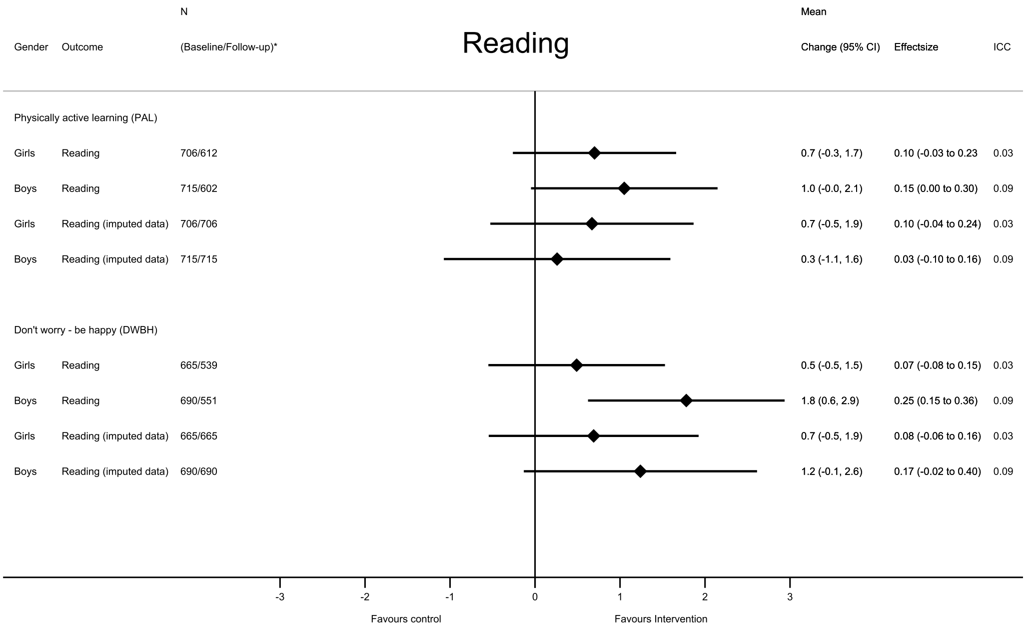

Fig. 4 Intervention effect on academic performance in reading stratified by study group compared with the control group. Each model contained fixed effects for intervention, time (baseline – follow-up), intervention x time interaction and random effects for school, class, and subject ID. CI = confidence interval; ICC = intraclass correlation coefficient (for school): N* indicates the number of participants in the analysis at baseline/follow-up in the intervention model and the control group

study included 632 Danish adolescents who performed 60 min of additional PA each school day over 20 weeks [12], The Active Smarter Kids study included 1100 Norwegian fifth graders who carried out 165 min of additional PA per week over seven months [11] and the Academic Achievement and Physical Activity Across the Curriculum study included 584 American children who engaged in more than 100 min of PA each week over three years [10]. The discrepancy in intervention effects could be due to several factors.

First, studies with non-significant results on academic performance consisted of various types of PA components, physically active learning, PA after school, active transportation and homework, short PA breaks during theoretical lessons, and recess [10–12]. Although no clear evidence indicate that some components of school-based PA would be more effective than others, Alvarez-Bueno et al. [18] concluded that all PA components, but especially PE, could improve academic performance. In ScIM, both interventions included additional PE, which LCoMotion, The Active Smarter Kids and Academic Achievement and Physical Activity Across the Curriculum study did not. However, neither did Physical Activity Across the Curriculum study [7] or the Fit & Vardig op School intervention [8], making it difficult to conclude which components of school-based PA are most effective.

Second, adherence to protocol might be of importance. In the LCoMotion [12], Academic Achievement and Physical Activity Across the Curriculum [10], and The Active Smarter Kids [11] studies, the teachers delivered an average of 40, 55, and 80%, respectively, of the weekly target dose across the intervention period. This adherence to protocol is lower than that reported in ScIM. When considering the per-protocol analyses it is important to emphasize that adherence was self-reported by the teachers every week across the intervention. Consequently, the self-report could be subject to bias; however, it is the same method used in the comparable studies. When designing and planning the ScIM interventions, we conducted a five-month pilot study, including seven schools and 700 adolescents, which led to adjusting both models to better reach the target group. The intervention models were simplified (i.e. one component – physically active breaks – was removed from the PAL model), and more resources were given to the teachers to increase adherence to the protocol. In ScIM, the teachers delivered approximately 80% of the intervention dose. The main reason for not reaching the intended target dose was various special events throughout the year (i.e., exams, holidays, and school trips). Nevertheless, ScIM indicates that it is possible to implement school-based PA interventions that positively affect academic performance in an already busy curriculum.

Third, the PAL intervention resulted in better daily PA development over time than the control group [14]. This results was also observed in the Physical Activity Across the Curriculum study [7], but was not reported in the other studies [11, 12]. The increased PA levels in the PAL model could theoretically be linked to changes in the brain structure, function or neurotransmitters concentration that occurs in students who are more physically active [19]. Furthermore, PA can affect the brain's physiology by increasing the cerebral capillary growth, blood flow and nerve cells in the hippocampus, supporting learning and memory related to academic performance [19, 20].

In the DWBH intervention, we found effects on academic performance despite no effect on PA levels. However, the focus in the DWBH-intervention was to promote friendships through PA, which was more important than the dose and intensity of the activities. We speculate that an alternative explanation for the intervention effect on academic performance in the DWBH intervention is that the self-elected activities may have enhanced arousal, minimized fatigue and boredom, and led to higher levels of self-efficacy, which could optimize student academic performance [21]. Furthermore, the chosen activities may have encouraged students to cooperate with classmates, employ strategies and adapt to changing task demands. Studies have reported that PE enriched with social interaction improves inhibition [22, 23]. In addition, PA is associated with planning performance [24] and cognitive flexibility [25], which relates to better academic performance. Another possible mechanism is that varied PA through the curriculum enhances the enjoyment of academic lessons, leading to higher motivation and engagement with theoretical materials. This outcome can improve the classroom climate and subsequently act as a confounder for the intervention effect. However, when we rerun the analysis with adjustments for the classroom climate, the results did not change from the main analysis.

Our results suggest that the PA content and relational quality seems to be as important as the dose and intensity when aiming to increase students' academic performance. These findings indicate that it is possible to develop new active teaching methods which could be more effective for increasing academic performance compared to more traditionally sedentary teaching methods. However, given limitations in small effect sizes and relative short intervention duration, more research is warranted. Studies implemented over a longer time period (e.g. two or three years) with direct measurement of cognition and other possible mechanisms can provide a more in depth understanding of how PA can affect academic performance among adolescents and should be prioritized.

The strengths of this study include the cluster randomized design using two different PA interventions, the high adherence to the protocols, and device measured PA, which ensures internal and external validity. Additionally, the large sample size (76% of eligible students) consisting of an understudied population recruited from four different regions across Norway reduces the risk of bias and suggests that the findings are generalizable to some extent. Finally, to provide an unbiased estimate of group allocation, we performed a mixed model analysis with all participants with valid data on either time point for academic performance. Multiple imputation when performing mixed models analyses can lead to unstable results [26], and when the analysis was rerun on the imputed data the estimates were attenuated and some no longer significant.

We did not include any measurement of cognition or biological pathways on how PA might influence academic performance. Furthermore, although several studies have used national tests to measure academic performance, these could be a potential limitation because no validation studies exist. Another limitation is that the effect size (Cohen's d) of the intervention effect in the primary analysis is considered very small or small ($d = 0.06$ to 0.23). However, other intervention studies that have demonstrated beneficial effects on academic performance have been implemented over two school years. As our intervention only lasted for nine months, we can speculate regarding whether a longer intervention duration would result in further improvements in academic performance.

Conclusion

The ScIM study demonstrates that two different school-based PA interventions providing approximately 120 min of additional PA weekly over nine months, significantly improved numeracy and reading performance in 14-year old students compared with controls. However, the results should be interpreted with caution as the effect sizes reported were very small or small and the estimates were attenuated when conducting ITT analysis. Despite this, our results are still positive and suggest that PA interventions are viable models to increase academic performance among adolescents.

Abbreviations

DWBH: Don't worry – be happy; MVPA: Moderate-to-vigorous intensity physical activity; PA: Physical activity; PAL: Physically active learning; PE: Physical education; RCT: Randomized controlled trial; ScIM: School in motion

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Authors' contributions
Each author has contributed to the conception and design of the work. RS conducted the analysis and wrote the first draft of the paper and contributed revisions to the manuscript. JSJ, SAA, UE, RS, TH, SV, AA, ØL, GKR, EK participated in writing of the paper and approved the final version.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available as publications are planned but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The ScIM study was reviewed and approved by the Norwegian Centre for Research Data and adhered to the Helsinki Declaration (2008). The trial's protocol was retrospectively registered at ClinicalTrials.gov on 01/25/2019 (NCT03817047). Written informed consent from the participants and their parents or caretakers was obtained prior to the data collection.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Aerobic fitness mediates the intervention effects of a school-based physical activity intervention on academic performance. The school in Motion study – A cluster randomized controlled trial

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ABSTRACT

Little information exists on the mechanism of how physical activity interventions effects academic performance. We examined whether the effects of a school-based physical activity intervention on academic performance were mediated by aerobic fitness. The School in Motion study was a nine-month cluster randomized controlled trial between September 2017 and June 2018. Students from 30 Norwegian lower secondary schools (N = 2,084, mean age [SD] = 14 [0.3] years) were randomly assigned into three groups: the Physically Active Learning (PAL) intervention (n = 10), the Don't Worry—Be Happy (DWBH) intervention (n = 10), or control (n = 10). Aerobic fitness was assessed by the Andersen test and academic performance by national tests in reading and numeracy. Mediation was assessed according to the causal steps approach using linear mixed models. In the PAL intervention, aerobic fitness partially mediated the intervention effect on numeracy by 28% from a total effect of 1.73 points (95% CI: 1.13 to 2.33) to a natural direct effect of 1.24 points (95% CI: 0.58 to 1.91), and fully mediated the intervention effect on reading, with the total effect of 0.89 points (95% CI: 0.15 to 1.62) reduced to the natural direct effect of 0.40 points (95% CI: −0.48 to 1.28). Aerobic fitness did not mediate the effects on academic performance in the DWBH intervention. As aerobic fitness mediated the intervention effect on academic performance in one intervention, physical activity of an intensity that increases aerobic fitness is one strategy to improve academic performance among adolescents.

1. Introduction

Physical activity (PA) and aerobic fitness is associated with several health benefits in youths (Poitras et al., 2016; Raghuveer et al., 2020). Worryingly, accelerometer data shows that PA levels decline throughout adolescents (van Sluijs et al., 2021) and a recent systematic review reported a decline in children and adolescents aerobic fitness over the past three decades (Tomkinson et al., 2019). Interventions aimed at increasing PA levels and aerobic fitness among adolescents are therefore warranted.

Schools is an ideal avenue for health promoting interventions cause you reach individuals from all backgrounds. Hence, numerous school-based PA interventions aimed at increasing children and adolescents PA and aerobic fitness have been developed (Hartwig et al., 2021; Love et al., 2019). Emerging evidence shows positive associations between PA, aerobic fitness and academic performance (Marques et al., 2018; Santana et al., 2017), making PA interventions relevant for schools, teachers and stakeholders. However, whilst the most recent systematic

Abbreviations: ScIM, School in Motion; PAL, Physically Active Learning; DWBH, Don't worry – be Happy; SD, standard deviation; ICC, intra class correlation.

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review on the effects of school-based PA intervention on academic performance reports strong evidence for the favourable effects on numeracy performance, the evidence of effects on overall academic performance is inconclusive (Singh et al., 2019). The fact that many studies do not show any effect of PA interventions on academic performance may be explained by failure of most school-based interventions to increase children and adolescents' PA level (Love et al., 2019). The inconsistent findings in the literature call attention to the lack of knowledge regarding through which mechanisms school-based PA intervention may enhance academic performance.

Several potential mechanisms have been suggested in the literature. One mechanism suggest that higher PA levels leads to increased neurogenesis in hippocampus associated with learning and memory (van Praag, 2008), increases in important growth factors leading to a variety of structural brain changes (Lubans et al., 2016), and higher levels of executive functions such as inhibition and working memory (Hillman et al., 2011). Another mechanism suggests that positive effects of increased PA on academic performance is mediated through aerobic fitness (Raghuveer et al., 2020). Increased PA of a certain intensity leads to improved aerobic fitness (Raghuveer et al., 2020) which can affect brain morphology (Chaddock et al., 2011) and thus improve executive functions and academic performance (Marques et al., 2018).

