UiT The Arctic University of Norway

Faculty of Health Sciences – Department of Psychology

Physical activity and mental distress among adolescents

Results from the Tromsø Study: Fit Futures

Ida Marie Opdal

A dissertation for the degree of Philosophiae Doctor, April 2020

Physical activity and mental distress among adolescents

Results from the Tromsø Study: Fit Futures

Ida Marie Opdal

Department of Psychology

Faculty of Health Sciences

UiT- The Arctic University of Norway

A dissertation for the degree of Philosophiae Doctor, March 2020

Table of contents

Acknowledgements

This thesis is the result of my doctoral project at UiT- The Arctic University of Norway. The research was carried out at the Department of Psychology, and founded by Helse Nord.

I am very grateful for being here at the finish line, and I am humbly aware that this is thanks to help and guidance from many lovely people. If I could thank all of them by name, reading this section would take years.

Having said that, I still wish to mention some of the people that helped me decide to pursue an education and a career in psychology. My research is based on adolescents in upper secondary school, and I felt it was only appropriate to start by thanking my upper secondary school teacher, Knut Holte, who ensured me that I should apply for psychology courses even though I felt that I was not good enough. This lead to six years of lectures, assignments and exams in psychology. I loved it, and there are many people at the Department of psychology that I wish to thank for it. However, there is one person who nudged me towards a Ph.D. without knowing; I would like to thank Frank Siebler because after reading and evaluating one of the aforementioned assignments during my master program, he decided to give praise directly to my supervisor, Kamilla Rognmo, who immediately called me to her office. This was how my involvement in this project began.

Kamilla, you are the best supervisor in the whole world! Your coaching and supervision have made these three years go by so fast with little to no problems. If I had the opportunity to do it all again, I would. You have always had time for me, and have been patient, caring and even strict when needed. Thank you for your support, and for sharing your knowledge with me. I hope that I have the opportunity to collaborate with you in the future.

To Bente Morseth, my co-supervisor, I am so grateful for your guidance and support. Your unique knowledge about physical activity measures in the Fit Futures study has been invaluable, and your quick response on my (sometimes untimely) e-mails have given me great peace of mind during these three years.

Big thanks is due to my huge arsenal of co-authors whose comments and involvement made enormous difference when conducting the studies and when writing the papers.

I wish to also express my gratitude towards my family, friends, colleagues, and fellow Ph.D. students for showing interest and encouragement during these years.

Finally, I am so grateful for my soulmate, Oskar. Thank you for your generosity and kindness, your insight and guidance, and your enormous amount of help. I could not have done this without you by my side. I am also thankful for Missi, my cat, for reminding me to take brakes and to never skip a meal.

Thank you, all!

Ida Marie Opdal

List of papers

Opdal, I.M., Morseth, B., Handegård, B.H., Lillevoll, K., Ask, H., Nielsen, C.S., Horsch, A., Furberg, A.S, Rosenbaum, S. & Rognmo, K. (2019). Change in physical activity is not associated with change in mental distress among adolescents: the Tromsø study: Fit Futures. *BMC Public Health*, *19(1)*, 916.

Opdal, I.M., Morseth, B., Handegård, B.H., Lillevoll, K.R., Nilsen, W., Nielsen, C.S., Furberg, A.S, Rosenbaum, S. & Rognmo, K. (2020). Is change in mental distress among adolescents predicted by sedentary behaviour or screen time? Results from the longitudinal population study The Tromsø Study: Fit Futures. *BMJ Open, 10.*

Opdal, I.M., Morseth, B., Kokkvoll, A.S., Horsch, A., Rosenbaum, S., & Rognmo, K. (2020). Is the association between physical activity and mental distress among adolescents mediated by peer acceptance, perceived barriers and enjoyment of activity? Results from the Tromsø Study: Fit Futures. *Submitted for publication*.

Summary

The onset of experiencing symptoms of mental distress, such as depression and anxiety, is most common during the adolescent years, and is concurrent with a measured decrease in physical activity levels. Physical activity is considered an easy and inexpensive measure that individuals can do by their own effort to prevent health problems, and based on research on the adult population, it seems that there is a relationship between physical activity and mental distress. However, the results from the field on the association between physical activity and mental distress among adolescents are ambiguous at best, and there is still a need for more longitudinal research with validated measurements.

This thesis explored the association between physical activity and mental distress among adolescents attending upper-secondary school using both objective and subjective data from the Tromsø Study: Fit Futures, and makes use of the longitudinal potential provided. Longitudinal regression analyses were conducted to investigate whether there was a relationship between change in objectively assessed physical activity and change in mental distress among the adolescents in the sample. Associations between both objectively measured sedentary time and self-reported screen-time and mental distress were also investigated due to the ambiguity in the results from the previous literature using these different modes of measurements. We also took upon us the task of more deeply exploring the relationship of mental distress to both physical activity and sedentary behavior, and if the relationships are mediated by peer acceptance, enjoyment of physical activity or perceived barriers towards physical activity, tested in a serial multiple mediator model using the PROCESS macro add on to SPSS.

The overall results showed that, in the sample of adolescents participating in the Fit Futures study, there are no longitudinal associations between change in objectively measured physical activity and change in mental distress, nor is there a longitudinal association between objectively measured sedentary behavior and mental distress. There was a significant longitudinal association between self-reported screen-time and mental distress for the adolescents, and there were results showing that low peer acceptance mediated the relationship between mental distress and both objectively measured physical activity and sedentary behavior.

This thesis has contributed to the research field on the association between physical activity and mental distress among adolescents with longitudinal studies using well validated

variables including objectively measured physical activity data, and has utilized the data from the same sample to answer several research questions adding to the understanding of the association. However, there is still a need for more research to be able to both establish an association and to understand how different relevant variables behave over time as there is some controversy in the field.

Keywords: *Adolescents, physical activity, mental distress, depression, anxiety, accelerometer, screen-time, low peer acceptance, Fit Futures.*

Abbreviations

BMI	Body Mass Index
HSCL-10	Hopkins Symptoms Checklist
MVPA	Moderate to vigorous physical activity
SPPA	Self-Perception Profile for Adolescents
WHO	World Health Organization

1. Introduction

Physical activity has long been identified as beneficial for good health. MacAuley (1994) writes in a short article about the history of physical activity, health and medicine that the earliest records for organized exercise meant to promote health are found in ancient China, 2500 BC. In ancient Greece, the principles of Hippocrates and the Greek school emphasized the importance of physical health and fitness in a healthy lifestyle. Moreover, practitioners in this period realized that physical activity had a wider application on disease and disabilities, as it was thought to have a healing effect. MacAuley further states that Galen of Pergamon, who was a Greek physician living in the Roman Empire and influenced by Hippocrates´ medical philosophy, elaborated on the ancient Greeks´ perceived association between physical activity and health, and stated that physical activity, even at moderate levels, has not only a beneficial effect on the physical body, but also the intellect.

A long time has passed since the great ancient minds identified an association between physical activity and health, and now, in the modern world, scientific research has confirmed these hypotheses. However, despite physical activity being associated with many different types of health indicators, there are still unknown factors that have a potential association to physical activity, and one of these factors is mental health.

Throughout history, people with mental distress have had to deal with both the illness, and with how mental distress was understood and perceived. Over different time periods, mental distress has been thought of as a result of demonic possessions, religious punishment, imbalance of bodily fluids, that certain body parts are wandering around the body searching for a baby, and penis envy, just to mention a few (Teigen, 2015). Luckily, our understanding of mental distress has improved significantly since then, and I can confidently say that we are on the right path when it comes to treating mental distress.

Mental distress is potentially devastating for people of any gender, age, life situation or nation, and it is one of the biggest health challenges in the western world (Ezzati, Lopez, Rodgers, Vander Hoorn, & Murray, 2002; World Health Organization, 2018, January 30th). Luckily, in the developing countries, people suffering from mental distress have the option to be treated by a therapist specialized in treating psychological difficulties. Yet, this type of treatment is expensive, in demand, and not available for all. Fortunately, there is an expanding field where researchers investigate if physical activity could also have a beneficial effect on mental health, such as it has for physical health.

The research field has investigated the potential association between mental distress and physical activity in numerous ways, however, the research designs are often weak and have failed to establish whether there is an association or not (Biddle & Asare, 2011). This knowledge is very desirable, because knowing whether physical activity has a protective or even an ameliorating effect on mental health would mean that we have an easy and somewhat pain-free solution for a complicated problem that affects many people. It is especially interesting to investigate this effect among adolescents as the onset for experiencing mental distress is during the adolescent years (Kessler & Bromet, 2013), and many adolescents who experience symptoms of depression or anxiety are unfortunately prone to be followed by these symptoms into adulthood (Zisook et al., 2007).

The following theoretical and empirical background presents an overview of the literature available on physical activity and mental distress among adolescents, and the potential association between the two. To better understand the research on the association, it is beneficial to first understand mental distress and physical activity among adolescents as separate constructs. Thus, the following background will start by presenting physical activity and mental distress separately before exploring the literature on the field of the association between mental distress and physical activity.

2. Background

2.1 Physical activity in adolescence

Physical activity is commonly defined as behavior where an individual moves its body by using skeletal muscles causing energy expenditure (Caspersen, Powell, & Christenson, 1985). Depending on the physical and social context, physical activity can take different forms and intensities, and can be categorized simply in either one of two categories: recreational (exercise, partaking in sports and games) and obligational (work related, housework and transportation). Children and adolescents are largely expected to be physically active as part of their education, and engage in play involving physical activity with peers both during school and leisure time.

What this entails varies as adolescents have many ways to be physically active. Among US high-schoolers, the most popular activities have been reported to be, among others: walking, running/jogging, weight lifting, ball games, active video games, dancing, bike riding, aerobics and swimming (Katzmarzyk, Lee, Martin, & Blair, 2017). The same trends are reported in Scandinavia, however, the adolescents here also report interest in physical activity involving winter sports, such as cross-country skiing, downhill skiing, or ski jumping, but also other activities involving nature, such as orienteering and hiking (Tammelin, Näyhä, Hills, & Järvelin, 2003).

2.1.1 Health benefits of physical activity in adolescents

Physical activity is associated with many health-related outcomes. Overall, there are benefits at all ages, such as lower risk for diabetes type 2 (Jeon, Lokken, Hu, & van Dam, 2007), higher health-related quality of life for cancer survivors, lower risk for cardiovascular disease, arthritis, sexual dysfunction, and pain (Penedo & Dahn, 2005) to mention a few. However, for older adults, there is also an additional benefit as physical activity is related to cognitive performance (Nelson et al., 2007; Willey et al., 2016), reduces frailty (Bray, Smart, Jakobi, & Jones, 2016), and a lower overall risk of mortality (Leitzmann et al., 2007).

For children and youth, physical activity influences cardiovascular health and metabolic syndrome clustering with weight and obesity, and with musculoskeletal health and fitness (Strong et al., 2005). It is important to mention that physical activity is also associated with different mental health factors for this age group as there is a strong relationship between

physical activity and anxiety, depression, self-concept, and academic performance (Strong et al., 2005). The association between physical activity and mental distress will be further elaborated in the Background section.

Knowing the benefits, practitioners and people in general understand that physical activity is crucial for a healthy life. The amount of physical activity needed to accumulate the benefits has been studied extensively. Some health organizations have published guidelines and recommendations based on results of research in order to assist health services and individuals to guide and reach the optimal physical activity level to live a healthy lifestyle.

2.1.2 Recommendations – WHO and The Norwegian Directorate of Health

World Health Organization (WHO) has published several guidelines for physical activity for different life phases (World Health Organisation, 2010). In their guidelines for children and young adults they describe that physical activity should include play, games, sports, transportation, chores, recreation, and physical education or planned exercise in the context of family, school and community activities. Additionally, they state that all children and youth should be encouraged to participate in a variety of physical activity that support natural development, as long as it is enjoyable and safe.

To improve cardiorespiratory and muscular fitness, bone health and other cardiovascular and metabolic health biomarkers, WHO suggests that children and youth accumulate at least 60 minutes of moderate- to vigorous intensity physical activity (MVPA) daily (World Health Organisation, 2010). These minutes can be spread in shorter bouts throughout the day, e.g. 30 minutes twice a day, and should preferably be aerobic physical activity. WHO's recommendations are applicable for all children and youth irrespective of gender, race, ethnicity, or income level, and should be done above and beyond the daily accumulated physical activity in non-recreational activities. For children and youth who are inactive, WHO suggest a progressive increase in physical activity to eventually achieve the 60 minutes of MVPA per day, and finish by stating that any amount of physical activity under the recommended levels will bring more benefits than doing none at all.

The WHO guidelines for physical activity for children and youth are based on the overall conclusion that physical activity provides fundamental health benefits (World Health Organisation, 2010), and they recognize that physical activity in adolescents and young adults has psychological benefits in addition to being beneficial for several of the mentioned health biomarkers (World Health Organisation, 2018, February 23rd). The recommendation is based

on findings from observational studies where higher levels of physical activity were associated with more positive health parameters, and experimental studies where physical activity as an intervention resulted in better health outcomes. It stems mainly from two reviews, "Physical activity guidelines for children and youth" (Janssen, 2007) and "Systematic review of the health benefits of physical activity and fitness in school-aged children and youth" (Janssen & LeBlanc, 2010)), and a document from the US government, "2018 Physical Activity Guidelines Advisory Committee Scientific Report" (Physical Activity Guidelines Advisory Committee (PAGAC), 2008)). WHO's guidelines are frequently evaluated against the development in the research.

The Norwegian Directorate of Health is legally obligated to develop and publish professional advice related to health to be used by the Norwegian health services and the population in general. In 2014, they published guidelines and recommendations for physical activity for all ages in the Norwegian population, and these were based on the results from studies conducted in the Nordic countries (Helsedirektoratet, 2014), and are based on the recommendation published from WHO. The Norwegian Directorate of Health recommends that children and adolescents be physically active for a minimum of 60 minutes per day, and furthermore, that the activity should be of moderate to vigorous intensity. In addition, they recommend that activities aimed to increase muscle and bone strength should be included three times a week at a minimum. All additional physical activity that exceeds the recommended 60 minutes per day, are thought to promote further health benefits for children and adolescents.

Regarding types of activities, the Directorate states that the children and adolescents' activities should be as versatile as possible to secure an optimal development of healthy physical features and qualities, along with properties such as stamina, muscle strength, flexibility, speed, mobility, reaction time, and coordination. Examples of activities that are mentioned include playing both inside and outside, physical education in school, participation in sports, outdoor recreation, active transportation like walking and biking. The Directorate further states that a variety of different physical activities give the children and adolescents an opportunity to develop both fine and gross motoric skills, and that regular physical activity has further a positive effect on psychological health, concentration and education. Additionally, it encourages public and private caretakers to facilitate enjoyment, social community and mastery of physical activity throughout all seasons.