In a recent cross sectional study, aerobic fitness mediated the associations between PA and academic performance among 186 Spanish children 9–11 year-olds (Visier-Alfonso et al., 2021). This corresponds with findings among 608 Japanese seventh graders where it was suggested that aerobic fitness meditated the associations between PA and academic performance among boys but not girls (Kyan et al., 2019). Also, in a study of 401 American children in second and third grade, aerobic fitness mediated the association between PA and numeracy but not reading (Lambourne et al., 2013). However, a study of 232 Swedish adolescents did not support these findings (Kwak et al., 2009). The cross-sectional design used in the mentioned studies precludes casual interpretation, and there is need for intervention studies examining the mediating role of aerobic fitness on effects of school-based PA interventions on academic performance.

We conducted a cluster randomized controlled trial (RCT) with two different PA interventions including more than 2,000 Norwegian 14-year-olds in 30 lower secondary schools titled the School in Motion (ScIM) study. The results revealed that students in both intervention arms significantly improved academic performance in numeracy and reading compared to students in the control group (Solberg et al., 2021), and students in one of the intervention arm also significantly improved accelerometer assessed PA levels (primary outcome) and aerobic fitness compared with controls (Kolle et al., 2020). The study design allows us to investigate whether aerobic fitness is on the causal pathway between increased PA and the intervention effects on academic performance. By performing mediation analysis, we can evaluate the possibility that an exposure variable causes changes in the mediator variable, which in turn causes the outcome variable to change (Valeri and Vanderweele, 2013). Further, the design in ScIM will reduce potential confounding observed with cross-sectional studies and contribute knowledge on which mechanism is important to enhance academic performance.

The aim of the present study was to examine the mediating role of aerobic fitness on the intervention effect of a school-based PA intervention on academic performance in 14-year-olds.

2. Methods

The ScIM study was a nine-month cluster RCT of 2,084 14-year-olds from 30 lower secondary schools in Norway. Schools were randomly allocated in a 1:1:1 ratio to either the Physically Active Learning (PAL) intervention ($n = 10$), the Don't Worry-Be Happy (DWBH) intervention ($n = 10$), or control ($n = 10$). One school withdrew after randomization but prior to baseline testing, leaving nine schools in the control group. The project was reviewed by the Regional Committee for Medical and Health Research Ethics (REK) in Norway, who according to the act on medical and health research (the Health Research Act 2008), concluded that the study did not require full review by REK. The ScIM study was approved by the Norwegian Centre for Research Data and adhered to the Helsinki Declaration (2008). Parents gave their written informed consent allowing their adolescents to participate. This content could be revoked by the parents or adolescents at any time. The ScIM is registered in ClinicalTrials.gov (25/01/2019), ID nr: NCT03817047. The design, conduct, and reporting of this trial follow recommendations of the CONSORT statement. The CONSORT checklist can be found in Supplementary File 1. The methodology and main effects of the ScIM study have been described in detail elsewhere (Kolle et al., 2020). A brief description is provided below.

2.1. The ScIM interventions

Both interventions were based on a socio-ecological framework that recognizes the complex interplay between personal and environmental influences on behavior (McLeroy et al., 1988) and provided approximately 120 min of additional PA in addition to the mandatory 120–180 min of physical education (PE), lessons per week. The interventions were delivered from September 2017 to June 2018, and intervention components were mandatory for all students. Control schools continued the current practice with the usual amount of mandatory PE and were asked not to implement additional PA in the curriculum.

The PAL intervention focused on increasing the students' PA levels and consisted of three components of at least moderate intensity: (1) additional lesson of PE per week (60 min); (2) 30 min/week lesson of physically active learning where physical activities were integrated in regular subjects; and (3) 30 min/week lesson of PA that included a variety of enjoyable activities. In contrast, the DWBH intervention's focus was to promote friendship through PA and consisted of two components: (1) 60 min of PE called the 'Don't worry' lesson (DW) and (2) a 60 min 'Be happy' lesson (BH). Based on PA interest, students formed groups of 3–8 students and chose one activity that was performed throughout the intervention period.

In the PAL intervention the components were led by teachers, while the DWBH intervention was led and organized by the students themselves.

2.2. Measurements

Measurements were taken at baseline (April–August 2017) and in the last phase of the intervention (April–June 2018). The test procedures were identical at both time points. Data were collected at the respective schools, and all test personnel were trained by members of the research team.

2.2.1. Academic performance

Numeracy and reading performance were measured using standardized computer-based national tests designed and administered by the Norwegian Directorate for Education and Training. Both tests included anchor questions, which made it possible to provide a baseline for an equating analysis between the two time points. The scores were standardized to a mean of 50 scale points with a standard deviation of 10 at each time point.

2.2.2. Aerobic fitness

We used the Andersen test to assess the students' aerobic fitness (Andersen et al., 2008). The Andersen test is an intermittent 10-minute running field test which is a reliable and valid test for determination of aerobic fitness on a group level among 10-year old children (Aadland et al., 2014). We administered the Andersen test as per standard procedures indoors on a wooden or rubber floor, however, due to different sizes of available facilities, we standardized the length to 16 m (original protocol 20 m). The test required the students to run back and forth between the two lines, with 15-second work periods and 15-second breaks standing still. Each time the students turned around at the end line, they had to touch the floor with one hand. Students were meant to run to voluntary exhaustion. Test personnel subjectively judged whether the student completed a valid test (whether the students worked hard enough) and recorded the distance covered. The distance covered (in metres) was used as a proxy for aerobic fitness.

2.2.3. *Anthropometry*

We measured weight to the nearest 0.1 kg using a Seca 899 scale and height to the nearest 0.1 cm using a Seca 123 Portable Stadiometer (Seca, Hamburg, Germany). To account for clothing, we subtracted 0.6 kg (light clothing; gym shorts and t-shirt) or 1.5 kg (normal clothes; trousers and jumper) from the body weight measurements. Body mass index (BMI) was calculated as weight (kg) divided by the height squared (m^2).

2.3. *Statistical analysis*

Continues outcome variables were assessed for normality and homogeneity of variance. Descriptive data are presented as mean and standard deviation (SD) unless otherwise stated. Baseline differences between participants in the three study arms were investigated using linear regressions adjusted for gender.

Prior to testing for mediation, we fitted linear mixed models to evaluate between-group differences in change from baseline to follow-up between participants in the interventions compared with controls (i.e intervention effect) for numeracy and reading performance (primary outcomes) and aerobic fitness (mediator) separately. Each model was adjusted for gender and contained fixed effects for intervention, time (from baseline to follow-up), and intervention × time interaction. We added random effects for school, in addition to class and subject ID, to accommodate for clustering within these units. Missing values were handled by the linear mixed models, so that participants with missing values in any of the variables were included in the analyses, as long as they had at least one measurement of the outcome variable. Intraclass Correlation Coefficients (ICC) for the school cluster are predicted using Statas *iccvar* command following each linear mixed model (Hedges et al., 2012).

Mediation analysis was performed using four stage linear regression models with the approach in Fig. 1 (Lee et al., 2019; Valeri and Vanderweele, 2013; VanderWeele, 2016). First, the between-group differences in change from baseline to follow-up between participants in the interventions compared with controls (i.e intervention effect) on primary outcomes were assessed individually to generate the 'total effect' (c path). Second, the intervention effect on the hypothesized mediator was assessed (α path). Third, the association between mediators and primary outcomes adjusted for group allocation (interventions) was assessed individually (β path). Finally, we generated the natural direct effect by estimating the intervention effect on primary outcomes conditional on holding the mediator variable constant (c' path) and consequently generating the natural direct effect.

The natural direct effect (c' path) refers to the relationship between two variables that is mediated by a third variable on the pathway. In order to meet the criteria for mediation, paths α and β have to be significant with a confidence interval not crossing zero (Valeri and Vanderweele, 2013). If the exposure coefficient of the total effect (c path) is considerably different compared with the natural direct effect (c' path), the difference could be interpreted as mediation (VanderWeele, 2016). Partial mediation is present if the natural direct effect is significant, and full mediation is present when it is attenuated and no longer significant. The total and natural direct effects were estimated with 95% confidence intervals (CI) obtained by means of the bootstrap re-sampling method with 1000 replications. Results are expressed as unstandardized, baseline-adjusted coefficients for primary outcomes (points) and mediator (meters covered) with corresponding 95% CI.

Due to differential intervention effect on academic performance for boys and girls ($p < 0.001$ for interaction), analysis was repeated stratified by gender. All statistical analyses were performed in Stata 16.0/SE (StataCorp LP), and the level of significance was set at $p < 0.05$.

3. Results

Of the 2,733 students invited to participate, 2,084 (76%) agreed to partake in the study. Of these, 1,999 students provided valid data on both outcomes (reading and numeracy) at baseline, and 1,682 students had valid data at follow-up. A total of 1,756 and 1,306 students provided valid assessment of aerobic fitness at baseline and follow-up, respectively, and were included in the analyses (Fig. 2).

At baseline, students in the PAL and DWBH had lower aerobic fitness (34 m and 21 m respectively) compared with their control school counterparts ($p < 0.002$), no differences were found for academic performance when comparing students in the intervention groups with students in the control group ($p > 0.05$ for all) (Table 1).

Over the intervention period, students in the PAL intervention, had a favorably mean difference in change in aerobic fitness by 19.7 m ($p < 0.001$, intra class correlation (ICC) for school = 0.13) compared with students in the control group (Fig. 3A & B, αpath). In comparison, students in the DWBH intervention had a unfavorably mean difference in change and decreased their aerobic fitness by 11.5 m compared with their control school counterparts ($p < 0.030$, ICC for school = 0.13; Fig. 4A & B, αpath).

3.1. *Mediation effects*

Aerobic fitness satisfied all steps for mediation in the PAL

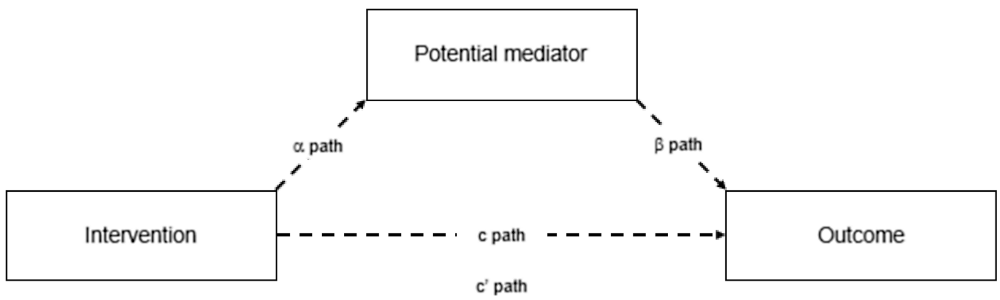

Fig. 1. The hypothesized mediation model. c path: Intervention effect (mean difference in change between intervention and control) on outcome (the total effect). α path: Intervention effect (mean difference in change between intervention and control) on mediator of interest. β path: Association between mediator and outcome adjusted for group allocation c' path: The natural direct intervention effect on outcome conditional on holding the mediator variable constant.