Finally, The Directorate recommends reducing sedentary behavior in general for all ages. Physical inactivity is suggested to be interspersed with everyday activities, for example by house chores, gardening, or active transportation. For children and adolescents, breaks in school work are regarded as important to reduce physical inactivity, and furthermore, it is recommended to have regular short activity breaks lasting a few minutes with focus on light muscle activities.

2.1.3 Do adolescents meet the recommendations?

The WHO guidelines for physical activity for children and youth is well-known and used internationally, and consequently, many studies use these to investigate and describe their results.

Norwegian adolescents. A study of the objective physical activity and fitness of the Norwegian youth, called ungKan, finds that an acceptable percentage of 6 and 9 year old children meet the recommended 60 minutes of MVPA per day, however, this drops considerably for the 15 year old adolescents, as only 40-50% meet the recommendation (Steene-Johannessen et al., 2019). Similar results were found by Hansen et al. (2019), 48% of 15 year old adolescents were sufficiently active in line with the recommendations, however, only a third of adults and older people meet the criteria.

Internationally. A review showed that for 15 year old adolescents in Europe, only 13.6% were sufficiently physically active in line with the WHO recommendations (McMahon et al., 2017). The number of adolescents that meet the recommendations varies between the countries in Europe (Van Hecke et al., 2016), and it could be explained by the cultural differences or the difference in policies, or even by the use of different thresholds or the wording of the questions. Moreover, when comparing obese with non-obese children and adolescents, the averaged minutes per day were even lower for obese adolescents compared to non-obese who still did not meet the recommended 60 minutes in MVPA (Elmesmari, Martin, Reilly, & Paton, 2018).

Gender differences. In Europe, more boys (17.9%) meet the recommendation compared with girls (10.7%) (McMahon et al., 2017). This finding is also consistent with research measuring physical activity by accelerometers, however, this gender difference in physical activity seems to disappear when taking maturity, measured by peak height velocity, into account (Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). Other studies find that the

overall difference in objectively measured physical activity between male and female adolescents seems to be modest (Trost et al., 2002).

Objective vs. subjective data. Nevertheless, there seems to be some discrepancy between how many meet the recommendations due to the method of measurement. For example, a review found that in the European countries, 5 – 47% of children and adolescents meet the recommendation of WHO when measuring the physical activity level subjectively, but when using objectively measured physical activity, 0-60 % seemed to meet the recommendation (Van Hecke et al., 2016). The next section will describe how objective and subjective physical activity is measured.

2.2 Measuring physical activity

There are several different methods for measuring physical activity, each with its own strengths and limitations. For simplicity, the measurements can be either categorized as objective or subjective measurements. The papers included in this thesis have used examples of both measurements, and these modes of measurement are highlighted in the following subsections. As mentioned, physical activity at its most basic is movement of skeletal muscles that cause energy expenditure, and it should be mentioned that there exists highly accurate methods for measuring energy expenditure by either measuring the total energy expenditure while fasting in a temper-natural environment, elimination of water from body in the doubly labeled water method, or direct or indirect calorimetry (Ndahimana & Kim, 2017). However, these methods are difficult to use, and not suitable for research concerning daily physical activity.

2.2.1 Self-reported measurements – subjective physical activity

Self-reported measurements have previously been the main method of measuring physical activity, and it is a relatively easy and inexpensive method for collecting data even for lager sample sizes. In addition, it is also considered to be of little burden for the participants as self-reported physical activity usually is measured by reporting the recollected hours of physical activity during a given period (Ndahimana & Kim, 2017). Nevertheless, when using self-reported measurement in research it is important to take into account

potential bias. Especially recall bias[1] and response bias[2] are problems that researchers encounter when using this kind of measurements.

Nonetheless, several validated physical activity questionnaires exist, and Ndahimana and Kim (2017) mention some in their review of physical activity measuring methods:

- International Physical Activity Questionnaire (IPAQ)
- The 7-day Physical Activity Recall (PAR)
- Modifiable Activity Questionnaire (MAQ)
- Previous Week Modifiable Activity Questionnaire (PWMAQ)
- Recent Physical Activity Questionnaire (RPAQ)
- Previous Day Physical Activity Recall (PDPAR).

In research, physical activity is often separated into different intensities, such as sedentary, light, moderate, and vigorous intensity. Objective measurements have an advantage when categorizing intensities as it can operate with predefined cut-offs for a quantified measurement. Self-reported measurements, on the other hand, need to rely on the participant's ability to distinguish between the intensities themselves, and the intensities are often separated by effort and bodily response. Moderate intensity requires a moderate amount of effort and results in a moderate increase in heart rate, vigorous intensity requires a large amount of effort and results in a substantial increase in heart rate (World Health Organisation, n.d.). Occasionally, to help the participants to distinguish between the intensities of physical activity, some studies use everyday activities to indicate an intensity. However, the intensities of the different forms of activities varies between people as it depends on the individual fitness and experience, and this can lead to inaccurate results. Table 1 show some examples of physical activity level for common daily activities.

[1] Recall bias – systematic error where participants do not remember previous events accurately, or it may be influenced by other memories and experiences.
[2] Response bias – tendency for answering untruthfully or misleadingly depending on the situation.

Table 1: *Examples of activities for physical activity intensities.*

Sedentary	Light intensity	Moderate intensity	Vigorous intensity
Watching TV	Strolling/shopping	Brisk walking	Jogging/running
Reading	Making the bed	Vacuuming	Fast swimming
Knitting	Preparing food	Shooting basketball	Jumping rope

It can be challenging to accurately operationalize the different intensities. An example of this is sedentary behavior, which is the opposite of being physically active. A majority of older studies have operationalized the intensity "*sedentary behavior*" as minutes of self-reported screen time (Hoare, Milton, Foster, & Allender, 2016). However, several studies have shown that screen-time is a poor estimate for sedentary behavior (Chastin et al., 2018).

2.2.2 Accelerometers – Objective physical activity

Objective measurement methods collect data that is not biased by the subjective opinion and feelings of the participant. Where a self-reported measurement can be affected by mood, the wish to please the researcher, or to be perceived as good or healthy, objective measurements measure how the participant perform regardless of what they experience while doing so. One method for objectively measure physical activity is to use wearable devices. It could be an accelerometer, a step-counter, or a heart rate monitor. Accelerometers and step-counters measure overall total movement in physical activity during a given period, often a week, and a heart rate monitor measure time spent in moderate or vigorous intensity physical activity and estimates energy expenditure. Accelerometers can be used to measure physical movement or sleep cycles over an extended period of time, and can be worn on either the wrist, the hip or the thigh.

The accelerometer is an electronic device that measure acceleration in its own rest frame[3], meaning that it does not measure change in coordination, but the force from a

[3] Rest frame (concept from the physics theory of special relatively) - I know little to nothing about physics, but I believe it means that it measures the movement inside the restrictions of itself, and not the movement relatively to an object.

dynamic movement. The mechanical movements are typically translated into digital data called “counts”. A count is an acceleration signal measured by the accelerometer that reaches the threshold deciding that it should count as activity. The accelerometer measures additionally the volume and intensity of the movement. These counts can then be sampled, for example every ten second over a predetermined period, also called epochs, which can later be separated into different intensities based on predefined cut-off values after it have been downloaded to the software of choice.

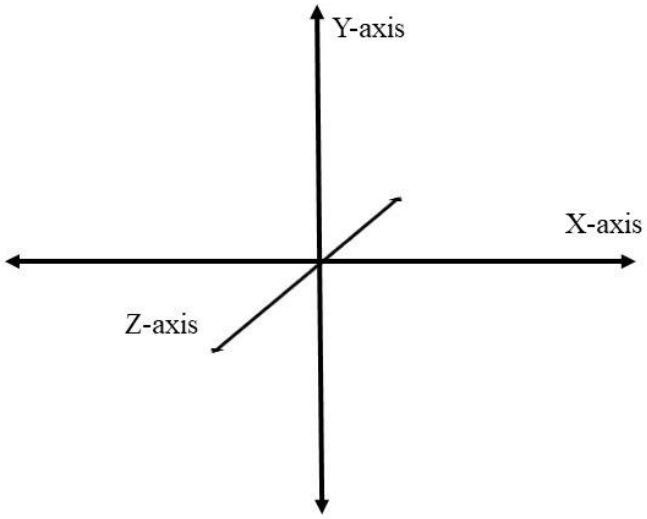
The cut-off values are defined by research, and there are a variation of them. Some cut-offs are suitable for children and other for adults. The cut-offs used in the specific research project are decided based on the research question and design, and are also dependent on the number of axes the data is collected from. The Fit Futures used cut-off values for uniaxial measurements of young adults and adults defined by Freedson, et al. (1998) to determine physical activity intensities among the adolescents. These cut-off values are shown in Table 2. Uniaxial means that it only measures movement in one plane, this usually means the vertical y-axis. Triaxial accelerometer measures movement on three planes, the y axis, x axis and the z axis (illustrated in Figure 1), and is suggested to be especially suitable for children, nevertheless, no research have concluded that triaxial accelerometer data is better than uniaxial (Freedson, Pober, & Janz, 2005; Kelly et al., 2013). However, when comparing triaxial data and uniaxial data from the same sample, there has been proven a discrepancy based on the accelerometry data processing criteria (Sagelv et al., 2019).

Table 2: *Uniaxial Freedson cut-off values for adults and adolescents.*

Physical activity intensity	**Cut-off values for uniaxial Freedson[1]**
Sedentary	0-99 counts per minute
Light	100-1951 counts per minute
Moderate	1952- 5723 counts per minute
Vigorous	> 5723 counts per minute

[1] Freedson, et al. (1998)

Figure 1: *The planes a triaxial accelerometer measure acceleration.*



There are validity issues concerning the use of accelerometers, although measuring physical activity with an accelerometer is regarded as a more accurate and unbiased mode of measurement than self-report. Accelerometers lack the ability to reliably measure different types of activities such as rowing and cycling because of its static position on the hip. It may also be challenging to reliably differentiate between measured sedentary time and non-wear time, and this can potentially lead to an over- or underestimation of sedentary time measured by accelerometers (Oliver, Badland, Schofield, & Shepherd, 2011). There is also the potential that the adolescent participants tune their physical activity level due to the effect of wearing a measuring device, however, research done on blinded and double-blinded participants show that the awareness of wearing an accelerometer seems to have no effect on the pattern of physical activity (Vanhelst, Béghin, Drumez, Coopman, & Gottrand, 2017).

2.2.3 Choosing accelerometer or self-report measurement for an adolescent sample

There is a growing interest in using objectively measured physical activity data in research now that measurement devices, such as accelerometers, have become more reliable and available. A quick search on scopus.com show that there were 86 published articles in the fields of health and medicine with the search term “accelerometer” in year 2000, in 2015 there

were 814, and in 2019 there were 1,038[4]. At the same time, self-reported measurement for physical activity is still considered a valid mode of measurement. However, one should be careful in assuming that accelerometer data and self-reported physical activity are equivalent.

It seems that the agreement between objectively measured and self-reported physical activity is dependent on age. Slootmaker, Schuit, Chinapaw, Seidell, and Van Mechelen (2009) found large differences between self-reported physical activity and objectively measured physical activity (measured by accelerometer) among adolescents, but a reasonable agreement among adults. Adolescents seemed to over-report the time spent in moderate and vigorous physical activity, as Slootmaker et al. found that adolescents on average reported having spent over 9 hours more in moderate physical activity per week and almost 3 hours more in vigorous activity per week than was assessed by accelerometer (Slootmaker et al., 2009). In addition, adolescents also seem to grossly underreport time in sedentary behavior (Affuso et al., 2011).

Therefore, despite self-reported measurement for physical activity being the most common measure, the validity is questionable for adolescents. Researchers conducting studies on physical activity should thoroughly assess the options when choosing either objectively or subjectively measured physical activity when collecting data for research.

2.3 Physical activity levels from adolescence to adulthood

Physical activity patterns could potentially change throughout the lifespan, and the transition from adolescence to adulthood is filled with many psychological and physical changes. For some, this is the period that one moves out for the first time, starts studying, gets a job, and so on, and the milestones are dependent on culture and possibilities available for each individual. From the perspective of the field of physical activity, the transition between adolescence and early adulthood is a poorly understood period (Ortega et al., 2013).

A review found that physical activity in general decreases with age, whereas sedentary behavior increases, and that the adolescents´ physical activity levels have a tendency to follow into adulthood (G. Hayes, Dowd, MacDonncha, & Donnelly, 2019). This is supported by the findings described in the previous section about adolescents not meeting the WHO recommendation of 60 minutes of MVPA, and that this additionally seems to be true for adults (Hallal et al., 2012). In addition, both adolescent's and adult's physical activity pattern

[4] Accessed March 3th, 2020.

seems to be motivated by health and fitness benefits (Hulteen et al., 2017). Encouragingly, there is evidence that if good lifestyle behavior, such as physical activity, is practiced early in life, it is a higher likelihood that the behavior persist later in life (Jones, Hinkley, Okely, & Salmon, 2013). On the basis of this it is desirable to increase physical activity among adolescents. In order to do so, it is important to know the mechanisms related to physical activity.

2.4 Mechanisms related to physical activity among adolescents

Park and Kim (2008) conducted a systematic review to identify factors related to and determinants of physical activity levels and patterns among adolescents, and they categorized the identified factors into five categories:

Demographic and biological factors. First and foremost, sex and age were highly associated with physical activity, which supports the aforementioned studies concluding that there is a gender difference and an age dependent decrease of physical activity. For the demographic factors, some studies included in the review found that the adolescents' mother's education to be significantly associated with lower levels of sedentary behavior, and furthermore, that higher total family income was associated with additional higher occurrence of MVPA.

Psychological, cognitive, and emotional factors. Based on a number of original research studies, the authors found that perceived self-efficacy was highly correlated with physical activity. Additionally, perceived barriers towards physical activity, such as lack of time, being too tired or being self-conscious, were also found to be highly related to sedentary behavior among adolescents. Finally, there was also evidence that perceived benefits related to physical activity were positively associated with the adolescents' physical activity level.

Behavioral attributes and skill factors. There was strong evidence that smoking and alcohol use was negatively associated with physical activity among the behavioral factors. Moreover, and unsurprisingly, past physical activity habits and skills predicted the present physical activity among adolescents.

Social and cultural factors. For the social factors, social support to be physically active was found to be significantly associated with physical activity among adolescents, especially parental and peer support. In addition to support, parents seem to also affect physical activity by being role models and by being physically active themselves. Strong

relationship with parents was also positively associated with physical activity, and so were parent-child communication and parental engagement in the adolescents' physical activity, such as sports, transportation, work, or planned exercise. Additionally, other studies reported that overall family support was positively associated with physical activity.

Physical environmental factors. Several studies investigated the association between factors in the environment and physical activity among adolescents. The review identified that perceived equipment accessibility had an indirect effect through self-efficacy, and low socioeconomic-status emphasized environmental factors for the adolescents' participation in physical activity. For adolescents in rural areas, educational classes were a significant factor for physical activity, however, other studies found no association between physical activity and where the adolescents lived.

2.5 Mental distress in the adolescent period

Mental disorders is an umbrella term that is used to describe a variety of mental problems from a wide ranging spectrum of symptoms. These symptoms can usually be categorized as a combination of abnormal thoughts, emotions, behavior, and relationship with others (World Health Organisation, 2019, November 28th). Illnesses that fall under "mental disorders" are for example: bipolar disorders, schizophrenia, dementia, but also developmental disorders, such as autism. However, this thesis covers the symptoms of two of the most common mental disorders: depression and anxiety.

Depression is a common, but serious mood disorder where one experience a persisting feeling of sadness and hopelessness. It causes symptoms such as fatigue, appetite changes, irritability, or feeling of "empty mood" (World Health Organization, 2018, January 30th), and it can have a negative impact on day to day life. Many people who suffer from depression are also at higher risk to suffer from anxiety (Hasin et al., 2018). People who suffer from an anxiety disorder have excessive worry and/or fears that can worsen over time, and are often experienced as hindering for daily function. There are different types of anxiety disorders which are usually categorized into general anxiety disorder, panic disorder, and phobia related disorders (National Institute of Mental Health, 2018). General anxiety disorder is excessive worry and/or fears about circumstances in everyday life such as personal health, work, and social interactions. Symptoms of general anxiety disorder are listed as (among others): feeling of restlessness, getting easily fatigued, having difficulties concentrating, and being irritable (National Institute of Mental Health, 2018).

There is no simple answer to what causes depression and anxiety considering that it is a combination of genetic and environmental factors. Furthermore, people can experience symptoms or periods of depression and anxiety at any given point in life, from childhood (Whalen, Sylvester, & Luby, 2017), adolescence (Kempfer et al., 2017), adulthood (Qin, Wang, & Hsieh, 2018), to old age (Elias, 2018). Nevertheless, across cultures, the onset of experiencing symptoms is reported to be during the teenage years (Kessler et al., 2007; Kessler & Bromet, 2013). Many adolescents suffering from depressive symptoms also have a history of anxiety (Merikangas & Avenevoli, 2002), as they often co-occur in childhood and adolescence (Cummings, Caporino, & Kendall, 2014). The expression of comorbidity varies because anxiety is more common in childhood and the onset of depression is more often in adolescence (Kessler et al., 2007).

From here on out, this thesis will use the term "mental distress" to describe symptoms of depression and anxiety. The term is commonly used in research to describe self-reported symptoms that could indicate a potential psychological disorder or diagnosis (e.g Bao Giang, Viet Dzung, Kullgren, & Allebeck, 2010; Jablonska & Lindberg, 2007; Sciamanna et al., 2017).

2.5.1 Mental distress as a global health challenge

Mental distress is thought to be one of the major public health challenges of our time (Ezzati et al., 2002). WHO states that depression is the leading cause of disability worldwide, and is a major contributor to the overall global burden of disease (Hoegh Poulsen, Biering, & Andersen, 2015; World Health Organization, 2018, January 30th). In addition, because mental distress can lead to the inability to work full time or work at all there is an economical burden for the affected individuals and for the society that supports and treat them. A study investigating the financial gain of investing in interventions preventing development of mental distress, found that the economic gain would be significant (Chisholm et al., 2016).

2.5.2 How many adolescents are suffering from mental distress?

The adolescent stage is a stressful period where many physical and emotional changes take place, and adolescents are at a high risk of experiencing a decline in mental health, including developing depression and anxiety (Kessler & Bromet, 2013). As mentioned previously, there are no simple causes for developing depression and anxiety, and it depends

very much on genetic factors, as well as opportunities and resources available for the adolescents.

In Norway. Results from a Norwegian study on adolescents aged 16 to 18 years old showed that 13.5% of girls, and 4% of boys are reporting depressive symptoms (Sivertsen, Harvey, Lundervold, & Hysing, 2014). Naturally, there are higher numbers of adolescents who experience symptoms when combining both the experience of symptoms of depression and anxiety. Of the Norwegian adolescents aged 13-19 years, 22.7% of the girls, and 11.1% of the boys reported that they are experiencing symptoms of depression and anxiety (Fløtnes, Nilsen, & Augestad, 2011).

Internationally. Worldwide, mental health problems affect 10% - 20% of children and adolescents (Kieling et al., 2011). A review study on the prevalence of mental disorders globally reports that one in ten children and adolescents suffer from a mental disorder at any given time (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Additionally, there is a well-established gender difference worldwide for mental health (Afifi, 2007).

Gender differences. Women are more likely to suffer from major depression than men (Blazer, Kessler, McGonagle, & Swartz, 1994), and this gender difference emerges already during adolescence (Kessler, 2003) as depression and anxiety seem to affect girls to a greater extent than boys (Van Droogenbroeck, Spruyt, & Keppens, 2018; Wiklund, Malmgren-Olsson, Öhman, Bergström, & Fjellman-Wiklund, 2012). Furthermore, regarding adolescents who receive treatment, female adolescents are more disposed to recurrence of episodes of depression, and male adolescents are more exposed to experience persistent depression into adulthood (Dunn & Goodyer, 2006).

2.5.3 On the other hand: what does being mentally healthy imply?

To put mental distress in perspective and to understand the concept better it would be appropriate to define what it means to be “mentally healthy”. The WHO states that being mentally healthy is more than being free from mental disorders or disabilities. It is a state of well-being where the individual is able to realize his/her own abilities, can cope with normal stress from everyday life, can work and contribute to his/her community (World Health Organisation, 2018, March 30th). Moreover, WHO emphasizes that national mental health policies should promote mental health itself in addition to focusing on mental disorders.

2.6 Mental distress – From adolescence to adulthood

Experiencing depression in the adolescent period significantly increases the risk of major depression (Fergusson, Horwood, Ridder, & Beautrais, 2005) and anxiety (D. Johnson, Dupuis, Piche, Clayborne, & Colman, 2018) later in life. There is also evidence that depression and anxiety in the adolescent period are associated with additional health reducing behavior in adulthood; nicotine dependence, alcohol abuse or dependence, suicide attempts, educational underachievement, unemployment, and early parenthood for both genders later in life are all associated with depression in adolescence (Fergusson & Woodward, 2002). However, these associations between early depression and psychosocial outcomes seem to reflect the effects of confounding familial, social and individual factors (Fergusson & Woodward, 2002). This implies that it is not the early experience of depression alone that is responsible for these outcomes in adulthood, but rather a combination of problematic familial, social and individual factors. Additionally, earlier ages of onset of depression are shown to be associated with substantial functional impairment (e.g., poor social and occupational function, poor quality of life), never to marry, and greater illness burden, e.g. more current general medical and psychiatric comorbidity, a more negative view of life and the self, more lifetime episodes of depression, more severe depressive episodes, more lifetime suicide attempts, and greater suicidal ideation (Zisook et al., 2007). For women, early onset of depression in adolescence is also found to be significantly associated with violent victimization by intimate partner in adulthood (up to 30 years later) (McLeod, Horwood, & Fergusson, 2016).

2.7 Measuring mental distress for research

Mental distress is often used as an outcome measure in medical and psychological studies, and just as physical activity, there are different ways to measure mental distress:

Questionnaires. Studies that aim to measure self-reported levels of experienced symptoms of mental health can often use one or more validated questionnaires. Often, the participants are asked to answer a set of questions which are then quantified into a score and finally summarized into a mean score. Internationally, researchers have several questionnaires to choose between depending on the study's design, sample population and study aims. For example, larger studies that collect data on multiple variables would benefit from including shorter questionnaires to save time.

There are questionnaires that measure depression and anxiety alone, such as the Beck Depression Inventory (BDI) and the Generalized Anxiety Disorder Assessment (GAD-7), in addition, there are questionnaires that combine the two diagnoses and measure them both in the same tool. Studies in Norway often use one of the different versions of the Hopkins Symptoms Checklist (HSCL) questionnaires for this purpose. The different versions differ in length, the shortest instrument have five items and the full version have 25 items. More on the validation of this instrument will be found in the Method section under "Measurements".

Nevertheless, the same limitations for self-reported physical activity are also present for self-reported symptoms of depression and anxiety. As mentioned, when using self-reported measurement in research it is important to take into account potential bias, such as the recall and response bias.

Systematic interview. The diagnostic interview is seen as the gold standard when it comes to measuring mental distress. The participants are interviewed by trained clinicians, often psychiatrist or a clinical psychologist, and the interview includes multiple testing and questioning for mental health related symptoms. The diagnostic interviews have predetermined questions like the questionnaires, however these are usually more detailed, and one big limitation is that an interview can potentially take many hours to complete.

The diagnostic interviews are more suitable for determining a depression or anxiety diagnosis than questionnaires. Limitations of diagnostic interviews are that it is time and resource consuming, and there are still possibilities that the data derived is affected by bias like the recall and response bias.

2.8 Mechanisms related to mental distress

The WHO declares that mental distress is not only dependent on the factors related to the individual such as being able to manage thoughts, emotions, behaviors and interactions with others, but also social, cultural, economic, political, and environmental factors including national policies, social protection, standards of living, working conditions, and communal support (World Health Organisation, 2019, November 28th). This means that different triggering factors could lead to development of symptoms of depression and anxiety in some individuals, but not all. Whether a person is likely to suffer from symptoms of depression and anxiety is a question that can only be answered by looking at both environment and heritability. Twin studies have found that depression is moderately heritable (Kendler, Gatz,

Gardner, & Pedersen, 2006). Epigenetics refers to studies on heritable changes in gene expression that do not involve alterations to the DNA sequencing, and research have found evidence that depression and anxiety can be caused by changes in a gene expression triggered by life events (Bartlett, Singh, & Hunter, 2017; Dalton, Kolshus, & McLoughlin, 2014).

Depression seems to arise from complex interaction between social, psychological and biological factors, and no one knows what exactly causes mental distress. However, some factors have shown to have an association to depression and anxiety. Symptoms of depression and anxiety are commonly known to be associated with social and psychological factors, such as death of a loved one, conflict, unemployment and abuse, among many other factors (World Health Organization, 2018, January 30th). Also, experiencing traumatic events or childhood maltreatment are potential triggers for depression and anxiety for epigenetically predisposed individuals (Chapman et al., 2004). The same is true for other familial factors, such as absence of support and social interactional, cognitive and affect regulation where the adolescent is unconsciously adapting depressive or anxiety behavior and thought patterns through positive or negative reinforcement (Sheeber, Hops, & Davis, 2001). Also, insecure parent attachments and perceived low social rank seems to be a mechanism for the development of symptoms of mental distress among adolescents (Irons & Gilbert, 2005; A. Lee & Hankin, 2009). Furthermore, poor social support and dissatisfaction with social contacts increases depressive symptoms in both genders (Van Droogenbroeck et al., 2018). Low socioeconomic status is one factor that may trigger depression, as it often coincides with poor housing facilities, subjective and objective stress, noise pollution, and exposure to violence (Barbeau, Krieger, & Soobader, 2004; Fryers, Melzer, & Jenkins, 2003; Goodman, Slap, & Huang, 2003; Swartz, Hariri, & Williamson, 2017).

As mentioned in the introduction of this thesis and because the potential consequences also mentioned in the previous sections, it is important to investigate potential factors that could help to prevent or treat mental distress, such as physical activity. Recurring depression can lead to more stress and dysfunction for the adolescent, and could potentially worsen the life situation and the depression itself (World Health Organization, 2018, January 30th).

2.9 The association between physical activity and mental distress among adolescents

The adolescent period can be crucial for intervening and preventing the development of mental health problems due to the aforementioned increase in prevalence of mental

disorders in the teenage years (Merikangas et al., 2010). For adults, the association between physical activity and mental distress has been investigated thoroughly and the results point towards it being adequately significant (Penedo & Dahn, 2005). For adolescents, the association is less researched and the existing results are far from conclusive. A systematic review found that people who suffer from depressive disorders are found to be significantly less likely to meet the recommended physical activity levels compared with people without the disorder (Schuch et al., 2017), and structured physical activity is suggested to reduce the depressive symptoms for people with a depressive disorder (Schuch et al., 2016). However, the previous research on the association between physical activity and mental distress among adolescents suffers from weak research designs and find small to moderate effects at best (Biddle & Asare, 2011).

To further complicate the matter, the terms "physical activity" and "exercise" are sometimes used interchangeably (Biddle & Mutrie, 2007). This is less than ideal as "exercise" is defined as planned, structured, and repetitive movement with the purpose of improving or maintaining physical health (Caspersen et al., 1985), and does not include all other types of physical activity as the broader term does. This makes comparisons between the research results difficult, as one can still be highly physically active without partaking in activates that one would classify as exercise. Therefore, conclusions made on research based on data of the narrow term *exercise* should ideally not be generalized to the broader term *physical activity*, and vice versa.

The following sections presents the relevant research on the association between physical activity and mental distress among adolescents, describing the research designs and the results, and furthermore, the theory behind the association.

2.9.1 Cross-sectional studies

The majority of the studies in the field on the association between physical activity and mental distress among adolescents are of a cross-sectional design (Biddle & Asare, 2011), measuring the association from only one specific time point. The overall results from the studies with this research design seem to imply an inverse relationship (K. E. Johnson & Taliaferro, 2011), meaning that adolescents that have low levels of physical activity also have symptoms of mental distress, and vice versa. However, the strength of the relationship is small to moderate, and the reliability of the results are limited by methodological weaknesses

relating to measurement and study design, as a majority of the existing cross-sectional studies have relied on single-item self-report measures of physical activity (K. E. Johnson & Taliaferro, 2011).