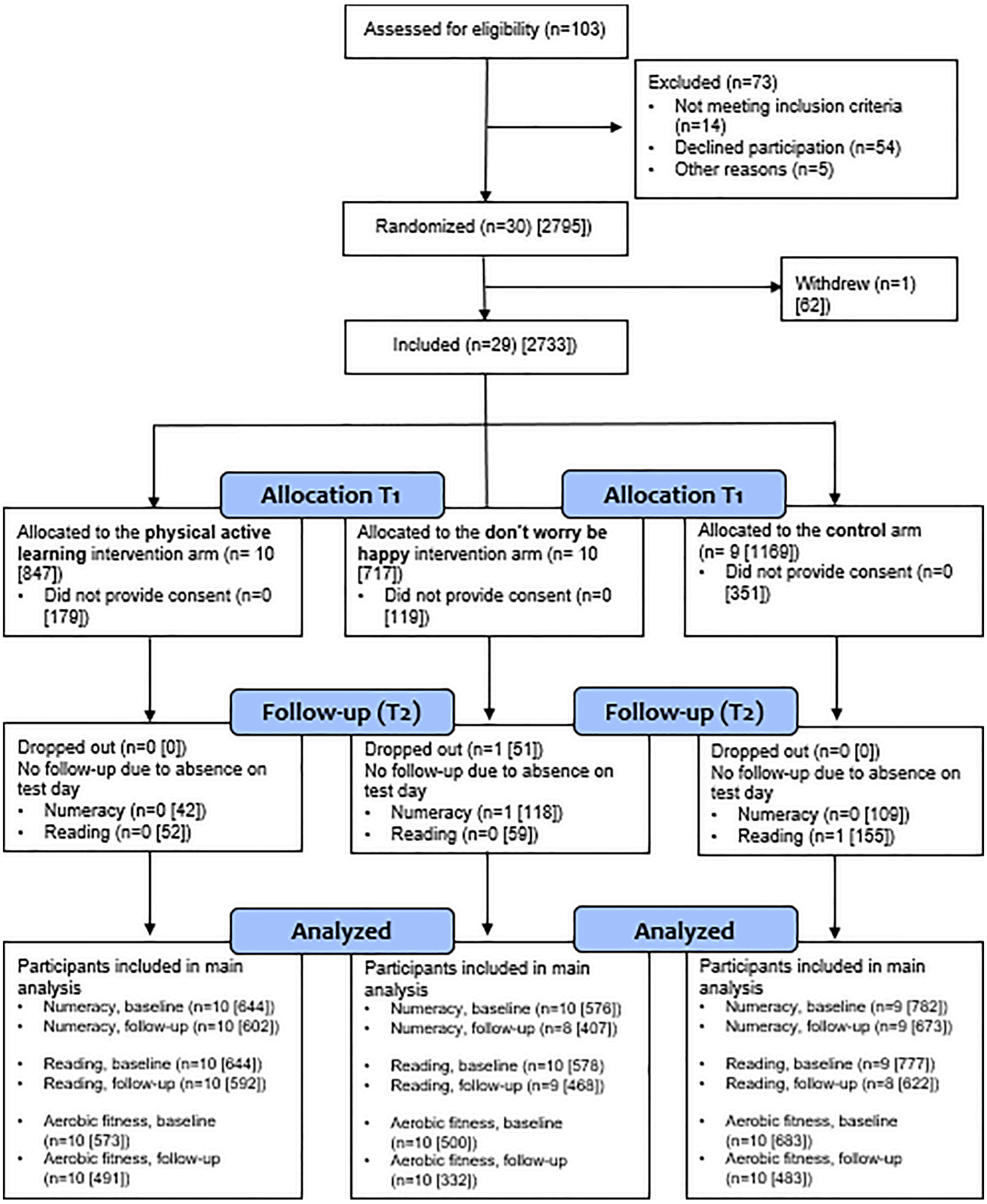

Fig. 2. Flow diagram of the included students (n = schools [students]).

intervention (Fig. 3A & B). For numeracy, aerobic fitness partially mediated the intervention effect by 28% from a total effect (c path) of 1.73 points (95% CI: 1.13 to 2.33) to a natural direct effect (c' path) of 1.24 points (95% CI: 0.58 to 1.91; Fig. 3A). When examining the mediation effect on reading, aerobic fitness fully mediated the intervention effect, with the total effect (c path) of 0.89 points (95% CI: 0.15 to 1.62) reduced to the natural direct effect (c' path) of 0.40 points (95% CI: −0.48 to 1.28) (Fig. 3B). The pattern of results from the main mediation analysis did not change when the analysis was rerun stratified by gender (data not shown).

Aerobic fitness did not mediate the effect of the intervention on academic performance in the DWBH intervention, as the natural direct effect (c' path) was not reduced when compared with the total effect (c path; Fig. 4A & B).

4. Discussion

Whilst our results suggest that PA that improve aerobic fitness mediates the intervention effect on academic performance in the PAL intervention, no evidence supported this in the DWBH intervention.

Table 1
Participants demographic and anthropometric characteristics by group allocation at baseline and follow-up.

	PAL Intervention (n = 655 – 491)		DWBH Intervention (n = 586 – 332)		Control (n = 795 – 483)	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Girls/Boys (%)	50/50	50/50	50/50	50/50	50/50	50/50
Age (year)	13.9 (0.3)	14.9 (0.3)	14.0 (0.3)	14.9 (0.3)	14.0 (0.3)	14.9 (0.3)
Anthropometry						
Height (cm)	164.6 (8.1)	168 (8.3)	166.4 (7.7)	170 (7.9)	165.8 (7.7)	169.7 (7.8)
Weight (kg)	54.2 (10.8)	58.2 (10.9)	56.2 (11.0)	59.9 (10.7)	54.4 (10.5)	58.2 (11.2)
BMI	19.9 (3.1)	20.5 (3.2)	20.2 (3.2)	20.8 (3.0)	19.7 (3.1)	20.1 (3.1)
Aerobic fitness						
Aerobic fitness (m)	894 (101)	925 (108)	909 (111)	909 (90)	928 (102)	940 (92)
Academic performance						
Numeracy (points)	54.9 (10)	55.2 (9)	54.5 (9)	55.0 (9)	55.2 (9)	53.8 (9)
Reading (points)	55.2 (9)	54.7 (9)	54.2 (9)	54.0 (8)	54.8 (10)	53.5 (9)

PAL = Physical active learning; DWBH = Don't worry – Be happy", M = meter. BMI = body mass index.

Specifically, the analysis reveals that aerobic fitness partially mediated the effect on numeracy performance, and fully mediated the intervention effect on reading performance, in the PAL intervention.

The results showing that aerobic fitness can mediate the relationship between PA and academic performance agree with some cross-sectional findings (Kyan et al., 2019; Lambourne et al., 2013; Visier-Alfonso et al., 2021) though there are conflicting results within the literature (Aadland et al., 2017; Kwak et al., 2009). The assumption that aerobic fitness may be a key factor in increasing academic performance among adolescents is supported by results from a longitudinal study where adolescents classified as aerobically fit had higher academic performance when compared with their aerobically unfit peers (Sardinha et al., 2016). Importantly, the same study also reported that students who were categorized as unfit at baseline, but improved their fitness during follow-up, observed a positive impact on academic performance (Sardinha et al., 2016).

Some mechanisms might explain why aerobic fitness mediated the effect of the intervention on academic performance in the PAL intervention. The increase in PA and aerobic fitness observed is associated with enhanced cerebral capillary growth, blood flow, and nerve cells in the hippocampus, which in turn are associated with learning and memory related to academic performance (Chaddock et al., 2011; Hillman and Biggan, 2017). Higher aerobic fitness can increase communications between neurons and integration of regions that support academic performance (Chaddock-Heyman et al., 2016). Research has also shown that PA and aerobic fitness enhance the synthesis of brain-derived neurotrophic factor, which is associated with increased volume of the hippocampus and improved memory (Cotman et al., 2007; Erickson et al., 2011). Hence, the indirect impact of the intervention on academic performance via aerobic fitness might be due to the positive relationship between aerobic fitness and the physiology of the brain.

We cannot disentangle the effect of the different components in the PAL intervention; the three components in tandem may explain the mediation role of aerobic fitness on the intervention effect on academic performance. The teachers were encouraged to perform activities of moderate to vigorousintensity, which in turn could have enhanced the student's aerobic fitness. Further, if we assume that most students in Norwegian lower secondary schools learn reading and numeracy skills through screen-based devices and lessons in the traditionally sedentary form, it is plausible that the components in the PAL intervention, in addition to enhancing aerobic fitness, also resulted in students being more focused in these learning situations and therefore taking better advantage of the lessons (Daly-Smith et al., 2018; Norris et al., 2020; Sneck et al., 2019).

The context of the components in the PAL intervention may explain why the mediation effect differed between numeracy and reading performance. As the structure and material of numeracy lessons make it suitable to incorporate into the PAL components, it is plausible that the partial mediation effect on numeracy is because the students practised numeracy related task while being active, thus, increased numeracy performance could not solely be explained by increased aerobic fitness. In comparison, the reading curriculum is more difficult to incorporate into the PAL components, which makes the argument that the intervention effect on reading was a result of their increase in aerobic fitness and not only the change in PA.

In the DWBH intervention, aerobic fitness did not mediate the intervention effect on academic performance. It is reasonable to believe that the lack of mediation is connected to the lack of significant intervention effect on PA and aerobic fitness. Therefore, the positive intervention effects we found on academic performance among students in the DWBH intervention are likely explained by other factors. We can only speculate about these factors. However, it is plausible that the self-selected activities chosen in the DWBH intervention may minimize fatigue and boredom, and lead to higher levels of self-efficacy, which in turn could optimize the students' academic performance (Fedewa and Ahn, 2011). Another possible explanation is that the varied PA provided throughout the curriculum can enhance enjoyment related to academic subjects and therefore stimulate higher motivation and engagement with theoretical subjects. The activities could also encourage students to cooperate with classmates, employ strategies, and adapt to changing task demands, which may create a more stimulating learning environment.

5. Strengths and limitations

The large sample size and cluster RCT study design are among strengths of this study as we can add causal evidence to the current literature. However, strong assumptions need to be met when conducting mediation analysis. To demonstrate causal pathways of the intervention effect, the intervention–outcome, intervention–mediator, and mediator–outcome must be unconfounded (VanderWeele, 2016). Even though ScIM was a cluster RCT and schools were randomly assigned to one of three groups, we cannot warrant that the intervention–outcome and intervention–mediator are unconfounded. Importantly, the students were not randomized to receive or not receive the mediator, thus the mediator–outcome may still be confounded. Potential confounders not measured in the study includes pubertal development and cognition. Additionally, we cannot exclude the possibility of random measurement error affecting our results. Even though our measurement of aerobic fitness is valid in this age group, students were meant to run to voluntary exhaustion, and whether the students worked hard enough to get a valid test was subjectively judged by trained test personnel. Peak oxygen consumption (VO2peak) would probably be more sensitive to changes in aerobic fitness than the shuttle run test, but those measurements require more resources (Aadland et al., 2018), which we did not have in our study. Random measurement error in the

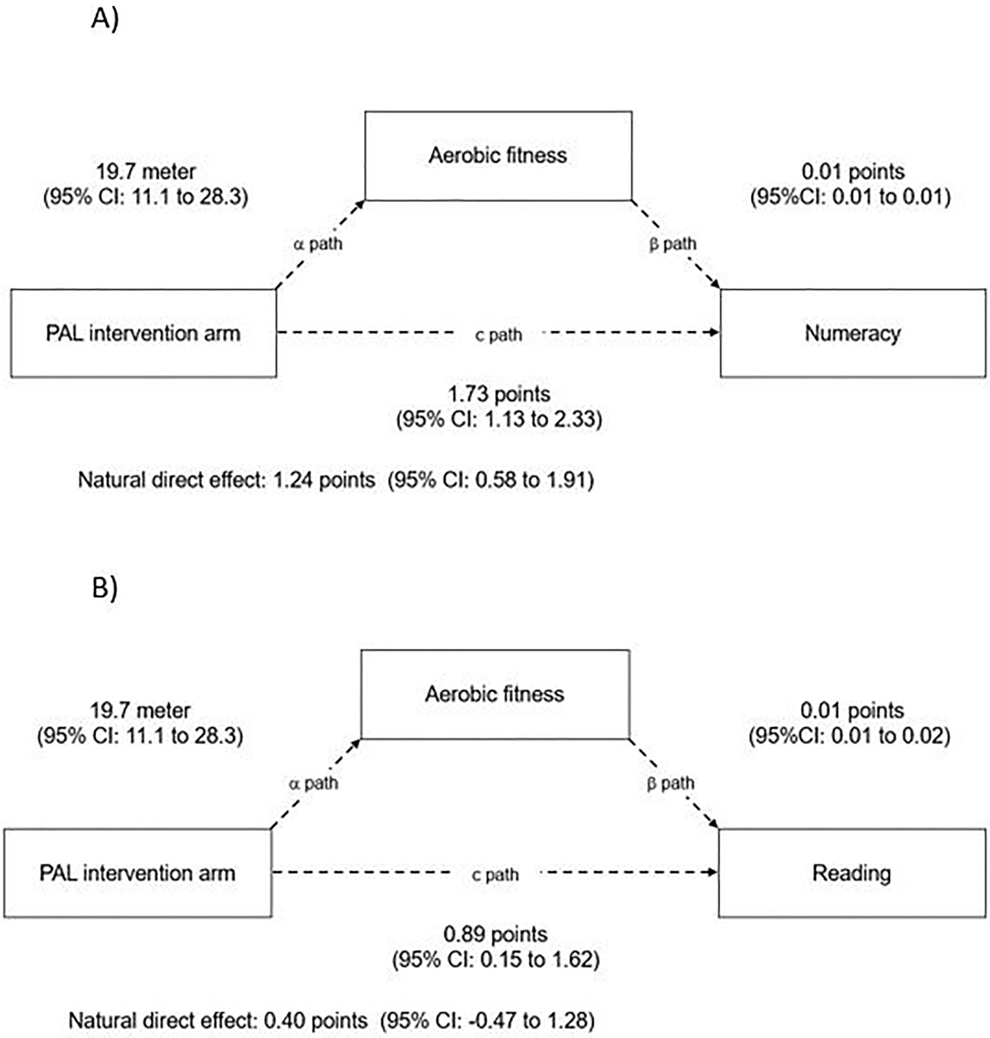

Fig. 3. Models of the mediation effect of aerobic fitness on the intervention effect (mean difference in change (c and c' path)) onA) numeracy and B) reading performance among students in the Physically Active Learning (PAL) intervention arm when compared with controls. All coefficients are unstandardized. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention × time interaction, in addition to random effects for school, class and subject ID. All models are adjusted for gender. CI: Confidence interval. Intra Class Correlation Coefficient for school (ICC)s: Model A: ICC: 0.04, Model B: ICC: 0.09.

measurement of PA and aerobic fitness may lead to regression dilution bias, which biases the estimates of regression models coefficients towards the null. Furthermore, even though we used a standardized national test for measuring academic performance, the validity of the test is unknown, which could affect the standard error of the estimates and widen the corresponding confidence intervals. Despite the importance of highlighting how statistical assumptions and random measurement error could have led to an underestimation of the pathways between the mediator and the outcome, it does not solely invalidate our findings. Finally, in line with most school-based PA interventions, the ScIM study did not include a non-active control group. Control schools performed the mandatory amount of PE; hence our findings need to be interpreted as the effects of additional school-based PA, and not of the individual effects of PA per se.