The major limitation of the cross-sectional studies is that the results do not contain information about how the association between physical activity and mental distress develops over time. To investigate this, researchers need to conduct research with repeated measurements for each individual, i.e. longitudinal studies. As we will see in the next section, results from longitudinal research do not necessarily arrive at the same conclusions as the cross-sectional studies.

2.9.2 Longitudinal studies

The longitudinal studies in the field of the prospective relationship between physical activity and depression on adolescents yield equivocal results. Some longitudinal studies conclude that there is a prospective relationship (Raudsepp & Neissaar, 2012; Sabiston et al., 2013; Sund, Larsson, & Wichstrøm, 2011), whereas others do not (Birkeland, Torsheim, & Wold, 2009; Rothon et al., 2010; Stavrakakis et al., 2013; Toseeb et al., 2014; Van Dijk, Savelberg, Verboon, Kirschner, & De Groot, 2016). There are methodological differences between the longitudinal studies, for example, different sample sizes, the duration to the follow-up period, follow-up examinations, and mode of measurement for the variables in the studies. This makes comparisons across studies difficult, and the only conclusion one can draw based on the existing research is that the relationship between physical activity and depression among adolescents is unknown. In addition, few of the longitudinal studies have used objective measurement for physical activity where they either use an accelerometer or a step-counter to measure the total physical activity in a given time period (Toseeb et al., 2014; Van Dijk et al., 2016). Interestingly, these studies do not show an association between objectively measured physical activity and mental distress among adolescents. Additionally, a recent meta-analysis showed that, for longitudinal studies that find a significant relationship between physical activity and mental distress among adolescents, the overall effect of physical activity on depressive symptoms is small (Korczak, Madigan, & Colasanto, 2017).

The majority of both the cross-sectional and longitudinal studies have been conducted on data of symptoms of depression and anxiety and physical activity in the general population. However, there are also intervention studies that have investigated how physical

activity, when introduced, affect individuals with symptoms of mental distress or a diagnosis of depression, leading to information about cohorts with symptoms of mental distress.

2.9.3 Intervention studies

Several intervention studies have been conducted to investigate the impact physical activity can have on participants who have confirmed diagnoses of depression and anxiety, and also here, the results seem to be inconclusive. A Cochrane review of randomized controlled trials of interventions of vigorous physical activity compared to control groups of children and adolescents aged 0 to 20 years found a small effect of physical activity on reduced depression (Larun, Nordheim, Ekeland, Hagen, & Heian, 2006), still, the diversity of participants, interventions and methods of measurement in the studies included in the review limited the ability to draw conclusions regarding a treatment or protective effect of physical activity. For adults, findings from another meta-analysis showed that supervised physical activity interventions had a stronger effect on depression when it included flexibility/resistance training and low-effort exercise, and that recommendations for exercising at a work-out center worked better for un-supervised exercise (Conn, 2010). For children and adolescents, a different meta-analysis found only a small overall significant effect for physical activity interventions on depression (Carter, Morres, Meade, & Callaghan, 2016).

2.9.4 Different physical activity intensities

Several studies investigating the association between physical activity and mental distress distinguish and investigate the effect of moderate to vigorous physical activity intensity on mental distress, and there are indications in the literature that more time in vigorous physical activity could confer a greater effect on mental health in the general population, but the results are mixed (Harvey, Hotopf, Øverland, & Mykletun, 2010). In addition, the degree to which the frequency and duration of the physical activity are of any relevance to the development of mental distress over time ought to be investigated, however these factors are rarely distinguished in research investigating the longitudinal relationship between physical activity and depression (Sabiston et al., 2013).

Physical inactivity is no physical activity at all, it is the exact opposite. However, as we will see in the next section, inactivity, from now on called sedentary behavior, does not

exclude physical activity. Therefore, significant positive results from studies that investigate the effect of sedentary behavior on mental distress should not be interpreted as evidence that physical activity is associated with mental distress.

2.9.5 Sedentary behavior and mental distress among adolescents

Sedentary behaviors are activities that involve sitting or lying down which result in low energy expenditure. As mentioned in the previous section about physical activity, television viewing, computer use, reading, and knitting are examples of sedentary activities. Studies on European adolescents indicate that they spend the majority of their waking time in sedentary behavior, on average 70 % (Ruiz et al., 2011). A significant portion of this percentage of sedentary behavior could be explained by time the adolescents spent in school and doing homework. Moreover, research has found indications that parents socioeconomic status seems to be inversely associated with sedentary time among adolescents (Van et al., 2007).

Furthermore, highly sedentary adolescents are at risk to maintain and increase their sedentary level going into adulthood (Gordon-Larsen, Nelson, & Popkin, 2004), and this may be a cause for concern as high levels of sedentary behavior has been shown to be associated with depressive symptoms (Primack, Swanier, Georgiopoulos, Land, & Fine, 2009). This is comparable with the results from the studies on physical activity and mental distress. Nevertheless, a person can be sedentary the majority of the day, and still exercise a satisfactory amount, as physical activity and sedentary behaviors are not mutually exclusive (Pearson, Braithwaite, Biddle, Sluijs, & Atkin, 2014). A review tracking physical activity and sedentary behaviors from adolescents to young adults found that the time adolescents spend in MVPA is independent from the time they spend in sedentary activity level (Healy et al., 2008). This is an important finding as the results from many of the existing studies on the association between sedentary time and mental distress are not adjusted for physical activity levels (de Wit, van Straten, Lamers, Cuijpers, & Penninx, 2011), leading to major uncertainties in the results. However, when adjusting for physical activity levels, persons with symptoms of depression seem to spend more time in sedentary behavior compared with persons without symptoms (Trinh, Wong, & Faulkner, 2015).

Self-reported screen time. The existing literature on the research of sedentary behavior shows that the term “sedentary behavior” often has been operationalized as self-

reported hours in screen-time, as in time spent watching a screen (Hoare et al., 2016). In general, studies that use this operationalization of sedentary behavior show that there is a positive association between screen-time and mental distress among adolescents (Arbour-Nicitopoulos, Faulkner, & Irving, 2012; Bickham, Hswen, & Rich, 2015; Hoare et al., 2016; Mathers et al., 2009; Primack et al., 2009; Stiglic & Viner, 2019; Trinh et al., 2015). However, the association between self-reported screen-time and mental distress, though significant, has a generally small effect size (Orben & Przybylski, 2019; Sund et al., 2011). In addition, there is evidence that screen-time has a significant positive effect on well-being for adolescents (high well-being and low levels of mental health problems), nevertheless, screen time only accounts for 0.4% of the variance in broadly defined well-being, suggesting that screen time is only associated with reductions in well-being to a very small extent (Orben & Przybylski, 2019). In contrast, objectively measured sedentary behavior measured by accelerometer shows no association to depression among children (Zahl, Steinsbekk, & Wichstrøm, 2017). The same is true for adolescents, where no significant association was found for neither self-reported screen-time nor objectively measured sedentary time with mental distress, cross-sectionally and longitudinally (Hume et al., 2011). However, depressive symptoms significantly predicted hours spent watching TV among girls (Hume et al., 2011).

2.9.6 Method of measurement

Looking through the results from previous research using different study designs and study aims, a reoccurring factor has made itself clear: there seems to exist a discrepancy in the results on the association between physical activity and mental distress among adolescents, and it appears to depend on whether the measurement is objective or subjective. However, very few studies have investigated whether this is true. Returning to sedentary behavior, studies have found that self-reported screen time is a poor estimate for sedentary behavior compared with objective measurement, such as data from accelerometers (Chastin et al., 2018). This is an important finding that calls for thorough assessment by the researchers on whether to use objective or subjective measurements when investigating an association between physical activity/inactivity and mental distress. As mentioned previously, when using self-reported measurement in research it is important to take into account potential recall and response bias. Where possible, researchers could benefit from using both types of measurements to provide important insight on how the different measurement types impact the results.

2.10 Gender differences in the association

There are strong indications in the literature that there are some significant gender differences in the association between physical activity and mental distress among adolescents. When a significant prospective association between physical activity and mental distress were found among adolescents, it seemed that the female adolescents experienced a stronger indirect effect from physical activity compared to male adolescents (Haugen, Johansen, & Ommundsen, 2014). However, it could seem that the intensity of physical activity is of importance for the association as there is evidence that only more hours in moderate to high physical activity levels were associated with lower levels of anxiety for female adolescents (Haugen et al., 2014). Moreover, female adolescents also seem to have a stronger association between physical activity and global self-worth through perceived appearance (body image) compared to male adolescents (Haugen, Säfvenbom, & Ommundsen, 2011). Nevertheless, another study found that physical activity was indirectly associated with psychological distress through perceived appearance (body image) in both male and female adolescents, however, there was still a stronger indirect association among females (Haugen et al., 2014).

2.11 Mediating factors of the association

Mediating factors are mechanisms that explains the relationship between a predictor and an outcome variable. The previously mentioned study that found that physical activity was indirectly associated with psychological distress through body image (Haugen et al., 2014) provides an example of an association with a mediating factor. Understanding what role mediating factors play in the association between physical activity and mental distress among adolescents could possibly provide insight into, among other things, why adolescents who experience mental distress also are less physically active, and this information could further be useful for designing interventions and implement strategies that aim to enhance physical activity among this group. Unfortunately, the research field on the association between physical activity and mental distress suffers from a lack of knowledge about potential mediating factors.

2.11.1 Emotional intelligence and self-efficacy

A study found that emotional intelligence, meaning skills that contribute to accurate appraisal and expression of emotion of oneself and others, play a partially mediating role on

the association between physical activity and mental health among students (Dev & Rahman, 2016). Another study found that improving physical activity self-efficacy mediated the association between leisure-time physical activity and depression through improved physical activity, but coping self-efficacy did not serve as a mediator (Pickett, Yardley, & Kendrick, 2012). However, there are other potentially mediating factors that would be interesting to investigate.

2.11.2 Perceived barriers towards physical activity

An example of a factor that can be related to higher levels of physical activity and lower levels of sedentary behavior is *perceived barriers*. The term has been used to investigate hindrance towards general health behaviors, but is also used for barriers towards specific health behaviors such as physical activity (Tappe, Duda, & Ehrnwald, 1989). There are several factors that an individual can perceive as a barrier that is keeping them from being physically active. The most common perceived barrier is lack of time to be physically active (Biddle, Whitehead, O'Donovan, & Nevill, 2005; Tappe et al., 1989). Other barriers commonly cited are the lack of someone to be active with (Tergerson & King, 2002), lack of enjoyment while exercising (Biddle et al., 2005) and inaccessibility of facilities (Dwyer, Allison, Goldenberg, & Fein, 2006).

Adolescents who experience more perceived barriers are less likely to be physically active (Allison, Dwyer, & Makin, 1999; Biddle et al., 2005; Sallis, Prochaska, & Taylor, 2000), and are more likely to engage in sedentary behaviors (Salmon, Owen, Crawford, Bauman, & Sallis, 2003). Nevertheless, the research available on the association between perceived barriers towards physical activity and physical activity is limited, and there is even less on the association between perceived barriers and mental distress, or how it contributes to the association between mental distress and physical activity.

2.11.3 Enjoyment of physical activity and perceived competence

Experience of enjoyment for physical activity and perceived competence of physical activities are other factors that can play a mediating part in the association between mental distress and physical activity. These factors have previously been found to correlate with physical activity (Sallis et al., 2000; Yang, Kelly, Pedro, Gregory, & Norma, 2018), in addition to predict physical activity levels (DiLorenzo, Stucky-Ropp, Vander Wal, & Gotham,

1998). However, the results are mixed and suffers from a lack of extensive research among adolescents (Biddle, Atkin, Cavill, & Foster, 2011). Moreover, it is unknown whether adolescents with symptoms of depression and anxiety have different experiences of enjoyment and competence in physical activity, and how this ultimately affect their physical activity levels.

2.11.4 Peer relations

Poor peer relations and loneliness have been found to predict depression (Joiner Jr, 1997; Moeller & Seehuus, 2019; Ueno, 2005). Furthermore, peer acceptance, defined as how the peer group feels about a specific individual, is an important determinant of sports continuation, perceived competence and enjoyment of activity (A. L. Smith, Ullrich-French, Walker, & Hurley, 2006; Ullrich-French & Smith, 2009), which all are related to higher levels of physical activity (e.g. Phillips & Young, 2009; Sollerhed, Apitzsch, Råstam, & Ejlertsson, 2008). Thus, mental distress may be related to physical activity through peer acceptance, which in turn may impact enjoyment of activity and perceived competence that also could be related to physical activity levels, making peer acceptance the most promising mediating factor in the association between mental distress and physical activity. Nevertheless, it has not previously been investigated as a mediator for the association between physical activity and mental distress among adolescents.

2.12 Causality in the association

Based on the results from previous research, it is tempting to conclude that physical activity is the causal agent, acting as a protective factor in the relationship between physical activity and mental distress. If one assumes that physical activity had a protective effect on mental distress, one could implement physical activity promoting measures for the exposed groups in a way to promote mental health. Nevertheless, very few studies have investigated the direction of the relationship, and the overall results fail to find a causal agent. In the aforementioned intervention studies, which can point towards a potential causal agent, it is difficult to identify the complexity of the relationship between physical activity and mental distress from the results (Hagmayer, Sloman, Lagnado, & Waldmann, 2007). Without a causal agent it is not possible to decide if it is physical activity that has an effect on depression among adolescents, or if it is that depressed adolescents cannot manage to be physically active. In order to answer if physical activity leads to changes in depressive mood, or if

depressive mood leads to change in physical activity, two directional hypotheses explaining the relationship between physical activity and depression have been proposed – the protection hypothesis and the inhibition hypothesis (Birkeland et al., 2009).

2.12.1 Causal hypotheses

The protection hypothesis postulates that physical activity protects against depression, and it builds on several biological and physiological mechanisms explaining the protective nature. One biological explanation could be that physical activity triggers physiological responses that enhance mood, such as higher levels of norepinephrine, endorphin and serotonin, and lower hormonal responses from stress (Birkeland et al., 2009; Oweis & Spinks, 2001). Studies have found that physical activity could have a protective effect when high intensity and frequent physical activity among young athletes were associated with lower levels of anxiety and fewer depressive symptoms compared to non-athletes, indicating that increased hormonal responses at higher levels of intensity exercise plays a part in the protection against mental distress (Brand et al., 2010; Silverman & Deuster, 2014; Zimmer et al., 2016).

The psychological explanation suggest that physical activity causes feelings of mastery and control (Birkeland et al., 2009), influences self-esteem (Dhillon & Hafiz, 2018), body composition (Swami, Weis, Barron, & Furnham, 2018), acts as distractors from stressors, negative thought and rumination (Birkeland et al., 2009), and could provide an arena for the individual to learn social skills (Haller, Cohen Kadosh, Scerif, & Lau, 2015) and gain a social network (Birkeland et al., 2009; Zhao et al., 2015). Research by Haugen, Säfvenbom, and Ommundsen (2013) show results that support this hypothesis as their findings suggest that sport participation during the adolescent period is indirectly associated with lower levels of loneliness through higher levels of perceived social competence knowing that childhood loneliness is associated with depressive symptoms in adolescence (Qualter, Brown, Munn, & Rotenberg, 2010). Moreover, research on organized sports also support the psychological explanation, as organized sports have been found to be associated with lower odds of depressive symptoms (Kleppang, Hartz, Thurston, & Hagquist, 2018). This could be explained through the idea that sport participation provides an opportunity where many adolescents can fulfill the aforementioned factors.

The inhibition hypothesis assumes that depressed mood causes lower levels of physical activity, meaning that a relationship between mental distress and physical activity could be explained by the depressed individual lacking the energy to engage in physical activities (Birkeland et al., 2009). One study that provided evidence supporting the inhibition hypothesis found that high depressive symptoms trajectories were associated with lower percentage of time spent in moderate physical activity and being less likely to meet the MVPA guidelines (Sabiston et al., 2013).

However, Birkeland et al. (2009) investigated if there exists any significant support for either the protection or inhibition hypothesis in an adolescents sample and the results did not find any support for neither hypotheses.

2.13 Summary of the knowledge gaps in the field

Physical activity is considered an easy and inexpensive measure that a individual can do by their own effort to prevent health problems, and it has little negative side effects. For mental health, there is evidence which shows that physical activity is inversely associated with, for example, symptoms of anxiety and depression (Mammen & Faulkner, 2013; Schuch et al., 2018), but the results are ambiguous and suffer from limitations. The Background section has presented and demonstrated some of the more prominent limitations. As a whole, it seems that the research field on the association between physical activity and mental distress among adolescents suffers from some knowledge gaps.

For instance, there is a need for more longitudinal research in the field with strong research designs and validated measurements that provide an insight into how the association behaves over time. Furthermore, there is a need to investigate how the impact of frequency and duration of physical activity sessions play a part on the association among adolescents. The contradictory results comparing research that use objective measurements vs. subjective measurement show the necessity of further research in order to shed light on the use of different modes of measurements and the effect it has on research in the field. Finally, since the association between physical activity and mental distress among adolescents is ambiguous, more research on potential mediating factors are needed in order to understand the possible underlying effects on the association.

3. Study aims

This thesis aimed to investigate the association between physical activity and mental distress among adolescents using data from the Tromsø Study: Fit Futures. These were the main study aims:

1. To investigate the relationship between change in objectively assessed physical activity as measured by accelerometer and change in mental distress.
2. To investigate the cross-sectional and longitudinal association between 1) objectively measured sedentary time and 2) self-reported screen time with mental distress.
3. To 1) investigate if mental distress is related to levels of physical activity and sedentary behavior among adolescents, and 2) if the association is mediated by peer acceptance, enjoyment or perceived barriers towards physical activity, tested in a serial multiple mediator model.

4. Materials and methods

This thesis and the papers included are based on the existing data of The Tromsø Study: Fit Futures, which is a population-based survey of adolescents attending upper secondary school in two municipalities in Northern Norway. There are many benefits of doing research on existing data from a completed population-based survey. Cheng and Phillips (2014) mention some of the benefits and limitations in their article about secondary analysis of existing data. First and foremost, the data is already collected, thus saving the researcher a lot of time. There is often a fee to access the data, but this is usually a small amount compared to the actual cost for conducting the study, so it is also cost efficient. Moreover, population-based surveys will invite the entire population to participate, resulting in a larger sample size with high representativeness. Finally, larger population-based studies often hire statisticians to generate ready to use variables that are made available for further studies.

Despite these advantages, there are some limitations that must be considered when doing research on existing data. For example, as the data were collected before planning this study and thus not customized for this particular research, the analysis could potentially be restricted by missing important variables. Another limitation is that since the researcher in this project were not present during the data collection, we could be unaware of crucial study-based details, such as nuances, issues and mistakes that could be important when interpreting the specific variables.

We used the longitudinal potential and the vast assortment of objective and subjective data available from the Fit Futures study when planning the current project and developing the research questions. This resulted in quality research with novel and important results that were completed over a relatively short time span of three years.

4.1 The Tromsø Study: Fit Futures

The Tromsø Study: Fit Futures (hereafter called Fit Futures) is a population-based youth study aiming to collect longitudinal data on lifestyle and general health information on adolescents attending upper secondary school in two municipalities in Northern Norway, Tromsø and Balsfjord, representing both urban and rural district adolescents. Moreover, Fit Futures is conducted in the framework of the Tromsø study in collaboration with UiT- The Arctic University of Norway, Norwegian Institute of Public Health and the University Hospital of Northern Norway.

The Fit Futures study included a web-based questionnaire (Questback), clinical examination and interview performed by trained research nurses at the study site at the University Hospital of Tromsø. The data collection was conducted during school hours and took about 3 hours to complete, and the participants were transported to and from the research site. Participants did not count as absence from school, and the students that were sick and unable to attend the study were booked for a new appointment at a later time. Additionally, as stated in §17 in the Norwegian Health Research Act, all participants aged 16 years or older provided written informed consent to partake in Fit Futures. Consent from a guardian was required for participants younger than 16 years.

In Fit Futures 1 (FF1) all first-level upper secondary school students in the two municipalities were invited to participate. The first data collection was conducted in the school-year of 2010-2011. In total, 1,117 students were invited, and 1,038 (92.9%) agreed to participate. The second wave, Fit Futures 2 (FF2), was conducted two years later in the school year of 2012-13. All attendees in FF1 and all students at the third level of the same upper secondary schools were invited to participate. The students who had switched schools or dropped out were also invited, and transport arrangements were made accordingly. In total, 1,129 students were invited, out of which 870 (77%) agreed to participate, of which 694 (67%) students also participated in FF1. The majority of the participating sample was 15-17 years old in FF1 and 17-19 years old in FF2.

4.2 Measurements

4.2.1 Mental distress - HSCL-10

Fit Futures collected data on mental distress in both FF1 and FF2 by including the Hopkins Symptom Checklist – 10 (HSCL-10) in the general health questionnaire. HSCL-10 aim to measure symptoms of depression and anxiety the previous week through 10 questions, and is a shorter version of HSCL-25 that is also commonly used in research to measure the same symptoms. Of the 10 items in HSCL-10, 4 items aim to measure symptoms of anxiety and 6 items symptoms of depression. The participants score the appropriate level of experience on a four-point Likert Scale. It is important to mention that the scale does not measure the presence of a clinical diagnosis, but mental distress in a more general sense, operationalized as symptoms of anxiety and depression.

The items of HSCL-10 are as follows[5]:

"Have you experienced sudden fear without apparent reason during the last week?"
"Have you felt afraid or worried during the last week?"
"Have you experienced faintness or dizziness during the last week?"
"Have you been tense or upset during the last week?"
"Have you easily blamed yourself during the last week?"
"Have you experienced sleeplessness during the last week?"
"Have you felt depressed or sad during the last week?"
"Have you felt useless, worthless during the last week?"
"Have you felt that life is a struggle during the last week?"
"Have you felt hopelessness with regard to the future during the last week?"

Response categories are "none" scored as 1, "slightly" scored as 2, "much" scored as 3, and "very much" scored as 4. The ten scores of the scale are averaged to get the HSCL-10 score. Strand, Dalgard, Tambs, and Rognerud (2003) found that an average score of 1.85 or higher indicated symptoms of anxiety and depression. However, for younger adolescents who are between 14-16 years old, a cut off from 1.6 is suggested appropriate (Haavet, Sirpal, Haugen, & Christensen, 2010).

The internal and external validity and reliability of the HSCL-10 have been found acceptable in a number of studies: e.g. Strand et al. (2003) argued that despite that the longer version of the Hopkins Symptom Checklist, HSCL-25, had higher reliability, the shorter versions had acceptable overlap and advised that shorter versions are used in cases where HSCL is a part of a comprehensive questionnaire. Moreover, Haavet et al. (2010) have concluded that HSCL-10 is a valid instrument for identifying depression among adolescents aged 16 years or under.

All papers included in this thesis used the HSCL-10 as one of the main key variables. Nonetheless, the score has been used in different variations. In the first paper, the average score of the HSCL-10 results were converted to a change score variable from FF1 and FF2, and served as the outcome variable. A standardized HSCL-10 score from FF2 served as the

[5] The adolescents participating in Fit Futures are and speak Norwegian, and therefore all test items, HSCL-10 included, have originally been in Norwegian during testing. These cited items are in English for comprehensibility for English speaking readers. However, if there are Norwegian speaking readers who wish to see the Norwegian translation of HSCL-10 it can be found e.g. on the Helsedirektoratets web page.

outcome variable in the second paper for easier interpretation, and the models controlled for the baseline score of HSCL-10. Finally, in the third paper, the HSCL-10 score was dichotomized into over/under the cut-off 1.85, and served as the predictor variable.

4.2.2 Objectively measured physical activity

Fit Futures collected objectively measured data on physical activity by using an accelerometer. All participants were invited to wear an accelerometer. The model used was the ActiGraph GT3X, and the participants who wore the accelerometer were instructed to wear it on their dominant hip for 8 days, and only take it off when sleeping, showering or swimming. The first day of wear time was deleted in an effort to counter reactivity, and wear time was organized to start at midnight the next day. Furthermore, the participants with at least ten hours wear-time for at least four of the seven days were considered to have valid data.

As mentioned in the Background section, the ActiGraph measures acceleration in movement referred to as "counts". Fit Futures used the ActiLife software provided by the manufacturer (ActiGraph, LLC, Pensacola, USA) for the ActiGraph device initialization, and the data was downloaded as raw data and data with aggregated 10-second epochs. Subsequently, the customized software Quality Control & Analysis Tool (QCAT) was used for further data processing. Epochs were categorized into intensity zones based on uniaxial cut-off values by Freedson et al (Freedson et al., 1998) described previously. Removal for non-wear-time was based on the triaxial algorithm described by Hecht, Ma, Porszasz, and Casaburi (2009) as it conforms to previous research definition of non-wear time (Tudor-Locke, Camhi, & Troiano, 2012).

Objectively measured physical activity is thought to provide more accurate measurement than self-reported measurement. The validity of the ActiGraph is typically measured against other accelerometers or against doubly labelled water or calorimetry (Farrahi, Niemelä, Kangas, Korpelainen, & Jämsä, 2019; Ndahimana & Kim, 2017). Despite research indicating that accelerometers lead to more accurate measurements of physical activity, the accelerometer data should be evaluated up against the potential biases, as mentioned earlier.

The studies of this thesis use several of the computed variables collected by the ActiGraph GT3X accelerometer in Fit Futures 1 and 2. However, the inclinometer function of

the ActiGraph GT3X has shown limited validity (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011), and therefore not used. In the first paper both steps per valid day, divided by 1000 for easier interpretation, and minutes in MVPA were used as predictor variables. In this paper we calculated change scores by subtracting the FF1 score from the FF2 score, and used it to investigate change in physical activity from baseline to two years later. In the second paper we used percentage of day spent in sedentary time measured by accelerometer as a predictor variable, and minutes in MVPA as a covariate in the analyses, and compared the results with the results from the analysis with self-reported screen-time as the predictor variable. The third paper, used objectively measured sedentary time and minutes in MVPA as the outcome variables.

4.2.3 Self-reported screen-time

The general health questionnaire in the Fit Futures study included two items measuring self-reported screen-time where the participants were asked to estimate the time spent each day watching a screen (PC, TV, and DVD) outside school. The two items were divided on self-reported screen-time for weekdays and weekends:

"How many hours per day do you spend by the PC, watch TV, DVD etc. outside school during weekdays?"
"How many hours per day do you spend by the PC, watch TV, DVD etc. outside school during weekends?"

The response method was originally ordinal, and the adolescents responded from none hours to ten hours or more, divided into seven categories. However, before the analysis in the second paper, these variables were recoded to an approximate continuous variable in order to facilitate a more accurate interpretation. Also, the two measurements, weekday and weekend, were summarized making a mean self-reported screen-time variable across the week.

4.2.4 Mediators

Low peer acceptance. The questionnaire in the Fit Futures study included five items measuring the adolescents' perceived social acceptance, and asked about the degree to which the respondents finds it hard to make friends, have many friends, feel accepted among his/her peers, feel liked among peers, and feel popular among peers. The responses were given on four point Likert type scales, ranging from highly incorrect to highly correct.

These items make out the subscale called Social Acceptance in the Self-Perception Profile for Adolescents (SPPA) developed by Harter (1988). The complete SPPA aims to measure domain specific and global self-perception/self-esteem among adolescents. Fit Futures used the Norwegian translated and adapted version of the social acceptance subscale of SPPA. This revised version was developed by Wichstrøm (1995) to fit the Norwegian adolescents. The most important differences between the original and the revised version are that the items in SPPA were changed to be less time consuming and requiring less explanation in advance. Subsequently, this made it easier to use SPPA as part of a larger questionnaire[6], such as the Fit Futures. Every subscale in SPPA is scored individually and therefore often used separately depending on the study aim of the research. The subscales have been validated individually, each with different results. However, the validation of the social acceptance subscale used in the Fit Futures has been deemed acceptable (Jozefiak & Backer-Grøndahl, 2019).

Low score on the social acceptance subscale was investigated as a mediator on the association between mental health and physical activity in paper 3. Additionally, the mean score from the social acceptance scale has been used in paper 1 and paper 2 as a covariate in the analysis.

Enjoyment and perceived competence towards physical activity. There were four items meant to measure the extent to which the participants experience enjoyment and competence of physical activity included in the general health questionnaire in the Fit Futures study. The items are based on the research by Ommundsen, Page, Ku, and Cooper (2008), and the incorporation of the Norwegian items in Fit Futures was in cooperation with Ommundsen. These items were:

"I have more fun during exercise or physical activity than doing other things"
"I wish I could do more exercise/physical activity than what I have the opportunity to"
"I feel that I am better than most people my age at sports/physical activity"
"I feel that I can easily keep up with others my age during sports/physical activity"

These variables were analyzed and recoded previous to the mediation analysis. First, the response categories were recoded to show the rate of agreement in an increasing rate. Three items were averaged into a mean score of enjoyment and perceived competence after a

[6] The Norwegian SPPA is free of charge with copy right by Lars Wichstrøm.

factor analysis showed that wishing to do more exercise and/physical activity than they have the opportunity for, loaded on a separate factor. This mean score variable serves as a mediator in the regression analysis, and the process is explained in detail in paper 3.