6. Implications and future perspective

Although the potential mediator confounding and measurement errors entail that the results presented in this study need to be interpreted with caution, the findings suggest that in school-based interventions, physical activities of an intensity that increases aerobic fitness should be emphasized when we are aiming to increase adolescents' academic performance. As school-based PA interventions in general often consist of several different components, it is in many cases unclear whether it is one specific component or the combination of several that is necessary for the effects observed. Future research should focus on specific components and intensities of PA, which may help reduce the intervention length and costs, and provide more nuanced knowledge of how school-based PA interventions affect academic performance.

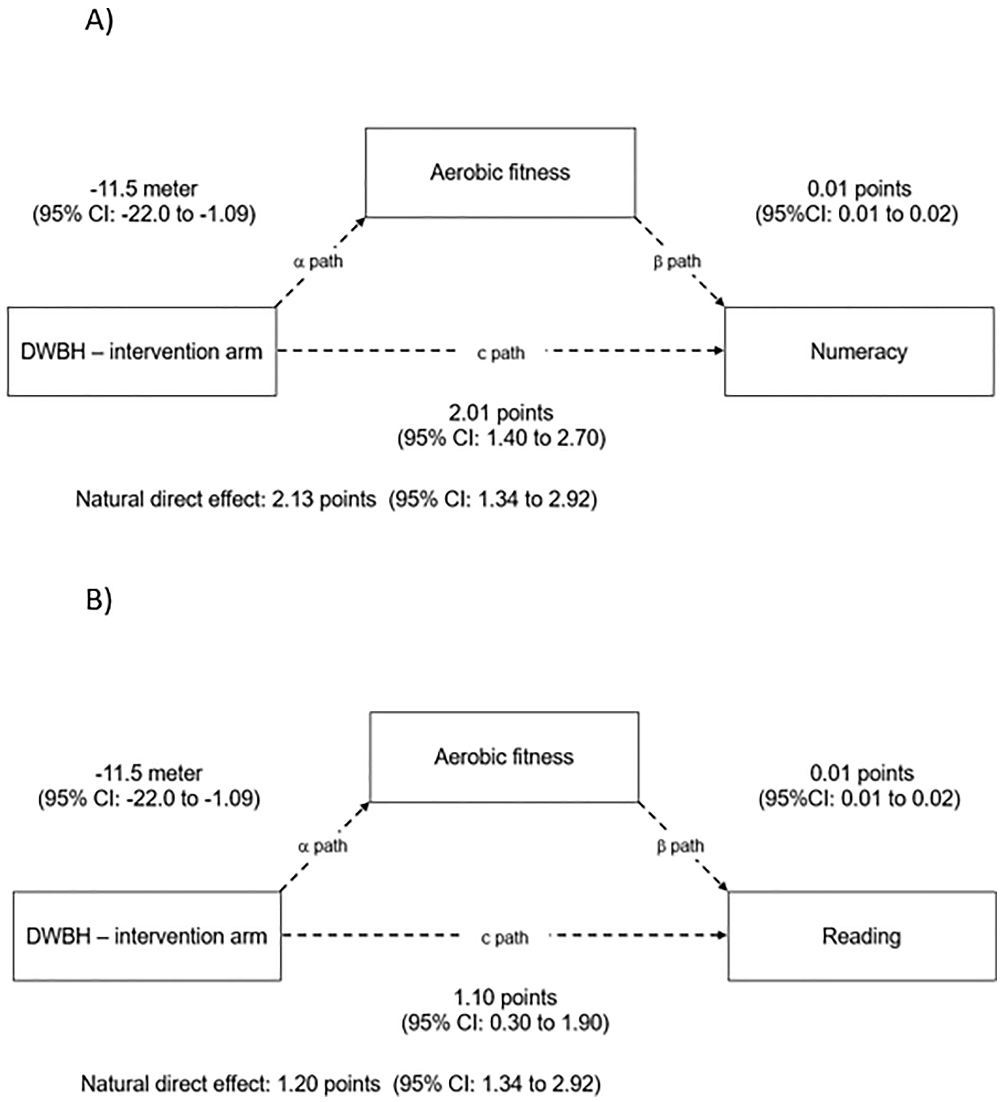

Fig. 4. Models of the mediation effect of aerobic fitness on the intervention effect (mean difference in change (c and c' path)) on A) numeracy and B) reading performance among students in the Don't worry – be happy (DWBH) intervention arm when compared with controls. All coefficients are unstandardized. Each model contained fixed effects for intervention, time (baseline – follow-up) and intervention × time interaction, in addition to random effects for school, class and subject ID. All models are adjusted for gender. CI: Confidence interval. Intra Class Correlation Coefficient for school (ICC)s: Model A: ICC: 0.08, Model B: ICC: 0.10.

7. Conclusion

With its cluster randomized design and corresponding results, our study adds causal evidence of the potential mechanism on how school-based intervention can affect academic performance. If aiming to increase academic performance, school-based PA interventions that leads to increased aerobic fitness may be particularly beneficial. Further investigation is needed to identify the pathways through which interventions focusing more on the social aspect of PA rather than dose and intensity, can influence academic performance.

CRediT authorship contribution statement

Runar Barstad Solberg: Project administration, Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Jostein Steene-Johannessen:** Conceptualization, Supervision, Writing – review & editing. **Morten Wang Fagerland:** Analysis, Writing – review & editing. **Sigmund A. Anderssen:** Writing – review & editing. **Sveinung Berntsen:** Writing – review & editing. **Geir K. Resaland:** Writing – review & editing. **Esther M.F. van Sluijs:** Conceptualization, Supervision, Writing – review & editing. **Ulf Ekelund:** Writing – review & editing. **Elin Kolle:** Conceptualization, Supervision, 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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Availability of data and material

The datasets generated and/or analyzed during the current study are not publicly available as publications are planned but are available from the corresponding author on reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2021.101648.

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Paper IV

Teacher-reported contextual factors are not associated with the intervention dose delivered: A quantitative implementation assessment of a school-based physical activity intervention

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Abstract

Teachers usually act as the implementors of school-based physical activity interventions and is essential for success. The present study investigates the associations between teacher-reported contextual factors and the intervention dose delivered in the School in Motion (ScIM) study. The contextual factors were selected from the Consolidated Framework for Implementation Research. Measurements were conducted online, after baseline and randomization but before intervention implementation. Intervention dose was reported weekly by teachers online and presented in percentage of maximum dose delivered. In total 56 teachers from 19 intervention schools took part. Schools in the ScIM study delivered approximately 80% of the intended dose. In general, teachers reported detailed knowledge and positive attitudes towards the intervention, supporting school culture, enough time and training. The linear mixed models in the main analysis showed no associations between intervention dose delivered and teachers self-reported knowledge and beliefs (regression coefficient -0.8, 95% confidence interval (CI) -4.1 to 2.3), school culture (-1.0, 95% CI -3.9 to 1.7), available time (0.6, 95% CI -2.0 to 3.3) and teacher training (0.8, 95% CI -2.2 to 3.8). Hence, arrange for a positive school and teachers' culture early in the intervention, while provide enough time and teacher training is important for dose delivered.

Keywords: School-based physical activity, implementation, dose delivered, teachers, CFIR, lower secondary school

Background

School-based physical activity interventions have been implemented to increase physical activity levels among children and adolescents (Corder et al., 2020; Dobbins, Husson, DeCorby, & LaRocca, 2013; Kriemler et al., 2011; Resaland et al., 2016; Tarp et al., 2016). These interventions often consist of a diverse portfolio of physical activity components, such as physically active learning, physical education and active breaks. This diversity makes school-based interventions complex and time-consuming to implement (Russ, Webster, Beets, & Phillips, 2015).

Dose delivered, which refers to how much of the intervention is delivered, has been identified as a key concept of implementation (Durlak, 2016; Steckler & Linnan, 2002). The complex nature of school-based physical activity interventions may lead to poor implementation and an inadequate dose delivered. This could partly explain why such interventions are often unsuccessful in increasing physical activity levels among children and adolescents (Hartwig et al., 2021; Love, Adams, & Sluijs, 2019).

Classroom teachers usually act as the implementors of school-based physical activity interventions (Nielsen, Bredahl, Bugge, Klakk, & Skovgaard, 2019; Russ et al., 2015), and their role is essential for success (Routen, Johnston, Glazebrook, & Sherar, 2018). However, teachers often find implementing a new interventions demanding as it may add an additional workload to their already busy schedules (Ballet & Kelchtermans, 2009). This point was emphasized in two systematic reviews, which examined factors that influenced the implementation of a school-based physical activity intervention (Naylor et al., 2015) and movement integration in elementary classrooms (Michael et al., 2019). Naylor et al. (2015) found that the top seven factors that influenced the implementation of physical activity interventions were related to the classroom teacher. These factors included limited time, competing demands, quality and availability of resources, school climate and the appropriateness of the intervention. Such factors are similar to those identified for movement integration in classrooms (Michael et al., 2019). This underline the need to understand factors related to real-world implementation of school-based interventions (Cassar et al., 2019).

The Consolidated Framework for Implementation Research (CFIR) was first introduced by Damschroder (Damschroder et al., 2009), to help researcher better identify and understand factors influencing an intervention's implementation. The CFIR includes 36 constructs that reflect barriers and facilitating factors regarding implementation, with the constructs grouped into five domains. Teacher-related factors can be conceptualized within three domains, namely *inner setting, characteristics of individuals* and *intervention characteristics* (Damschroder et al., 2009). *Inner setting* refers to the school- and teacher-related culture. It includes the amount of time dedicated for teachers to plan, organize and conduct the intervention components and the extent to which teachers receive training in delivering these components. The *characteristics of individuals* include the teacher's knowledge, beliefs and attitudes towards the intervention, whilst the *intervention characteristics* are key attributes of the intervention. These factors are elements that surround the implementation of an intervention and impact its success (Campbell et al., 2015; Robbins, Pfeiffer, Wesolek, & Lo, 2014). Understanding how these contextual factors relate to the dose delivered can inform the development of strategies to improve the implementation and sustainment of future interventions (Shoesmith et al., 2021). For example, if teacher training were to be identified as a key implementation contextual factor, future interventions could target teacher training to increase the dose delivered.

The aim of this study was to investigate the associations between teacher-reported implementation contextual factors and the intervention dose delivered in a school-based intervention study to increase physical activity in adolescents called the School in Motion (ScIM) study. As a secondary analysis, we examined the association between teachers' knowledge and beliefs about the ScIM study and their perceived effects on students' outcomes.

Methods

Intervention description

Briefly, the ScIM study was a nine-month, three-group, cluster randomized controlled trial that included 30 lower secondary school. Its aim was to evaluate interventions to increase physical activity among Norwegian adolescents. Schools were located in four geographical areas of Norway and were randomly allocated in a 1:1:1 ratio to the following three groups: physically active learning (PAL) intervention (n = 10); 'don't worry-be happy' (DWBH) intervention (n = 10); and a control group (n = 10). One school withdrew after randomization but before baseline testing, leaving nine schools in the control group. The professional who performed the random allocation did not participate in other areas of the study. Neither the participants, schools, or testing personnel who performed data collection in the schools, nor the researchers, were blinded to the allocation. We observed significant intervention effects on physical activity and aerobic fitness in the PAL intervention compared with controls (Kolle et al., 2020), whilst academic performance increased in both interventions compared with control (Solberg et al., 2021).

The core components of the two interventions consisted of 120 min of additional physical activity per week. In the PAL intervention, teachers implemented the following: one additional physical education lesson of 60 min; 30 min of physical activity not related to a particular subject; and 30 min of physically active learning. Teachers in the DWBH intervention group implemented 60 min of additional physical education lesson (60 min) and 60 min of physical activity. The time required for the additional physical activity was derived by allocating 5% of time from other subjects and adding 60 min physical education lesson to the curriculum each week. All schools received €90 per student who attended the school as participation incentive. This amount covered the increased expenses of the additional physical education lesson; hence the controls received the same amount the following year.

To facilitate the ScIM intervention being implemented according to the study protocol, the research group visited intervention schools to introduce ScIM to all staff members before the interventions were implemented. Teachers who were assigned a particular responsibility for implementing the intervention at their schools were invited to a one-day seminar at the university. Here, in-depth information about the two interventions was given together with practical training on how to deliver the components. The seminar also focused on implementing the various intervention components in both indoors and outdoors settings.

Teachers who attended the seminar also acted as a local ambassador and participated in quarterly collaboration meetings between the researchers and the schools. The purpose of these meetings was to bring teachers together to share and discuss the schools' experiences, whether positive or challenging.

The ScIM study was initiated by the Ministry of Health and Care Service, Ministry of Education and Research, Norwegian Directorate for Training and Education and Norwegian Directorate of Health. The Regional Committee for Medical and Health Research Ethics (REK) in Norway, reviewed the ScIM study. The REK determined that, according to the Act on medical and health research (Health Research Act 2008), the study did not require full review by REK. The ScIM study was approved by the Norwegian Centre for Research Data and adhered to the Helsinki Declaration (2008). The study is registered in ClinicalTrials.gov (25/01/2019, ID NCT03817047). This report is prepared according to the STROBE checklist for observational studies (supplementary file 1).

The implementation framework

The contextual factors for implementation were selected from the CFIR (Table 1).

In the *characteristics of individuals* domain teachers reported how satisfied they were with the way in which the aim and interventions in the ScIM study had been introduced to them. This is operationalised as teacher's knowledge and beliefs of the ScIM study. Two questions assessed the *inner setting* domain: one assessed how much the teachers perceived that their school supported them in implementing the intervention; the other assessed whether the teachers perceived that they received enough time to include the intervention components in the normal curriculum. The teachers reported to what extent they agreed with relevant questions. One question assessed *intervention characteristics by* asking whether teachers had received enough training to be able to implement the intervention. Finally, one item assessed teachers' perceived benefits of the interventions. The teachers reported to what extent they believed the intervention could influence the expected outcomes among students, such as their physical health, mental health, school climate and academic performance.

All response scales were as follows: 1 = ‘to a very little extent’, 2 = ‘to little extent’, 3 = ‘to some extent’ and 4 = ‘to a great extent’. The responses are shown as mean (SD) in each domain.

Table 1. Selected constructs from the Consolidated Framework for Implementation Research

Domain	Constructs	Short description
Characteristics of individuals	Knowledge and beliefs about the ScIM trial	Teacher’s individual attitudes towards ScIM and the interventions, after the project was introduced to teaching staff by the research group.
Inner setting	School culture	Teachers’ expectations for support by leaders and colleagues for them to implement the intervention.
Inner setting	Available time	Amount of time the school’s administration gave teachers to plan and deliver the intervention.
Intervention characteristics	Teacher training	Extent to which teachers agreed they had received sufficient training on how to deliver the intervention components before the intervention started.

Participants

All the teachers involved in implementing the intervention were invited to participate in the study. Recruitment was conducted through the schools and the denominator was thus unknown. Power calculation for this study was not performed. In total, 56 teachers from 19 intervention schools responded and gave their written consent to participate.

Measures

Contextualised factors related to implementation

All implementation-related constructs were collected through a teacher questionnaire. The questionnaire was distributed online via SurveyExact. The survey was administrated in one wave during August 2017, after randomization but before the actual intervention began. The questionnaire took approximately 10 minutes to complete.

Dose delivered

The intervention dose that the teachers delivered was reported via an online platform. Each week, one teacher at each school reported the exact number of components that had been performed or not performed. They also reported the intensity and duration of each component. The intervention dose delivered is presented as a percentage of the maximum of the possible delivered intervention components.

Statistical analysis

Data from the teacher survey were imported from SurveyExcact into Stata 16.0 (StataCorp LP) for processing, and all the analyses were performed using this software. Univariate analysis was conducted for the descriptive characteristics and the results are presented as the mean and standard deviation (SD) unless otherwise stated. Intraclass correlation coefficients (ICCs) were calculated for each implementation contextual factor; this test was used to investigate how similar teachers within a school were to one another. Higher ICC indicates higher homogeneity within a school. The dose delivered did not differ statistically between the two intervention groups ($p = 0.689$). Hence, these were combined for the main analysis.

In the main analysis, general linear mixed models were used to examine the associations between selected implementation contextual factors and the intervention dose delivered. Each implementation contextual factor was examined in a separate model. All models included school as a random intercept to account for the nesting of teachers within schools.

Next, in the stratified analysis (stratification by teachers' responses), we assessed whether the dose delivered differed between teachers reporting different responses. That is, we assessed the delivered dose for each category of teacher reported contextualized factor, with those reporting least ('to little extent') as referent. For reporting purposes, the contextual factors were grouped into three categories with response options 1 = 'to a very little extent' and 2 = 'to little extent' merged.

Results

Most of the participating teachers were female (59.6%) and were between 30 and 39 years old (50.1%), as shown in Table 2. The dose delivered ranged from 67% to 93% among the schools. Overall, schools in the PAL intervention group reported delivering 83% of the intended dose, whereas schools in the DWBH group reported 78%.

Teachers reported that they were on average satisfied to some extent with their knowledge and beliefs about the ScIM study, and also that their school culture supported the implementation of the ScIM intervention to some extent (Table 2). The teachers were also either ‘to little extent’ or ‘to some extent’ satisfied with the time given to plan and conduct the intervention components and whether they received enough training from the research group about how to conduct the intervention components.

Table 2: Descriptive characteristics of participants (n=56)

	Total	PAL intervention	DWBH intervention
	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %
Teacher and classroom characteristics			
Female (%)[τ]	34 (60%)	17 (60%)	17 (58%)
20-29 years (%)[τ]	13 (22%)	6 (21%)	7 (24%)
30-39 years (%)[τ]	29 (50%)	17 (60%)	12 (41%)
40-49 years (%)[τ]	10 (17%)	4 (14%)	6 (20%)
50-59 years (%)[τ]	1 (2%)	x	1 (3)
60-69 years (%)[τ]	3 (5%)	1 (3)	2 (7%)
Characteristics of individuals			
Knowledge and beliefs (1 item, range 1-4)	3.1 (0.6)	3.1 (0.6)	3.0 (0.6)
Inner setting			
School culture (1 item, range 1-4)	3.1 (0.7)	3.1 (0.7)	3.1 (0.7)
Available time (1 item, range 1-4)	2.6 (0.7)	2.4 (0.8)	2.8 (0.6)
Intervention characteristics			
Teacher training (1 item, range 1-4)	2.7 (0.6)	2.6 (0.6)	2.8 (0.7)

PAL = Physically Active Learning intervention arm, DWBH = Don’t worry – be happy intervention arm,
[τ] number with the percentage of n

The main analysis showed no associations between teacher-reported implementation contextual factors and the intervention dose delivered (Table 3).

Table 3: Associations between teacher-reported implementation contextual factors and intervention dose delivered

Implementation contextual factors	Unstandardized regression coefficients	95% Confidence interval	P-value
Knowledge and beliefs	-0.84	-4.08 to 2.38	0.608
School Culture	-1.09	-3.93 to 1.74	0.450
Available Time	0.60	-2.09 to 3.29	0.662
Teacher Training	0.81	-2.20 to 3.82	0.598

Mixed model containing school as cluster variable. Responses from n=56 teachers.

When the contextualized factors were split into subgroups of teacher responses, the dose delivered did not differ between groups (Figure 1). Almost all teachers reported that they were to some extent (70%) or a great extent (21%) satisfied with their own knowledge about the ScIM study; the dose these teachers delivered did not differ from that delivered by teachers who reported that they were 'to little extent' satisfied (Figure 1).

The same pattern was observed regarding teachers' perceptions of the school culture and the intervention dose they delivered. Almost 85% of teachers reported that their school had a supportive culture for implementing the ScIM intervention, but the intervention dose they delivered did not differ compared to that of teachers reporting that the school culture only to a little extent supported the implementation (Figure 1).

This pattern of association was again observed regarding the time devoted to planning and conducting the intervention components and the intervention dose delivered. Specifically, 36% of teachers reported that they 'to little extent' received enough time to plan and conduct the intervention according to the study protocol. Nonetheless, there was no difference in the doses they delivered compared with that of teachers who reported that they had enough time to plan and conduct the intervention (Figure 1).

Furthermore, no association was found between dose delivered and the teachers' satisfaction with training before the intervention started. Approximately 22% of the teachers reported that they were 'very little' or 'little' satisfied with the training. However, there was no difference in the doses they delivered compared with the doses delivered by teachers who were satisfied with the training provided by the research group (Figure 1).

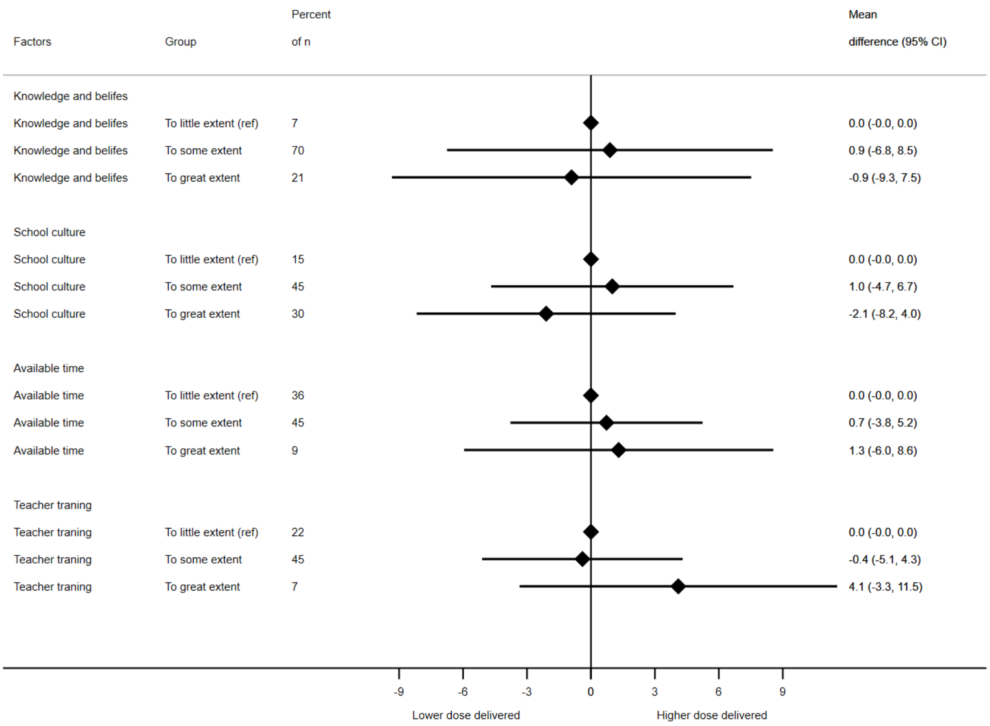

Figure 1 Stratified relationship between the teachers' perceptions of ScIM and the dose delivered. Mixed model containing school as a cluster variable. Responses from n=56 teachers.

Lastly, we examined the association between teachers' knowledge and beliefs about the ScIM study and their perceived effects on students' outcomes (Table 4). The results showed that teachers with greater knowledge were more likely to consider that the ScIM intervention would have an effect on students' physical health ($p < 0.001$), learning environment ($p = 0.002$) and academic performance ($p = 0.012$). Teachers knowledge and believes were not associated with change in students' mental health ($p = 0.052$).

Table 4: Associations between teachers' knowledge about the ScIM study and the perceived outcomes

Expected outcome	Unstandardized regression coefficients	95% Confidence interval	P-value
Enhanced student's physical health	0.47	0.24 to 0.69	<0.001
Enhanced student's mental health	0.26	-0.01 to 0.52	0.052
Enhanced student's learning environment	0.42	0.15 to 0.69	0.002
Enhanced student's academic performance	0.40	0.09 to 0.72	0.012

Mixed model containing school as cluster variable. Responses from n=56 teachers.

Discussion

This paper indicates that none of the teacher-reported contextual factors surrounding implementation were associated with the intervention dose the teachers delivered. Hence, teacher-reported contextual factors in the ScIM study – such as their knowledge and beliefs of the study, their school's culture towards implementing the intervention, the time they were given for planning and implementing the programme and the training they received – did not limit the intervention dose delivered. However, each educational system is unique and differ across countries. The further discussion will contextualise the findings to provide a nuanced dissemination of the findings in this paper.