Barriers towards physical activity. Perceived barriers of physical activity were measured in the questionnaire by asking participants to rate how much they agreed to the eight following statements, using items based on the research by Ommundsen, Page, Ku, and Cooper (2008) and Deforche, De Bourdeaudhuij, and Tanghe (2006). The items were:

"I don't like to exercise while others are watching"

"Access to a private dressing room would make exercising easier"

"I get uncomfortably breathless, unpleasant sweat or bodily pain when exercising"

"The exercise lessons at school are organized in a way so that I cannot keep up"

"I have nobody to exercise with"

"I don't have the equipment necessary to do the activity I want to"

"I have too many other tasks to get time for exercising (e.g. homework, household work)"

"There is a lack of suitable sports halls, or good outdoor areas to engage in physical activity where I live".

Also these variables were analyzed and recoded previous to the mediation analysis as described for the enjoyment variable. All eight items were averaged into a variable that was used in the regression analysis as mediator, and the process is explained in detail in paper 3.

4.2.5 Covariates

A number of variables can have a potential impact on the relationship between physical activity and mental health among adolescents, and controlling for relevant covariates will increase the precision of the estimated coefficients. Consequently, this thesis has included a variety of covariates in the analyses. Nonetheless, the number of variables included in the different analyses varies from each paper due to the response from reviewers when submitting to journals and the trend in the literature.

The covariates that were included in the analyses are described in the Summary of papers and results chapter.

4.3 Data analyses

4.3.1 Treatment of missing data – Multiple imputation

Missing data refers to the occurrence where there is no data value reported for a variable in an observation. Despite being very common, missing data can have a significant impact on the results and conclusion of statistical analysis. There are different categories of missing data: Unit-non response refers to no data reported by the unit (participant), and could occur when the participant fail to send in the questionnaire, not being available for interview, or hand in a blank questionnaire. Wave-non response is a second type of missing data, and refers to the failure to complete data collection at later measurement point in a longitudinal study, meaning that the data is available at base-line for a participant, but is not completed at follow-up. A third kind of missing data is item non-response, and refers to missing data on some questions or measures. Item non-response can occur because of sensitive, difficult or irrelevant questions, but also because of failure to notice the question or tiredness.

Furthermore, missing data is divided into groups of randomness that will have different impact on the validity of the conclusions derived from the research. These types are: missing not at random, missing at random, and missing completely at random. There exist a potential of varying degree for there being bias present in the dataset if the missing data is categorized as missing not at random or missing at random. If the missing data is missing completely at random, it is still acceptable to believe that the sample is representative to the population despite the missing data. However, if it is not, and the data is missing systematically, any conclusions derived from an analysis are likely false because of the biased data.

When analyzing the data, many researchers will run the analysis on complete cases only, and only include the data from the participants who have no missing data on the variables included in the analysis. This will increase the possibility of biased results, and cause loss in precision and power because of the reduced sample size. The possible bias depends on the pattern of the missing data, as mentioned previously.

Multiple imputation is an approach to deal with missing data in a dataset, and can easily be done in many statistical packages. It makes multiple copies of the dataset where the missing values are replaced by imputed values sampled from a predictive distribution based on the observed data, and with random variation. The estimated imputed values will vary

between the multiple copies of the dataset, and are only useful when averaged together into a pooled dataset that can be used in the analysis. However, there are some conditions that must be met before doing multiple imputation: 1) the missing data should be missing at random, 2) the model for imputation should be appropriate, and 3) the model the researcher use should match with the model of the multiple imputation.

There were missing data in the Fit Futures study's dataset, and we found that the objectively physical activity measurement and questions about parents' highest completed education level had large amounts of missing data. After analyzing the pattern of missingness and the results from sensitivity analysis of the original data that showed that participants who dropped out of the study between FF1 and FF2 did not differ in terms of physical activity, screen-time, or symptoms of anxiety and depression, we concluded that the missing data seems to be missing at random. Although, there is no way one can be completely sure about the randomness of missing values without conducting a follow-up survey among participants with missing data. In order to increase power to detect an effect, as well as reduce possible bias due to missing values, multiple imputation was used to impute FF1 and FF2 ActiGraph and socioeconomic data because of their high representation of the missing data. Furthermore, it was set as a requirement prior to the imputations that only missing ActiGraph and parental highest education data of participants who had questionnaire data from both FF1 and FF2 were to be imputed.

Separate multiple imputations were conducted for paper 1 and paper 2, and different proportions of the missing data were imputed due to the predictive model consisting of all variables included in the different analyses. Both papers imputed 50 datasets that were subsequently pooled and analyzed. In paper 1 we imputed both missing FF1 and FF2 accelerometer data, steps and minutes in MVPA per valid day, and data on parental education for participants who had questionnaire data from both measurements. In paper 2, FF1 accelerometer data, percentage of sedentary time and minutes in MVPA per valid day, and parental education for participants who had data from both FF1 and FF2 were imputed. Table 3 shows the percentages of the imputed values for each paper. Further analysis confirmed that participants who had missing data were not significantly different from those with complete data, and the observed values were perceived as good predictors for the multiple imputation for both papers.

Paper 3 did not have any imputed variables because the SPSS macro add on, PROCESS, does not support multiple imputation files. Moreover, it was not possible to use

other imputation methods, such as the Expectation Maximization method, as objectively measured physical activity is measured in a single measurement, and not a sequence of measurements of which one may estimate a probable value for missing data.

Table 3: *Percentages of the total number of values that were imputed missing values in paper 1 and 2.*

	Accelerometer*	Parents highest education		Total n
		Mother	Father	
Paper 1 (FF1 and FF2)	35.2%	25%	29.3%	676
Paper 2 (FF1)	35%	26%	29%	686

**Paper 1 imputed steps and minutes in MVPA per valid day, paper 2 imputed percentage of sedentary time per day and minutes in MVPA per valid day*

4.3.2 Statistical analyses

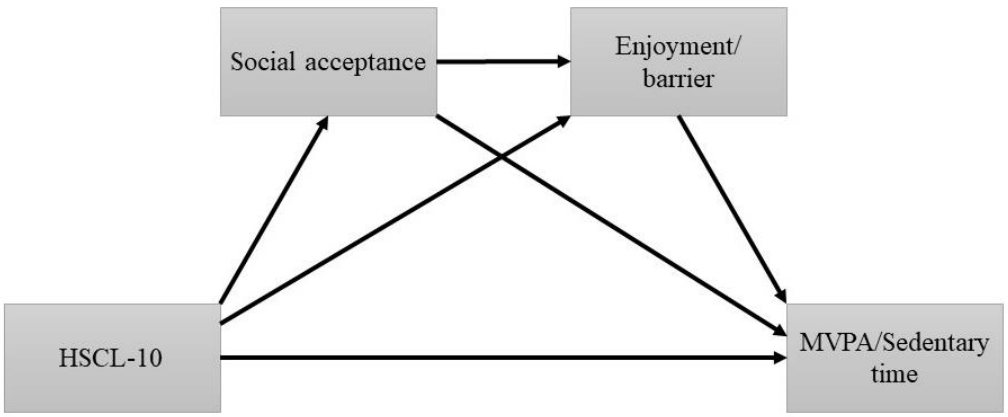
The statistical analyses used in this thesis has been regression analysis. The regression analysis attempts to determine the character and strength of a relationship between one or more predictor variable and an outcome variable. It is often used when the predictor variable cannot be controlled, for example when they are collected in a survey or an observational study, such as the Fit Futures study. A well modeled regression analysis can decide if there is a statistically significant association between the predictor variable and the outcome variable, but it cannot establish a causal relationship.

Moreover, there are several ways predictor variables can be entered into a regression model, and choosing the right type of predictor selection is crucial because the potential correlation to the outcome variable will affect the parameters in the model. The papers 1 and 2 used hierarchical linear regression, but in the third paper we used a regression available as a macro add on in SPSS. A hierarchical linear regression is the method of adding predictors to the model in a predefined order based on previous research. This method is also called blockwise entry. We used SPSS version 25.0 (IBM Corporation, Armonk NY, USA) for Windows® (IBMCorp, 2017) for our analyses. The model is briefly described in the next section, Summary of papers and results, but for a more thorough description see the published and submitted articles.

Mediation analysis. By analyzing mediation one can investigate the underlying process or mechanisms of a relationship between the predictor and the outcome variable by including one or more explanatory variables, meaning that the relationship between mental distress and physical activity can be explained by a third factor, for example enjoyment and barriers towards physical activity.

In order to investigate whether the effect of mental distress measured by HSCL-10 on MVPA/sedentary behavior is mediated by peer acceptance, enjoyment and perceived barriers towards physical activity, we used a SPSS add on called PROCESS macro written by A. F. Hayes (2017). The PROCESS macro add on is a tool to conduct analysis of moderation and mediation in SPSS in a way that reduces the possibility to perform mistakes and is significantly less time consuming. It has its' own menu and dialog boxes. This study investigates if there is a mediation chain in the relationship between mental distress and physical activity, and therefore a serial multiple mediator model was conducted. The model used in paper 3 is referred to as model 6 (see Figure 1).

Figure 1: *Model 6 from the PROCESS macro add on illustrating the mediator analysis in paper 3.*



5. Summary of papers and results

5.1 Paper 1

Opdal, I.M., Morseth, B., Handegård, B.H., Lillevoll, K., Ask, H., Nielsen, C.S., Horsch, A., Furberg, A.S, Rosenbaum, S. & Rognmo, K. (2019). Change in physical activity is not associated with change in mental distress among adolescents: the Tromsø study: Fit Futures. *BMC Public Health, 19(1)*, 916.

The purpose of the study in paper 1 was to investigate the relationship between change in objectively assessed physical activity measured by accelerometer and change in mental distress measured by HSCL-10 among adolescents in the Fit Futures sample. After using multiple imputations to estimate missing values, the study had a total of 676 participants included in the analysis. Change score variables were computed as FF2 score minus FF1 score for the predictor variables, number of steps per valid day and minutes of MVPA per valid day, and for the outcome variable, mean score of HSCL-10. In this study we hypothesized that change in physical activity was inversely associated with change in mental distress over the two year period between FF1 and FF2. In addition, we hypothesized that the participants with the highest levels of mental distress at baseline benefitted more from a change in physical activity between T1 and T2 than the less mentally distressed individuals, and that higher levels of change in physical activity over time were related to greater change in mental distress.

Two separate hierarchical linear regressions[7] were conducted with change in steps per valid day as predictor in one, and change in minutes in MVPA as predictor in the other. Covariates describing sex, age, socioeconomic status for mother and father, season for actigraphy measurement, considering quitting school, change in social network (baseline and follow-up), chronic pain and disease, BMI, smoking, sleep-onset latency, the feeling of getting enough sleep, self-reported health, healthy and unhealthy diet, and change in healthy and unhealthy diet were added to the analysis in three blocks.

[7] A watchful eye will notice that in the published article in BMC Public health the described analysis has been called *stepwise* linear regression. This is a concept lost in translation. What I originally meant was that the covariates were entered in one block at the time as described further in the article, and not the stepwise predictor selection method.

When controlling for the relevant covariates, the results showed that change in steps per valid day showed no statistically significant relationship with change in mental distress, nor did minutes in MVPA. Furthermore, there was found no significant moderating effect of level of mental distress on the association, meaning that even among the most mentally distressed adolescents, there were still no significant association between change in physical activity and change in mental distress. The additional covariance analysis examined if high negative change in physical activity was related to change in mental distress, compared to a high positive change, was also not significant. These results suggest that there is no longitudinal association between change in physical activity and change in mental distress among adolescents regardless of the baseline levels of mental distress and levels of change in physical activity between baseline and follow-up.

5.2 Paper 2

Opdal, I.M., Morseth, B., Handegård, B.H., Lillevoll, K.R., Nilsen, W., Nielsen, C.S., Furberg, A.S, Rosenbaum, S. & Rognmo, K. (2020). Is change in mental distress among adolescents predicted by sedentary behaviour or screen time? Results from the longitudinal population study The Tromsø Study: Fit Futures. *BMJ Open, 10.*

In paper 2, the study aimed to investigate if the association between sedentary behavior and mental distress was dependent on the mode of measurement of sedentary behavior for the sample of Fit Futures, and therefore expand on the previous knowledge in a field that traditionally used self-reported measurements for physical activity. The study explored both the cross-sectional and longitudinal association of mental distress, measured by HSCL-10, and sedentary behavior, measured by either accelerometer (percentage of day spent in sedentary time per valid day) or self-reported screen-time.

After imputing missing data, this study had a total of 686 participants with complete data on all variables used in the analysis. A hierarchical linear regression analysis was conducted, analyzing the degree to which the predictor variables were cross-sectionally (baseline) or longitudinally (change between baseline and follow-up) associated with mental distress. Both analyses included the covariates sex, age, socioeconomic status, season for measuring accelerometry, BMI, sleep onset latency, self-reported health, social network, chronic pain, objectively measured MVPA, and either percentage of sedentary time per day or

screen-time depending on the predictor variable. However, for the longitudinal study, HSCL-10 from Fit Futures 1 was included, in order to investigate residualized change in mental distress over time.

The results from the analysis showed that for both the cross-sectional and longitudinal relationships, self-reported screen-time was associated with mental distress, but not objectively assessed percentage in sedentary behavior per day. These results indicate that there is a disparity in the results depending on how sedentary behavior is measured, objectively or by self-report, and that self-reported screen-time is not a suitable proxy for the broader term of sedentary behavior. The conclusion calls for thoroughly assessed validity and reliability of the chosen mode of measurement in future research.

5.3 Paper 3

Opdal, I.M., Morseth, B., Kokkvoll, A.S., Horsch, A., Rosenbaum, S., & Rognmo, K. (2020). Is the association between physical activity and mental distress among adolescents mediated by peer acceptance, perceived barriers and enjoyment of activity? Results from the Tromsø Study: Fit Futures. *Submitted for publication*.

In the third paper, we aimed at investigating deeper into the relationship between mental distress and levels of physical activity by studying the potentially mediating effect of peer acceptance, enjoyment or perceived barriers towards physical activity on the association between mental distress and physical activity. Contrarily to the previous two papers, mental distress was set as the predictor variable, and not the outcome, because of the research aim. We suggested that low peer acceptance and enjoyment or barriers towards physical activity mediated the relationship between mental distress and physical activity in a serial multiple mediator model, model 6 in the PROCESS macro. Because the PROCESS macro tool is unable to use multiply imputed datasets, we decided to study the mediation models by using cross-sectional data, in order to retain power to detect an effect. 582 participants had valid data on all variables, and were included in the study. Subsequently, four different mediator analyses were conducted, two separate mediator analyses where peer acceptance was the first mediator and either enjoyment or barriers was the second mediator on the relationship between mental distress and MVPA, and two separate mediator analyses with the same mediators on the relationship between mental distress and sedentary behavior. The social

network factor, peer acceptance, is prominent in this study as it is has been found to play a significant role in predicting mental distress and physical activity levels, but also that it is related to enjoyment of activity and perceived competence, which in turn has been found to predict physical activity levels.

The study found that the total effect of mental distress on MVPA was significant, but that the direct effect was not significant. This means that mental distress and levels of physical activity are not associated for adolescents when taking the mediators in to account. Moreover, low peer acceptance did mediate the relationship between mental distress and MVPA, and between mental distress and sedentary behavior. This indicate that the association between mental distress and physical activity/sedentary behavior is explained by feeling low peer acceptance. Enjoyment and perceived barriers did not mediate the effect of mental distress on MVPA nor sedentary behavior.

6. Discussion

From the previous studies and the existing literature presented in this thesis we have learned that the onset for experiencing mental distress is during the adolescent years (Kessler & Bromet, 2013), and that physical activity levels decreases from childhood to the adolescent period (McMahon et al., 2017). Furthermore, the existing research in the field on the association between physical activity and mental distress among adolescents suffers from weak research designs and has failed to confirm whether there is an association or not (Biddle & Asare, 2011).

The studies included in this thesis were designed to investigate the association between physical activity and mental distress among adolescents using robust research designs and to utilize the well validated measurements available by the Fit Futures study. Overall, the aim of this thesis was to investigate the potential association between objectively measured physical activity and self-reported symptoms of anxiety and depression, and to further explore different factors relevant to the association in order to acquire a deeper understanding of the relationship between physical activity and mental distress among adolescents participating in the Fit Futures study. The separate specific aims of the underlying studies were constructed to explore some of the known knowledge gaps in the field.

6.1 Main findings

Neither change in objectively measured steps per valid day nor change in minutes in MVPA per valid day were associated with change in mental distress among the adolescents two years later. In addition, we found that experiencing a high level of change in physical activity between FF1 and FF2 (+/- 3000 steps) did not prove to be associated with change in mental distress. Furthermore, the commonly used self-reported screen-time was found to be a bad proxy for objectively measured sedentary behavior as separate analyses investigating their association to mental distress among the adolescents in the Fit Futures study showed that these variables give different results. Finally, there was a significant association between mental distress and minutes in MVPA among the adolescents in the sample, mediated by low peer acceptance. Furthermore, mental distress among the adolescents was not found to be associated with objectively measured sedentary behavior, but a significant indirect effect of mental distress on low peer acceptance that in turn was related to higher levels of sedentary time was found. Enjoyment of physical activity and perceived barriers towards physical

activity did not mediate the effect of mental distress on minutes in MVPA nor sedentary behavior, but both had a significant relationship with minutes in MVPA, whereas only enjoyment significantly predicted sedentary behavior.

When looking at the broader question of whether objectively measured physical activity is associated with mental distress among adolescents, the results of this thesis point towards a lack of a direct association between the two. These results are in concordance with other studies that use objective method of measure for physical activity. For instance, a longitudinal study by Van Dijk et al. (2016) found that change in objectively measured physical activity was not associated with change in mental health among adolescents. Another study by Toseeb et al. (2014) also failed to find a longitudinal association between objectively measured physical activity at baseline and the development of symptoms of depression during a three-year period.

However, instead of rejecting an association between physical activity and mental distress among adolescents, future research, using objective data, can further investigate whether the association is related with other factors in the individual, the activity or the individuals' environment. The next sections will discuss some of the potential reasons for why our study has failed to find an association before discussing the methodological limitations within the studies.

6.2 The relationship between anxiety and perfectionism

All three of the studies in this thesis used either the mean score of HSCL-10 or a dichotomized HSCL-10 score indicating over/under cut-off as measure of mental distress among the adolescents. As previously mentioned, the HSCL-10 questionnaire measure symptoms of both anxiety and depression, of which six items measured symptoms of depression, and four items symptoms of anxiety. In our studies, we have not accounted for differences between depression and anxiety, and this could have affected our results as there is a possibility that physical activity can have different effects on anxiety and depression. Such a difference could potentially counteract each other when combining the two in one mean score.

It is important to be aware that there could exist different factors related with depression and anxiety that comes into play when associated with physical activity. As mentioned in the Background section, previous research has found a connection between

lower levels of physical activity and higher levels of symptoms of depression (Birkeland et al., 2009; Rothon et al., 2010). There are different factors related to anxiety that can counteract the inverse association between physical activity and depression in a sample, an example of this is perfectionism. Anxiety is associated with perfectionism (M. M. Smith, Vidovic, Sherry, Stewart, & Saklofske, 2018), which is further found to be associated with high physical activity (Longbottom, Grove, & Dimmock, 2010).

Perfectionism is often divided into maladaptive and adaptive perfectionism. One study has found evidence for positive aspects related to perfectionism that could potentially increase physical activity levels, as they found that adaptive perfectionism is associated with motivation and assist in achievement-striving processes for athletes (Longbottom et al., 2010). In addition, the same study found that maladaptive perfectionism could trigger fear of failure and avoidance of participating in physical activity among undergraduate students (Longbottom et al., 2010). These are very interesting results, and could give an explanation to why we failed to find an association between physical activity and mental distress among the adolescents in our study.

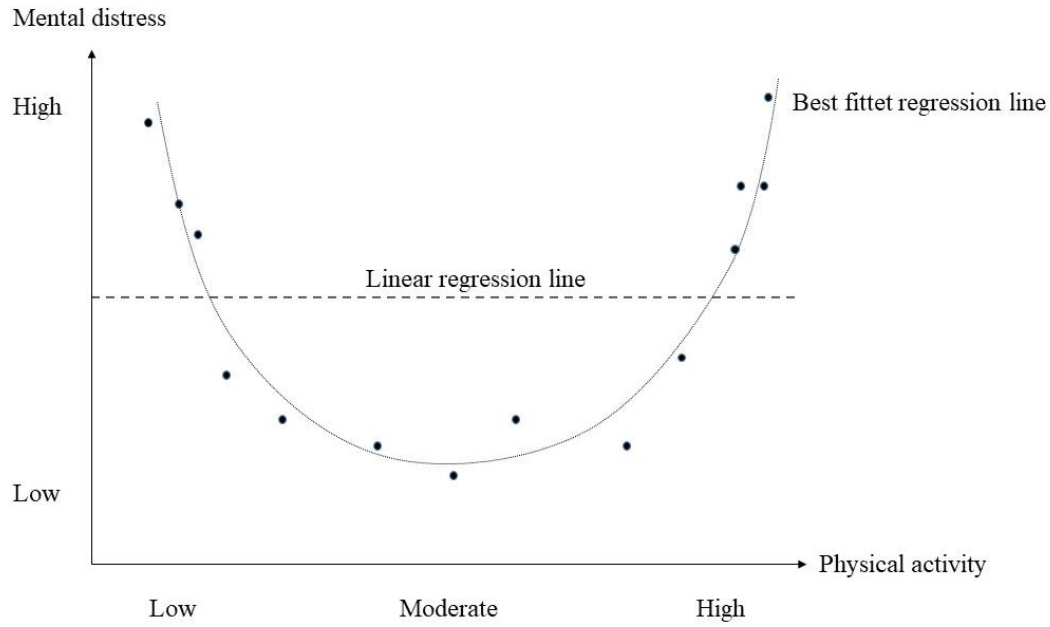
We did not have access to variables measuring perfectionism in the study sample, and were therefore unable to control for this in our research. The potential separation of the items that measure depressive symptoms from the anxiety items, has no known clear support in research. Moreover, using or disregarding the four items that measure symptoms of anxiety does not necessarily result in high sensitivity, and we have no reason to believe that the specific four HSCL-10 items are associated with perfectionism. Nevertheless, our studies aimed to investigate the association between physical activity and mental distress, and not solely depression, and consequently, our decision to use full scale HSCL-10 is reasonable.

6.3 Possibility of a non-linear association

This thesis has focused on the presumption that the association between physical activity and mental distress among adolescents is somewhat linear. Nonetheless, it should be mentioned that it is also plausible that the association could be U-shaped. A result indicating a U-shaped relationship between physical activity and mental distress could for example show that low levels of physical activity were associated with high levels of mental distress, and as physical activity levels increased to a moderate level, we would see that mental distress symptoms decreased, however, instead of decreasing further as physical activity hits the highest level, mental distress increased. When conducting a linear regression analysis on a

relationship that is in reality U-shaped, the researchers could in the worst case find no significant association as the combined relationship is counteracting itself (see Figure 2 for visualization).

Figure 2: *Visualization[8] of how linear regression fails to find a significant association if the data is U-shaped*



It is acceptable to presume that the adolescents that have high levels of physical activity could be participating in competitive sports. Interestingly, there is a connection between athletes and depression and suicide (Rao & Hong, 2016), and the prevalence of depression among college athletes is suggested to be just as high as the rest of the population (Wolanin, Gross, & Hong, 2015). Athletes are suggested to be influenced by stressors that could counteract the physiological benefits on mental health, such as pressure, risk for injuries, or fear of failure (Rao & Hong, 2016). The studies of this thesis did not take into account competitive athleticism among the adolescents nor the aforementioned perfectionism. Two of the upper secondary schools included in the study offer programs that have a high focus on sports and athleticism, and these were not accounted for in our analysis as we did not

[8] Disclaimer: This figure is poorly drawn using measurements by eye and is only meant to serve as a visualisation of a potential U-shaped dataset. It does not represent the data found in the studies.

have access to information about the study programs of the subjects because of the fear of recognition. A potential U-shaped relationship between physical activity and mental distress could be a possible explanation for the non-significant association between physical activity and mental distress among the adolescents in the sample.

Nevertheless, as many of the existing studies have shown, there has found a significant linear association between physical activity and mental distress. Therefore, it is credible to assume that our linear regression analysis would have found significant results if there existed a linear relationship between physical activity and mental distress among the adolescents in the sample. Hence, we encourage future research to investigate the potential U-shaped association between physical activity and mental distress among adolescents.

6.4 Social factors

In the third study where we looked more closely at the relationship between mental distress and levels of objectively measured physical activity and sedentary behavior by exploring mediation, we found that low peer acceptance served as a mediator for the relationship between mental distress and physical activity. As this result indicates that social factors play an important role in the association, there is a possibility that social factors play an even more important role in the association between physical activity and mental distress than we have taken account for in our studies.

A review found children's physical activity level to be positively associated with encouragement from friends, their friends´ physical activity level, and engagement with friends in physical activity (Maturo & Cunningham, 2013). Another review found evidence that different network characteristics in friendship among adolescents have different outcomes on physical activity, as the proportion of active friends was positively associated with minutes in MVPA, while network density, connectedness between individuals in a group, were positively associated with sedentary behavior (Wen, Rissel, & He, 2015). Social connectedness with peers is also associated positively with mental health among adolescents (Lamblin, Murawski, Whittle, & Fornito, 2017). These findings can explain why we fail to find an association between objectively measured sedentary behavior and mental distress, as it seems that connectedness with peers can counteract the effect. Moreover, longitudinal studies have found that an individual's physical activity level conforms over time to match friends' physical activity levels (Sawka, McCormack, Nettel-Aguirre, Hawe, & Doyle-Baker, 2013), and friendships seem to be an important factor for increasing motivation to engage in physical

activity and promote higher levels of physical activity for youth (Salvy et al., 2008). Friends affect each other's physical activity levels, for better or worse, and could potentially contribute or interfere with the association between physical activity and mental distress among adolescents.

In addition, social factors can have interesting effects on symptoms of depression and anxiety. A study has found that symptoms of depression and anxiety in a reciprocal friendship group predicted change in individuals internalizing symptoms of anxiety and depression (Veed, McGinley, & Crockett, 2019). This evidence is supported by a finding indicating that children and youth suffering from social anxiety show tendencies to choose friends that also suffers from social anxiety, and influences each other to become even more socially anxious over time (Van Zalk, Van Zalk, Kerr, & Stattin, 2011). These results show that social network and other social factors does not only affect physical activity levels, but also mental distress among adolescents.

Based on these findings, we cannot be confident that we have taken all important social factors into account in our studies, and this could have affected our results. The adolescents at baseline in our studies are at their first year of upper-secondary school and could possibly have been separated from their old classmates and friends, and a potential loss or change in social circle could have impacted the data collected in this period. However, this is only speculation, and whether our data is affected by this is unknown.

6.5 Active vs. passive sedentary behavior

Research and literature on the association between sedentary behavior and mental distress has commonly included all types of inactive behaviors under the umbrella term "sedentary behavior" as long as it fulfills the criteria for little to no energy expenditure. However, there is evidence that the context and characteristics of sedentary behavior could be important when investigating its effect on mental distress. A study by Hallgren, Dunstan, and Owen (2020) differentiated between mentally active and mentally passive sedentary behavior and found evidence that passive sedentary behavior, such as television watching, was related to an increase in depression, and that mentally active sedentary behavior, such as reading, was thought to have a protective effect on depression onset. These results supported findings from a meta-analysis that concluded that television watching was associated with increased risk for depression, but computer use was not (Huang et al., 2020). Categorizing sedentary behavior

based on context and level of mental engagement is relatively new in research, but could potentially be a very important angle of research in the future.

In our studies, neither objectively measured sedentary behavior nor self-reported screen-time were differentiated by specific context. Nevertheless, self-reported screen-time is context specific in itself, but it does not differentiate between computer use, TV- watching or playing video games with friends. In the second study described in this thesis, we found that there was a significant association between self-reported screen-time and mental distress among the adolescents, but found no association between objectively measured sedentary behavior. The results are interesting, but should be seen in the light of the potential biases involved, especially when using self-reported measurements. The effect of overall sedentary time independent of context is still crucial to investigate because it could show the implications of the biological consequence of not being active.