In the *characteristics of individuals* domain, teachers' self-reported knowledge and beliefs about the ScIM study was not associated with the intervention dose delivered. However, more than 90% of teachers reported that they had either some extent or great knowledge of the ScIM study. This homogeneity may limit the possibility of identifying associations. Furthermore, teachers viewed the ScIM study positively and perceived that the intervention could improve students' physical health, learning environment and academic performance. The latter finding is important, because improving academic standards may have a higher priority for teachers than implementing a new physical activity component in the curriculum (Clarke, Fletcher, Lancashire, Pallan, & Adab, 2013). A motivated classroom teacher who is convinced of the relevance of an intervention for the school's main purpose of academic excellence strongly facilitates the successful implementation of a school-based physical activity programme (Gadais, Caron, Ayoub, Karelis, & Nadeau, 2020). This point was emphasized by Naylor et al. (Naylor et al., 2015) who indicated that linking the perceived benefits of a programme to established goals (such as the teacher's aim of increasing academic performance) is important for successful implementation in schools. This is also underlined in a recent paper where teachers and stakeholders attended a workshop to identify how to successfully implement physically active learning into the school day (Daly-Smith et al., 2020). They argued that physically active lessons provides opportunities to enhance health while also affecting the learning environment (Daly-Smith et al., 2020).

More than 75% of the teachers experienced their school administration and teacher colleagues as supportive. A supportive school culture is an important factor for implementing additional components in the curriculum (Gadais et al., 2020; Naylor et al., 2015). As seen in the dose delivered in ScIM, implementing physical activity interventions in schools can be obtainable when all members of the teaching staff agree to participate in the additional work. However, school leaders' and teachers' attitudes towards physical activity are likely to vary, and interventions should be easy to implement and not compromise traditional teacher responsibilities. At the same time, students' academic standards and learning processes should be improved (Webster, Russ, Vazou, Goh, & Erwin, 2015; Webster et al., 2017). For example, Lerum et al. (2019) reported that school-based physical activity interventions in primary schools influenced teachers' perspectives about teaching and provided professional spaces for development. Thus, teachers may experience personal development through introducing new teaching methods, including physical activity components in the curriculum. However, for this to happen it is important that the school culture supports teachers and builds their confidence to deliver the physical activity components. Fear of delivering physical activity components, and especially physically active learning, could lead to lack of creativity and innovation in teacher practice (Daly-Smith et al., 2020).

The ScIM study involved interventions that were arguably technically demanding as well as time-consuming for school administration and classroom teachers. Therefore, all schools received €90 per student to account for increased expenses related to incorporating the intervention into the normal curriculum. Generally, it is not reported whether similar resources were given to schools in comparable studies. It is possible that these funds could have led to a better foundation for schools in the ScIM study to implement the intervention components and provide enough and motivated staff. It is known that competing assignments and teacher overload are common in schools (Ballet & Kelchtermans, 2009). The time allocated to increased physical activity must be viewed as an investment rather than a barrier (Mullins, Michaliszyn, Kelly-Miller, & Groll, 2019). Time – or the lack of it, has been reported as a main factor for teachers being unable to implement physical activity interventions in the curriculum (Dyrstad, Kvalø, Alstveit, & Skage, 2018; Michael et al., 2019; Naylor et al., 2015). However, this point does not resonate with our findings. More than half the teachers in our study reported that they were satisfied with the time devoted to planning, organizing and conducting the intervention components. Providing teacher with competence on how to incorporate physical activity in the school day may reduce the amount of preparation required (Daly-Smith et al., 2020), which could be one explanation of the high dose delivered in ScIM.

Finally, we found no associations between teacher training and intervention dose delivered. However, there is a trend in our results, even though not significant, that teachers reporting being satisfied to great extent with the teacher training given by the research group, delivered higher dose than others. Given the low power of these analyses, these positive perceptions about the training may have been associated with greater implementation. This may be of importance as teacher have reported that minimal training may a potential barrier for effectively incorporate physical activity into the curriculum (Daly-Smith et al., 2020). One important aspect of the ScIM study was that the implementation and progress of the two interventions should be viable without active involvement by the research team. Hence, teachers at the intervention schools received minimal training, attention and follow-up during the actual intervention period. However, the teachers were satisfied with the training they received, and they felt capable and qualified to handle and conduct the intervention components. As such, to overcome competing priorities in the school setting, such as limited time and teacher overload, it is necessary to provide quality training, materials and additional resources to ensure that the schools are fully prepared to implement the interventions.

Strengths and limitations

The strengths of this study included evaluating the implementation of a school-based physical activity intervention in lower secondary schools. Most studies on the implementation of school-based physical activity interventions have been conducted in primary schools, and the lower secondary school context is understudied. This paper therefore adds important knowledge in an understudied population and school-context. Furthermore, the weekly assessment of dose delivered is a major strength. Finally, the study used the CFIR (Damschroder et al., 2009) as a framework to evaluate the implementations; however, other unmeasured contextual factors might also be important in explaining the implementation.

Limitation of the study was the method used to assess teacher-reported implementation contextual factors. One way to accommodate this would have been through the use of a more comprehensive process evaluation with a mixed-methods approach (Jong et al., 2020). The survey data were collected before the intervention but after the schools had organized the components and had arranged additional resources to comply with the study protocol. Furthermore, because the questionnaire distribution was managed by appointed classroom teachers, we lacked information about how many eligible teachers received the questionnaire. Thus, selection bias might have occurred, and it is possible that only the most interested, engaged and outspoken teachers may have responded. Furthermore, the dependent variables, namely, ‘implementation contextual factors’, relied on teacher self-reports. This is an imprecise measure and is potentially subject to social desirability bias. Furthermore, fidelity was not systematically measured through the intervention period. Therefore, the research team lacked knowledge of whether the intervention models were implemented as intended.

Lessons learned

The first lesson we learned was the value of dedicating time and efforts to enhance teachers detailed knowledge of the interventions. This resulted in teachers viewing the interventions as a tool to enhance students’ academic performance and learning environment, and not as a time thief. Without this it would be difficult to allocate time from traditional subjects to physical activity. The second lesson learned is the importance of a supportive school culture. Implementing physical activity components into the curriculum can be demanding for teachers. Hence, a supportive school culture can build teachers confidence to deliver the components as planned, in addition to ensure that teachers got devoted enough time to implement the components. The final lesson learned is that detailed training in tandem with high quality material ensure that schools and teacher are fully prepared to implement the intervention. Thus, teachers do not need to choose between increased physical activity in the curriculum or upholding academic standards.

Conclusions

This study provided insight into the implementation of a school-based physical activity intervention in lower secondary schools. Teachers reported in general detailed knowledge and positive attitudes towards the intervention, supporting school culture and enough training and resources. Neither of the teacher-reported contextual factors were associated with intervention dose delivered although the homogeneity of the responses may limit the possibility of identifying associations. Hence, adapting for a positive school and teachers’ culture early in the intervention, while provide enough resources and teacher training may be important for dose delivered.

Acknowledgements

We are grateful to all the teachers who participated in this study for their time and effort allowing us to complete this study. A special thanks goes to the teachers at the intervention schools for the great job they did in delivering the physical activity intervention. We would also like to thank all students and research assistants who participated in the data collection. We are also grateful to the ScIM Study group; Lena Malnes Hansen (University of Agder); Eva Leibinger (University of Stavanger); Andreas Åvitsland (University of Stavanger).

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Supplementary file 1

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2/3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4/5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5/6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5/7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5/7*
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5/6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*e*) Describe any sensitivity analyses	7
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
Outcome data	15*	Report numbers of outcome events or summary measures	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9/10
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13/14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Appendix

Appendices

Appendix 1:

Approval letter from the Norwegian Social Science Data Service

Elin Kolle
Seksjon for idrettsmedisinske fag Norges idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 01.09.2016 Vår ref: 49094 / 3 / ASF Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 29.06.2016. All nødvendig informasjon om prosjektet forelå i sin helhet 31.08.2016. Meldingen gjelder prosjektet:

49094	*Utprøving og evaluering av modeller for fysisk aktivitet for elever i ungdomsskolen*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Elin Kolle*

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, 01.01.2019, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Kjersti Haugstvedt

Amalie Statland Fantoft

Kontaktperson: Amalie Statland Fantoft tlf: 55 58 36 41
Vedlegg: Prosjektvurdering

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

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 49094

REK
Forskergruppen har søkt godkjenning fra REK, men fikk tilbakemelding om at prosjektet ikke er helseforskning

FORMÅL OG BAKGRUNN
Som et ledd i å skape et bedre kunnskapsgrunnlag for framtidig arbeid med fysisk aktivitet på ungdomstrinnet, er det i "Folkehelsemeldingen - Mestring og muligheter" definert at det skal igangsettes et forsøk på ungdomsskolen der man skal se på effekten av økt fysisk aktivitet (FA) på utvalgte variabler. Hensikten med dette prosjektet er derfor å gjennomføre en randomisert kontroller studie (RCT) for å undersøke om to timer ekstra med FA/kroppsøving ukentlig har effekt på helse, læring og læringsmiljø blant elever på 9. trinnet. Intervensjonen skal gjennomføres over ett skoleår, og elever på 30 skoler vil bli inkludert.

Studien gjennomføres på oppdrag for Utdanningsdirektoratet, Helsedirektoratet, Kunnskapsdepartementet og Helse- og omsorgsdepartementet.

SAMARBEIDSSTUDIE
Prosjektet er en nasjonal samarbeidsstudie mellom Norges idrettshøgskole, Høgskolen i Sogn og Fjordane, Universitetet i Agder og Universitetet i Stavanger. Norges idrettshøgskole er behandlingsansvarlig institusjon. Personvernombudet forutsetter at ansvaret for behandlingen av personopplysninger er avklart mellom institusjonene. Vi anbefaler at det inngås en avtale som omfatter ansvarsfordeling, ansvarsstruktur, hvem som initierer prosjektet, bruk av data og eventuelt eierskap.

METODE
Studien vil gjennomføres som en randomisert kontroller studie (RCT). Det inkluderes elever fra 30 ungdomsskoler totalt, og for to tredjedeler av skolene vil det gjennomføres en intervensjon, mens en tredjedel vil fungere som kontrollskoler. Intervensjonen består av utvidet tid til fysisk aktivitet i løpet av en skoleuke.

Intervensjonsskolene blir tildelt en av to modeller, hvorav modell 1 kalles «aktiv læring». Modell 1 består av følgende komponenter i løpet av en skoleuke:

- En ekstra kroppsøvingstime (KRØ-time) pr uke. All aktivitet vil gjennomføres i tråd med gjeldende læreplan. Timen ledes av skolens kroppsøvingslærer.
- Aktiv læring. Undervisningstimer i fag (feks matematikk og norsk) der det pedagogisk didaktiske metodevalget er gjennom faglige aktiviteter utendørs. Det skal gjennomføres 30 minutter per uke.
- Fysisk aktivitet. Timeplanfestet tid til fysisk aktivitet som ikke er koblet mot fag. Det skal gjennomføres 30 minutter med fysisk aktivitet per uke.
- Aktiv pause. Daglige pauser fra stillesittende tid organisert som 5 minutters klasseroms aktivitet en gang i løpet av dagen. Dette blir ledet av faglærer.

Modell 2 er basert på en ekstra obligatorisk kroppsøvingstime per uke, en ekstra obligatorisk time per uke til bevegelsesaktivitet samt mulighet for ytterligere (frivillig) aktivitet etter skoletid.

Intervensjonen skjer i samsvar med skolens ledelse og blir en obligatorisk del av elevens skolehverdag. Aktivitetene i intervensjonen er ikke vurdert til å være forbundet med risiko, og kan sammenlignes med aktiviteter og metoder nyttet i en vanlig kroppsøvingstime.

For å teste effekten av intervensjonen, vil elevene gjennomføre tester ved oppstart og avslutning av 9.trinn.

For elever ved kontrollskoler vil det ikke gjennomføres økt fysisk aktivitet, og skoleåret vil gå som normalt, men elevene vil gjennomføre tester ved oppstart og avslutning av 9. trinn

Selve studien vil gå over to år, der det første året (2016-17) brukes til pilottesting før den randomiserte kontrollerte studien vil bli gjennomført skoleåret 2017-18.

UTVALG
I hovedstudien vil det inngå omtrent 1800 ungdommer fra 9.klasse i utvalget. Utvalget i prosjektet vil bli gjort ved klyngeutvelgelse, der den primære klyngeenheten er skole. Når en skole takker ja til å delta i prosjektet vil alle i 9. trinn på skolen bli invitert til å delta. Skolen blir randomisert til enten intervensjon eller kontrollgruppe. Dette uttrekket gjøres av en nøytral tredjepart, og den gjøres basert på liste over ungdomsskoler i det aktuelle distriktet.

Skoler som allerede tilbyr utvidet tid til fysisk aktivitet vil ekskluderes fra deltakelse i prosjektet. Dette gjelder ikke for skoler hvor det kun i liten grad er tilrettelagt for utvidet tid til fysisk aktivitet.

Skolene som blir randomisert til kontrollgruppen vil få tilbud om intervensjonsinnholdet året etter at studien er avsluttet, og de vil også få økonomiske ressurser fra Utdanningsdirektoratet for å øke antall kroppsøvingstimer.

I pilotstudien vil det inngå omtrent 900 ungdommer fra 9.klasse i utvalget. I pilotstudien inviterer prosjektet interesserte skoler til deltakelse. Dette blir dermed et bekvemmelighetsutvalg.

INFORMASJON OG SAMTYKKE
Det er foreldre til ungdommene og ungdommene selv som skal samtykke til deltakelse. Informasjonsskriv mottatt 26.08.2016, er godt utformet.

Forskergruppen har også utviklet et informasjonsskriv til ungdommene hvor begrep som anonymitet, konfidensialitet og samtykke er forklart på en måte som er tilpasset ungdommene. I skrivet er det også lagt vekt på at deltakelsen i prosjektet er frivillig for ungdommene selv om foreldrene har samtykket, og at ungdommene kan trekke seg når som helst uten konsekvenser. Personvernombudet mottok informasjonsskrivet til ungdommene på e-post 14.08.2016.

Vi forutsetter at lærerne og andre ansatte på skolene informeres om prosjektet. Videre legger vi til grunn at alle som inkluderes i prosjektet (ansatte på skolene, testpersonale etc.) skriver under på en taushetserklæring.

DATAMATERIALETS INNHOLD
For å evaluere effekten av intervensjonen skal det gjennomføres fysiske og psykiske tester. Testene skal gjennomføres på både intervensjonsskolene og kontrollskolene. Testene gjennomføres i skoletiden på hver enkelt skole, og vil bli gjennomført av erfarent testpersonell. Dette er tester med lav eller ingen risiko for skader, og samtlige tester/registreringer er gjennomført og kvalitetssikret i flere tilsvarende studier. Alle elever som deltar i studien vil bli testet før intervensjonen starter, og etter intervensjonen er fullført.

FYSISKE TESTER

Fysisk aktivitet:
- Prosjektet måler fysisk aktivitetsnivå ved bruk av et akselerometer. Hver deltaker vil bære akselerometeret i et belte rundt livet i 7 påfølgende dager.
- Forskergruppen skal også utvikle spørreskjema for å få informasjon om type aktivitet og konteksten aktiviteten skjer i, noe data fra akselerometeret ikke gir svar på.

Helserelatert fysisk form:
- Utholdenhet måles ved en løpetest validert for den selekterte aldersgruppen.
- Muskelstyrke måles ved: i) Utholdende styrke i overkroppen: sit-ups, ii) Styrke i overkroppen: gripestyrke og iii) Eksplosiv styrke i underekstremiteten: stille lengde.
- Kroppssammensetning måles ved: høyde, vekt og maveomkrets.

PSYKISKE TESTER

Psykiske plager:
- Prosjektet vil benytte seg av screeningsinstrumentet Strength and Difficulties Questionnaire (SDQ). Instrumentet har 25 spørsmål og dekker temaområdene emosjonelle symptomer, atferdsproblemer, hyperaktivitet/oppmerksomhetsproblemer, problemer i relasjon til venner og prososial atferd.
- Prosjektet vil også benytte Hopkins symptom check list (HSCL). HSCL regnes for å være et godt verktøy for kartlegging av psykisk helse. Spørsmålene i skjemaet besvares på en firdelt skala: "ikke plaget", "litt plaget", "Ganske plaget" og "Veldig plaget".

Livskvalitet:
- For å måle helserelatert livskvalitet vil prosjektet gjennomføre KIDSCREEN. Dette er et spørreskjema hvor elevene skal svare på 27 spørsmål som omhandler fysisk og emosjonell velvære, selvfølelse og forhold til famille, venner og skole. Spørsmålene besvares på en fempunkts-skala.

Selvbilde:
- For å måle selvbilde til elevene vil prosjektet bruke Harters Self-perception Profile for Adolescents (SPPA). SPPA består av 35 spørsmål knyttet til generelt, sosialt, fysisk og atletisk selvbilde.

Alle de psykiske testene inngår i det vedlagte spørreskjemaet.

LÆRING
Læring måles ved følgende registerdata og undersøkelser:

Elevundersøkelsen:
- Trivsel
- Motivasjon
- Hjem-skole
- Støtte fra lærerne
- Vurdering for læring
- Medvirkning
- Trygt miljø
- Medbestemmelse
- Arbeidsmiljø

Nasjonal utdanningsdatabase(NUDB):
-Nasjonale prøver:
  o Regning
  o Lesing
-Foreldres høyeste utdanning

SSB søkes om tilgang til NUDB for de data som ligger der, og Utdanningsdirektoratet (Udir) søkes om tilgang til Elevundersøkelsen.

Prosjektgruppen skulle opprinnelig ha informantenes karakterer fra Nasjonal utdanningsdatabase (NUDB). På e-post mottatt 14.08.2016, informerte forsker at de har gått vekk i fra dette ettersom det allerede inngår som et spørsmål i spørreskjemaet.

LÆRINGSMILJØ
For å måle læringsmiljø, som defineres som kulturelle, relasjonelle og fysiske forhold på skolen, vil prosjektet benytte Classroom Climate Scale. Skjemaet består av 22 spørsmål som besvares på en firedelt skala. Lærere vil også besvare en lærerversjon av dette skjemaet som består av 14 spørsmål.

I tillegg vil læringsmiljø måles gjennom spørsmål om læringsmiljø og trivsel på skolen.

SPØRREUNDERSØKELSE
De objektive målingene suppleres med data innsamlet gjennom spørreskjema. I spørreskjemaet vil det inngå spørsmål om bakgrunnsfaktorer, type aktivitet, transport til og fra skole samt inaktiv tid (stillesittende aktiviteter, PC- og TV-vaner). Spørreskjemaet inkluderer også spørsmål om søvn og helsevaner som røyking/snus og alkohol.

Datamaterialet vil omfatte sensitive opplysninger om etnisitet og helseforhold, jf. personopplysningsloven § 2 punkt 8 a og c.

INFORMASJONSSIKKERHET

Data fra Elevundersøkelsen sendes SSB før kobling, og SSB kobler data fra Elevundersøkelsen og NUDB. Datamaterialet som samles inn av forskergruppen sendes til SSB med personnummer/ID-nummer og SSB kobler data fra NUDB, Elevundersøkelsen og innsamlet data i prosjektet med personnummer/ID-nummer. Deretter anonymiserer SSB data og sender den tilbake til prosjektet. SSB generer og oppbevarer koblingsnøkkelen. Utvalget er blitt informert om hvordan koblingen skal gjennomføres, og samtykker til dette.

Datamaterialet lagres på et nettverksområde tilhørende NIH som er passordbeskyttet. I tillegg vil datamaterialet være passordbeskyttet. PC oppbevares i låsbart rom.

Kun Elin Kolle (prosjektleder, NIH), Sigmund Anderssen (NIH), Reidar Säfvenbom (NIH), Ulf Ekelund (NIH), Runar B Solberg (NIH), Jostein Steene-Johannessen (NIH, Høyskolen Kristiania), May Grydeland (NIH), Geir Kåre Resaland (HiSF), Sveinung Berntsen (UiA), Sindre Dyrstad (UiS) og Åse Sagatun (RBUP) skal ha tilgang på data.

BARN I FORSKNING

Utvalget i prosjektet er barn, og det er viktig at forskningsprosjektet utføres på en måte som ivaretar informantene på en forsvarlig måte.

Prosjektet innebærer intervensjoner hvor effekten skal testes på en relativt omfattende måte. I tillegg blir intervensjonene en del av den obligatoriske skoledagen til elevene på intervensjonsskolene. Det er imidlertid frivillig å bli testet. Elevene som ikke har samtykket til å testes, vil gjennomføre ordinær undervisning når testene pågår.

Vi vurderer at det er lagt stor vekt på elevenes frivillighet til deltakelse i forskningsprosjektet. Eksempelvis skal elevene motta egne informasjonsskriv som forklarer begrep som frivillighet, anonymitet og konfidensialitet på en forståelig måte. Personvernombudet mottok dette informasjonskrivet på e-post 14.08.2016. Vi forutsetter at elevene minnes på at alle testene er frivillig når disse skal utføres.

Videre skal prosjektet samarbeide tett med skolehelsetjenesten for å sikre at barn med behov for medisinsk eller psykologisk oppmerksomhet blir henvist til egnede omsorgspersoner.

Personvernombudet vurderer at samfunnsnytten i forskningsprosjektet er stor da formålet er å skape et bedre kunnskapsgrunnlag for framtidig arbeid med fysisk aktivitet på ungdomstrinnet. Prosjektet skal altså evaluere om økt fysisk aktivitet og kroppsøving har innvirkning på elevens læring, læringsmiljø, samt fysiske- og psykiske helse. Som det er vist til i studieprotokollen, er det gjennomført lite forskning på feltet, da majoriteten av tidligere lignende studier er utført på barnetrinnet. Kunnskapsgrunnlaget for effekten av fysisk aktivitet på ungdomstrinnet er altså begrenset, og resultatet av forskningen kan være av nytteverdi for samfunnet generelt, samt gruppen det forskes på.

DATABEHANDLER

Dere har opplyst om at dere vil anvende SurveyXact som databehandler. Vi forutsetter at det foreligger en databehandleravtale mellom NIH og SurveyXact.

ANDRE TILLATELSER
Vi ber om at dere ettersender alle tillatelser til personvernombudet@nsd.no.

PROSJEKTSLUTT OG ANONYMISERING
Forventet prosjektslutt er 01.01.2019. Datamaterialet vil da oppbevares med personidentifikasjon til 21.06.2028 for oppfølgingsstudier.

PILOTSTUDIE
I løpet av skoleåret 2016-17 vil studien pilottestes. Et av hovedmålene er å pilotteste de ulike intervensjonsmodellene, i tillegg vil det inkludere utprøving av måleinstrumentene og de ulike testene/undersøkelsene som skal gjennomføres. I piloten vil sju ungdomsskoler i Osloområdet inkluderes. Det vil være omtrent 900 elever som forespørres om deltakelse

Skolene i piloten velges ut til deltakelse. I piloten vil hver intervensjonsmodell testes ut i fem skoler, samt vil to skoler fungere som kontrollskoler.
Deltakerne i pilotprosjektet vil bli testet før og etter intervensjonen, og de samme testene og metodene som skal brukes i hovedstudien vil bli benyttet. I følge studieprotokollen vil forskergruppen følge samme etiske prosedyrer i pilotstudien som i hovedstudien. Det vil innhentes skriftlig samtykke fra elevenes foresatte før inklusjon i pilotprosjektet. Informasjonsskrivet mottatt 22.08.2016, er godt utformet.

Pilotstudien avsluttes 01.01.2019. Data anonymiseres ved prosjektslutt.

OPPFØLGINGSSTUDIE
I følge studieprotokollen er kunnskapen om langtidsvirkninger av skolebaserte fysisk aktivitets- /kroppsøvings intervensjoner ikke tilfredstillende. Det kan derfor bli aktuelt å vurdere langtidseffekter av intervensjonen, og at elevene igjen blir kontaktet på et senere tidspunkt. Utvalget samtykker til å bli kontaktet på ny dersom det blir aktuelt med en oppfølgingsstudie.

Vi minner om at oppfølgingsstudien må meldes til personvernombudet som et nytt prosjekt.

Appendices

Appendix 2:

Informed consents.

Kjære foreldre i 9.klasse skoleåret 2017-18

Forespørsel om deltakelse i forskningsprosjektet

"Utprøving og evaluering av modeller for fysisk aktivitet for elever i ungdomsskolen"

Bakgrunn og formål med prosjektet

Norges idrettshøgskole (NIH) skal i skoleåret 2017-18 gjennomføre et intervensjonsprosjekt blant elever på 9. trinn. En intervensjon betyr i praksis at en innfører noe nytt som man deretter måler effekten av. Hensikten er å evaluere om økt fysisk aktivitet og kroppsøving har innvirkning på elevens læring, læringsmiljø, samt fysiske- og psykiske helse.

Prosjektet gjennomføres på oppdrag fra Utdanningsdirektoratet og Helsedirektoratet, og er et samarbeid mellom NIH, Høgskulen i Sogn og Fjordane, Universitetet i Agder og Universitetet i Stavanger. Vi skal inkludere elever fra 30 ungdomsskoler lokalisert i områdene rundt de fire universitetene og høgskolene. For å måle effekten av økt fysisk aktivitet og kroppsøving skal to tredjedeler av skolene være intervensjonsskoler, mens en tredjedel skal være kontrollskoler.

Hva innebærer deltakelse i studien for deres sønn/datter dersom deres sønn/datter går på en skole som *skal* gjennomføre daglig fysisk aktivitet?

Intervensjonsskolene blir tildelt en av to modeller, hvorav den ene kalles «aktiv læring». I korte trekk består denne modellen av følgende komponenter i løpet av en skoleuke:

- 1 dag x 45 minutter ekstra kroppsøving
- 1 dag x 30 minutter «Aktiv læring» (elevene er fysisk aktive og øver på fag (f.eks. mattebingo))
- 1 dag x 30 minutter fysisk aktivitet (mest mulig fysisk aktivitet på elevens premisser)
- 5 dager x 5 minutter «Aktiv pause» (elevene er aktive 5 minutter i klasserommet hver dag)

Den andre modellen består av følgende komponenter i løpet av en skoleuke:

- 1 dag x 45 minutter ekstra kroppsøving («Don`t worry timen»)
- 1 dag x 60 minutter bevegelsesaktivitet («Be happy timen»)

«Be happy timen» skal organiseres i grupper på tvers av klassene, og elevene skal i samarbeid med lærer finne frem til forskjellige aktiviteter, som de ønsker å utføre. Det skal utvikles (et sosialt) mål, årsplan og periodeplaner for «be happy timen», og den sosiale dimensjonen med vennskap i bevegelse skal stå sentralt i arbeidet. «Dont worry-timen» skal foregå som normale kroppsøvingstimer, men elevene skal fortsette med aktiviteten som de utøver i «be happy timen».

Den økte aktiviteten skjer i samsvar med skolens ledelse og blir en naturlig del av elevenes skolehverdag. Den daglige fysiske aktiviteten er ikke vurdert til å være forbundet med risiko, og kan sammenlignes med aktiviteter og metoder nyttet i en vanlig kroppsøvingstime.

Hva innebærer deltakelse i studien for deres sønn/datter dersom deres sønn/datter går på en skole som *ikke* skal gjennomføre daglig fysisk aktivitet?

For elever ved kontrollskoler vil skoleåret gå som normalt, men elevene vil gjennomføre tester ved oppstart og avslutning av 9. trinn (se under).

Hva innebærer testingen i studien for deres sønn/datter?
Det vil ved oppstart og avslutning gjennomføres tester for å evaluere effekten av intervensjonen. *Dette er derfor en forespørsel til dere som foreldre/foresatte om deres sønn/datter kan delta på ulike tester*

Testene gjennomføres i skoletiden på hver enkelt skole, og vil bli gjennomført av erfarent testpersonell. Velutviklede spørreskjema vil anvendes for temaer relatert til læringsmiljø, selvbilde og psykisk helse. Vi vil teste elevenes fysiske form og registrere deres fysisk aktivitetsnivå, samt måle deres vekt, høyde og maveomkrets. Det er ønskelig å innhente opplysninger fra nasjonale prøver, elevundersøkelsen og grunnskolekarakterer fra nasjonal utdanningsdatabase. Deltakelse i prosjektet innebærer at vi vil koble de nevnte data med registerdata fra Utdanningsdirektoratets database.

Hva skjer med informasjonen om deres sønn/datter?
Samtlige opplysninger som samles inn vil bli behandlet konfidensielt, og alle medarbeidere i prosjektet har taushetsplikt. Alle data som blir samlet inn, både elektronisk og papirbasert vil håndteres i tråd med personvern og IKT-trygghet nedskrevet i helseforskningsloven og personopplysningsloven. Prøvene som tas og informasjonen som registreres om eleven skal kun brukes i tråd med formålet til studien. Alle skjema og tester vil bli avidentifisert, som betyr at navn og andre personopplysninger som kan kobles til eleven fjernes. Identifiserbare opplysninger som knytter eleven til opplysninger erstattes med en kode. Lister som kobler kode og navn skal oppbevares på en sikker måte, atskilt fra resten av datamaterialet. Det er kun prosjektledelsen som har tilgang på navnelistene.

Prosjektet skal etter planen avsluttes 01.01.2019. NIH ønsker å oppbevare datamaterialet i 10 år frem i tid (21.06.2028). Navnelister over deltakere og koden som kobler de til data vil bli lagret av en autorisert tredjepart. Det eksisterer i dag ikke tilfredsstillende kunnskap vedrørende skolebasert fysisk aktivitet i ungdomsskolen, og det kan derfor bli aktuelt at deltakerne blir spurt om å delta i oppfølgingsstudier ved et senere tilfelle. Dersom dette blir aktuelt tar vi kontakt.

Frivillig deltakelse
Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert. Dette vil ikke få konsekvenser for elevens videre undervisning.

Dersom dere aksepterer at deres sønn/datter deltar i testingen i intervensjonsprosjektet, skriver dere under samtykkeerklæringen på neste side.

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Dersom dere på noe tidspunkt har spørsmål, ta gjerne kontakt på telefon eller e-post.

Vennlig hilsen

Elin Kolle
Prosjektleder/førsteamanuensis
Tlf. 23 26 24 23
e-post elin.kolle@nih.no

Runar Solberg
Prosjektkoordinator
Tlf. 90 97 96 48
e-post runarbs@student.nih.no

Samtykke til deltakelse i forskningsprosjektet

" Utprøving og evaluering av modeller for fysisk aktivitet for elever i ungdomsskolen"

Jeg har lest informasjonsskrivet, og jeg er villig til å la min sønn/datter få delta.

(Signert av foreldre til prosjektdeltaker, dato)

Elevens for- og etternavn: (Skriv tydelig, helst med blokkbokstaver)

………………………………………………………………………………………..

Foreldre/foresattes for- og etternavn: (Skriv tydelig, helst med blokkbokstaver)

………………………………………………………………………………………..

Appendices

Appendix 3:

Form assessing the teacher related contextualised factors.

School in Motion (ScIM) er et forskningsprosjekt der hensikten er å evaluere hvordan økt fysisk aktivitet og kroppsøving kan påvirke fysisk- og psykisk helse, læring og læringsmiljø blant elever på 9.trinnet ved 30 ungdomsskoler i Norge.

Prosjektet er initiert av Helse- og omsorgsdepartementet, Kunnskapsdepartementet, Helsedirektoratet og Utdanningsdirektoratet. Norges idrettshøgskole (NIH) koordinerer prosjektet og det gjennomføres som et samarbeidsprosjekt mellom NIH, Høgskulen på Vestlandet, Universitetet i Agder og Universitetet i Stavanger.

Nedenfor følger noen spørsmål om skolen du arbeider på og om klassemiljøet i klasen du underviser i. Spørreskjemaet tar omtrent 7-8 minutter å gjennomføre.

Samtykker du til å svare på spørreskjemaet?

(1) ❑ Ja

(2) ❑ Nei

Tusen takk for at du velger å svare på spørreskjemaet.

Hvilket kjønn er du?

(1) ❑ Mann

(2) ❑ Kvinne

Hvilken alderskategori er du i?

(1) ❑ 20 - 29

(3) ❑ 30 - 39

(4) ❑ 40 - 49

(5) ❑ 50 - 59

(6) ❑ 60 - 69

(7) ❑ 70 - 79

Først noen spørsmål om skolen du arbeider på.

Er du klar over at skolen du arbeider på er med i ScIM-prosjektet?

(1) ❑ 1. Ikke klar over
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig klar over

Forstår du hensikten og målsettingen med ScIM-prosjektet?

(1) ❑ 1. Forstår ikke
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Forstår godt

Hvor oppnåelig tror du det er at elevene på din skole får bedre fysisk- og psykisk helse, læring og læringsmiljø etter ScIM-prosjektet?

(1) ❑ 1. Ikke oppnåelig
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig oppnåelig

Tror du at ScIM-prosjektet kan endre deler av undervisningshverdagen på din skole?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Er ledelsen på din skole er dedikert til å gjennomføre ScIM-prosjektet i tråd med retningslinjene?

(1) ❑ 1. Ikke dedikert i det hele tatt
(2) ❑ 2.

(3) ❑ 3.
(4) ❑ 4. Veldig dedikert

Føler du at du får nok tid og støtte av ledelsen til å forberede arbeidsoppgavene i prosjektet?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Tror du ledelsen på din skole har de riktige personene involvert for å oppnå en varig endring etter ScIM-prosjektet?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Tror du den lokale ScIM-koordinatoren på din skole er dedikert til å gjennomføre ScIM-prosjektet på best mulig måte og i tråd med prosjektets retningslinjer?

(1) ❑ 1. Ikke dedikert i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig dedikert

Tror du din lokale ScIM-koordinator vil hjelpe og støtte deg til å forstå hvordan du kan endre gjennomføringen av ScIM-prosjektet ved behov?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Hvor effektivt er kommunikasjonen fra prosjektledelsen på NIH til personer på din skole som arbeider med ScIM-prosjektet i hverdagen?

(1) ❑ 1. Veldig ineffektiv
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig effektiv

Hvor ofte mottar du tilbakemeldinger fra prosjektledelsen på NIH om hvordan dere gjennomfører ScIM-prosjektet i hverdagen?

(1) ❑ 1. Veldig sjeldent
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Hele tiden

Hva er den mest effektive måten for deg å motta kommunikasjon på?

(1) ❑ Epost
(2) ❑ Intranett
(3) ❑ Notater
(4) ❑ Nyhetsbrev
(5) ❑ Møte
(6) ❑ Uformelle samtaller
(7) ❑ Andre

Er din rolle i ScIM-prosjektet klart definert?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig klar

Fikk dere nødvendig opplæring slik at dere kunne starte arbeidsoppgavene i ScIM-prosjektet ved prosjektstart?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Forstår du hvordan ScIM-prosjektet kan påvirke din undervisningshverdag?

(1) ❑ 1. Ikke i det hele tatt
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig mye

Er du sikker på at du vil motta relevant opplæring og støtte underveis for å kunne gjennomføre ScIM-prosjektet i tråd med retningslinjene?

(1) ❑ 1. Ikke sikker
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Veldig sikker

Hvor raskt tilpasser du deg endringer?

(1) ❑ 1. Bruker land tid
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Med en gang

Hvor lang tid bruker din organisasjon på å tilpasse seg endringer?

(1) ❑ 1. Bruker land tid
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. Med en gang

Har tidligere prosjekter på din skole oppnådd sine målsettinger?

(1) ❑ 1. I liten grad
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. I stor grad

Mener du at din skole endrer seg for mye eller for lite for øyeblikket?

(1) ❑ 1. For lite
(2) ❑ 2.
(3) ❑ 3.
(4) ❑ 4. For mye

Når du tenker på din skole, hva er kulturen for å gjennomføre endringer?

	1.	2.	3.	4.
Gammeldags (1) eller fremtidsrettet (4)	(1) ❑	(2) ❑	(3) ❑	(4) ❑
Lite mottakelig (1) eller mottakelig (4)	(1) ❑	(2) ❑	(3) ❑	(4) ❑
Passiv (1) eller involverende (4)	(1) ❑	(2) ❑	(3) ❑	(4) ❑

Med utgangspunkt i din erfaring, hva kjennetegner prosjekter som har vært suksessfulle på din skole?

______

Med utgangspunkt i din erfaring, hva har begrenset suksessen til prosjekter som har vært igangsatt på din skole?

______

Hva mener du er essensielt for en god gjennomføring av ScIM-prosjektet?

______

Hva mener du kan begrense gjennomføringen av ScIM-prosjektet?

______

Hvor mange år har du undervist i grunnskolen?

______

For spørsmålene under skal du svare basert på klassen der du er kontaktlærer.

Elevene i klassen er gode venner

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Det er konkurranse blant elevene om å være flinkest

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Det er god arbeidsro i timene

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Det er mye rot og bråk i timene

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

De fleste elevene følger med når læreren underviser

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Elevene i klassen samarbeider godt når de blir bedt om det

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Vi får som regel gjort det vi skal i timene

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Elevene fullfører vanligvis pålagte oppgaver

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Undervisningen forstyrres ofte av elever

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Det er grupper eller klikker i klassen som ikke går så godt sammen

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Lærerne som har klassen samarbeider ganske mye

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Lærer og klasse kommer godt ut av det med hverandre

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Enkelte lærere har problemer med denne klassen

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Elevene er interesserte og aktive i timene

(1) ❑ Stemmer ikke i det hele tatt
(2) ❑ Stemmer litt
(3) ❑ Stemmer godt
(4) ❑ Stemmer svært godt

Du har nå fullført spørreskjemaet.

Tusen takk for hjelpen!

Runar Barstad Solberg // Physical activity, physical fitness and academic performance among adolescents.