6.6 A more prominent effect when entering adulthood?

Existing literature suggest that the association between physical activity and mental distress is more evident among adults, in addition to being more researched, than for adolescents. This could indicate that the effect of physical activity on mental distress potentially becomes clearer with increasing age. One can speculate if the motivation for engaging in physical activity in adolescence could be more dependent on friend support and influences, but become more intrinsically triggered when entering adulthood.

It is also worth mentioning that there is a possibility that physical activity could serve another function for adolescents than for adults as the effect of physical activity on mental health seems to be present in adulthood, but not in adolescence. For example, exercise could be a welcomed break from the everyday stressors, or a way to attend to and treat chronic pain. Of course, this is only speculation. Furthermore, another explanation for the discrepancy in results between the studies conducted on adults and adolescent could be that the majority of the studies on the association between physical activity and mental distress among adults have weaknesses in measurement methodology as the majority is conducted on self-reported data, and should be studied using more objective data for physical activity. Thus, it is unsure if the use of objective measurements to a greater extent to study the relationship between physical activity and mental distress among adults would yield different results compared to the existing findings.

6.7 Causality

Assessing the direction of causality of the association between physical activity and mental distress among adolescents is important because it determines whether it is possible to use physical activity as a mean for protecting against mental distress, or if it is mental distress that causes the reduction of the physical activity levels. As presented previously, Birkeland et al. (2009) investigated whether physical activity has a protective effect on mental distress, or if mental distress inhibited physical activity, but did not find clear indications for any causal agent. Nor did Rothon et al. (2010) in their study on prospective effects of physical activity on depressive symptoms. This thesis did not aim to determine a causal agent, and because of its research design, it cannot contribute to the field in this aspect. However, as the literature indicates, the association seems to be complex.

The difficulty of confirming a causal agent could indicate that the relationship between physical activity and mental distress does not have a clear causal agent, and could be influenced by several factors that affect one or both variables, under various circumstances. This corresponds with observations that one will not necessarily develop depression and anxiety disorders as a result of sedentary behavior, as well as the fact that there are physically active individuals that have anxiety and depression. However, intervention studies conducted on individuals with confirmed symptoms or diagnosis of depression and anxiety have established that physical activity interventions have a treatment effect on depression and anxiety. This gives an indication that physical activity can be a causal agent causing a change in mental distress among individuals who already suffer from symptoms. Nonetheless, these results say little about the potential effect mental distress has on physical activity as a causal agent.

Despite our results not showing an effect of physical activity on mental distress among adolescents, they still contribute to the knowledge in the field of the association between physical activity and mental distress through assessing the association using sound measurement methods and a longitudinal research design. Being physically active has many benefits, and adolescents participating in activities of both moderate and vigorous intensity level will have positive effects. Even if there is not an effect on mental health, adolescents can still benefit from the advantages for their physical health. It is therefore still advisable to maintain or increase physical activity considering overall health.

We recommend future research to incorporate multiple measurement points, and to follow the adolescents frequently and closely to be able to observe how change in symptoms of anxiety and depression is affected by physical activity. Furthermore, studies that follow should employ better methods of measurement for not only physical activity, but also for anxiety and depression, and should focus on relevant variables that can affect the association between physical activity and mental distress among adolescents.

6.9 Strengths of the study

The studies that this thesis is built on have several strengths that build on and expand upon previous research in several ways, and each study possesses different strengths. For example, in paper 2 we were able to investigate the effect of both objectively measured sedentary behavior and self-reported screen time on mental distress over time for the same sample. This made it possible to investigate the effect the different measurement methods had on the relationship with mental distress, as well as to say something about the validity of using self-reported screen-time as a proxy for sedentary behavior.

The overall thesis has several important strengths, and many of these are a result of the qualities of the Fit Future study. First and foremost, one of the most important strengths in the thesis is that the studies use data on objectively measured physical activity over two time periods in the analyses. Moreover, the results are based on data from a relatively large sample of adolescents living in and attending upper secondary school in both urban and rural regions of Norway resulting in high generalizability for adolescents in the Norwegian population. Furthermore, there is a high response rate for the Fit Futures study. For all three studies, due to the vast volume of the test battery conducted by the Fit Futures study, the analyses were also able to be adjusted for several relevant confounders. Additionally, an interesting strength that occurs when investigating different research questions using the same sample is that it gives an opportunity for a deeper understanding of the sample that could potentially lead to better knowledge of the association one is trying to understand. Nevertheless, despite these strengths, the results should be interpreted in light of several methodological limitations. The most important limitations are listed in the next section.

6.10 Methodological considerations

Methodological challenges are errors that might occur either in the planning phase, the data-collecting phase, or during the analysis of a study, and occur within any research design,

and in any field. The consequences could be very severe in that the study produce results and conclusions that are untrue.

6.10.1 Missing data and sample

Missing data. The dataset of the Fit Futures study suffers from missing data on different variables and items despite its relatively large sample and the participation rate. The variables with the highest proportion of missing data are the accelerometer variables, and there are several potential explanations for why these data are missing:

- The participants turned down the opportunity to use the accelerometer
- Technical errors with the device resulting in invalid data
- The accelerometer was not returned
- The participants did not wear the accelerometer for the minimum of 10 hours per day in at least 4 days, and thus the data was regarded as invalid

Multiple imputation. A relatively large amount of the data was imputed using multiple imputations due to the high percentage of missing data, and despite the benefits mentioned previously in the Method section, this could potentially have introduced bias to our results. Nevertheless, it is not necessarily the high percentage of imputed missing data that are the cause of bias. Providing that data is missing at random, multiple imputation provides unbiased estimates, even with high proportions of missing values (J. H. Lee & Huber Jr, 2011).

The uncertainty lies within whether the data is missing completely at random, which is the requirement for multiple imputations to produce unbiased results. As it is impossible for us to know exactly the reason for why the data is missing, there will always be a possibility that the data is not missing completely at random. In our studies we have conducted sensitivity analyses that investigated the degree to which the participants with missing data differed from the participants with missing data. Results from such analyses could provide an indication of the pattern of missingness, but it does not guarantee that the missing data is completely missing at random. In our studies, the participants with missing data did not differ significantly from the participants that had valid data giving us an indication that the results from the analysis on multiple imputed dataset did not suffer from significant bias.

Another common way to handle missing data is by using Listwise deletion of the subjects that have missing data. This technique excludes a subject from the analysis if it detects missing values and should also only be used if the missing data are missing completely at random. Considering the large amounts of missing data in the accelerometer data in our dataset, using the Listwise deletion technique would have resulted in an extensive reduction in the sample size for the analyses which further would have led to loss of power. Therefore, we concluded that multiple imputations of the missing data were appropriate for our studies.

Generalizability. The Fit Futures dataset is collected from students form upper secondary school in the municipality of Balsfjord and Tromsø in Northern Norway. The results should not be generalized to the Norwegian population of adolescents without consulting results from similar research. Physical activity levels can potentially differ between the northern and southern regions of Norway because of climate and distances between essential infrastructural functions. Nevertheless, the findings of the studies of physical activity levels are similar to those from national and European samples (Beldo et al., 2019), suggesting that the participants are no more or less active or sedentary than other adolescents. Still, caution with generalizing the findings is advised.

6.10.2 Limitations of the measurements and potential bias

Misclassification bias, also called information bias, refers to bias occurring from measurement errors, and can be defined as 1) "A flaw in measuring exposure, covariate, or outcome variables that results in different quality (accuracy) of information between comparison groups. The occurrence of information biases may not be independent of the occurrence of Selection biases. 2) Bias in an estimate arising from measurement errors" (Porta, 2014). The misclassification bias is further divided into non-differential and differential misclassification, which describe whether the probability of misclassification is the same for all study objects or not. Non-differential misclassification bias refers to cases where there is no difference in the misclassification between the subjects in the study, that is, when the misclassification is equal across the categories. Differential misclassification bias is when there is a notable difference in the misclassification between the subjects, or in other words, if the misclassification is present within one category. Misclassification bias can affect a perceived association between the predictor and the outcome variable by either making it stronger or weaker.

Misclassification bias can occur as a result of recall bias, reporting bias, observer bias, or imprecise or poorly calibrated measurement instruments, thus, the errors that arise can be random or systematic. Systematic error is particularly important to prevent as it can lead to misleading conclusions if not detected, and can occur when an instrument always measures wrong, it has high reliability but low validity. In studies investigating physical activity levels this could result in that the true activity level is not being measured. For example, if a measurement of weekly physical activity levels is conducted right after PE class and the instrument does not specify the wanted period of measurement. It is very difficult, if not impossible, to completely prevent misclassification bias from occurring in a study. However, it is essential to make the necessary precautions to prevent these biases as much as possible, as it can lead to over- or underestimation of the exposure or the strength of association to the exposure which can heavily influence the results.

Misclassification bias could be present in the variables in the Fit Futures dataset. And could for example easily occur in the both the HSCL-10 variable and the accelerometer variables, and is potentially still occurring despite the precautions taking place to an unknown extent. Nevertheless, due to standardized questionnaires, validated tests and good procedures, the misclassification is prevented to a great extent. Some of the potential biases that can exist in the mental distress variable and the objectively measured physical activity variables are described in the next section.

HSCL-10 – Self-reported data. Mental distress was measured by the Hopkins Symptom checklist-10 (HSCL-10) in the general questionnaire. The instrument is well-validated (Strand et al., 2003), but because it relies on the participants´ self-reporting it is prone to inaccuracy. There are many factors in play when the participants answer a questionnaire, which all can color their response. Some scores could be inaccurate as the participant potentially want to give a more or less favorable impression of him-/herself to save time or save face, or they could have an inaccurate perception of themselves. The HSCL-10 includes some sensitive questions that depressed adolescents could find uncomfortable to answer. Additionally, non-depressed adolescents could perceive and interpret the questions as heavily negative and for a group of people that they do not associate themselves with that they disregard the questionnaire as irrelevant and answer the lowest score independent from how they feel. Moreover, the HSCL-10 score could also be impacted by the individual's interpretation of what the difference is between the report categories, as this depend on their subjective opinion and experience.

ActiGraph – Objectively measured data. Despite objectively measured physical activity being more accurate than self-reported measurements, the objectively measured physical activity variable using actigraphy is still prone to information bias. This could be based on the way the device is calibrated. As mentioned before, accelerometers have a weakness in the ability to reliably register different types of activities, such as cycling and weight lifting, because of its static position on the hip. This could potentially be explained by the possibility that participants that suffer from mental distress and are depressed are more prone to partake in solitary physical activity behaviors, such as cycling or swimming, however this is just speculation. Since the device does not report this correctly or at all, the association between low physical activity and mental distress could appear stronger than the true association. However, accelerometer measurements of physical activity could arguably be better suited than self-reported measurements as adolescents with symptoms of depression and anxiety could be more hesitant to report favorable qualities such as physical activity.

6.10.3 Investigating mediation in a cross-sectional design

Paper 3 differs from paper 1 and paper 2 as its study sample is drawn solely from FF1, and therefore, the study design was cross-sectional. Despite being necessary for investigating the research question, it limits the finding as it makes it impossible to provide reliable knowledge about the longitudinal processes. As all the data was collected at the same time point, the order of the variables is only based on theoretical and/or empirical grounds. When investigating mediation, longitudinal data is commonly preferred (Selig & Preacher, 2009), as it allows the proposed mechanisms time to unfold and to take previous levels of the variable in to account, controlling for baseline levels. Some suggest that, even though possible, examining mediation using observational cross-sectional data is not advised as it relies strongly on that the ordering of the variables in the mediation chain is correct and is unable to examine a process that naturally occur over time (Fairchild & McDaniel, 2017). Examining mediation using cross-sectional data can be problematic as it infers an instantaneous effect, and using longitudinal data removes some of the variance that is explained by individual differences as the individual acts as a control for itself. On this basis, the gold standard for examining mediation would seem to be RCT studies with multiple measuring points, one for each link in the causal chain, where the researchers have full control over the variables. However, it is fully possible to use cross-sectional data in a mediation analysis as long there exist a reasoning based on research and logic. A. F. Hayes (2017), the developer of the

PROCESS macro add-on, argues that statistical methods are not used to make causal inferences, establishing cause and effect is based on research design and logical reasoning.

Our study is limited by the lack of previous literature and research on the field of the relationships between mental distress and perceived barriers towards physical activity and enjoyment of physical activity. Thus, it was challenging to determine the probable temporal precedence of barriers and enjoyment relative to mental distress. We argue in the paper that as anhedonia is a core symptom of depression, it would be reasonable to believe that experiencing mental distress could impact the degree to which physical activity influences enjoyment and barriers, rather than the other way around. Thus, previous research and logical reasoning suggests that the temporal precedence of the variables used in our models in paper 3 is appropriate despite the literature used to argue for the order of causality being quite thin. However unlikely, there is still a possibility that the causal direction is the other way around. Regardless of whether a study has the ideal study design, it can reveal important information. Our study contributes with important information and provides a foundation for further research on the role that peer acceptance has in the association between mental distress and physical activity among adolescents.

7. Conclusion and directions for future studies

The main conclusion of this thesis is that there is no evidence for a longitudinal association between different levels of objectively measured physical activity and mental distress among the adolescents in the Fit Futures cohort. However, there is evidence which indicates that low peer acceptance mediates the association between mental distress and levels of physical activity.

Despite the controversy of the results, these findings are supported by other longitudinal studies using objectively measured physical activity. The discrepancy between our findings and that of previous studies are possibly due to use of objectively measured physical activity rather than self-reported data which has been more commonly used. Our findings suggest that the association between physical activity and mental distress is complex, and future research should aim to investigate further underlying factors that can lead to better understanding of the association.

8. References

Affuso, O., Stevens, J., Catellier, D., McMurray, R. G., Ward, D. S., Lytle, L., . . . Young, D. R. (2011). Validity of self-reported leisure-time sedentary behavior in adolescents. *Journal of Negative Results in BioMedicine, 10*(2). doi:10.1186/1477-5751-10-2

Afifi, M. (2007). Gender differences in mental health. *Singapore medical journal, 48*(5), 385-391.

Allison, K. R., Dwyer, J. J. M., & Makin, S. (1999). Perceived Barriers to Physical Activity among High School Students. *Preventive Medicine, 28*(6), 608-615. doi:https://doi.org/10.1006/pmed.1999.0489

Arbour-Nicitopoulos, K. P., Faulkner, G. E., & Irving, H. M. (2012). Multiple health-risk behaviour and psychological distress in adolescence. *Journal of the Canadian Academy of Child Adolescent Psychiatry, 21*(3), 171-178.

Bao Giang, K., Viet Dzung, T., Kullgren, G., & Allebeck, P. (2010). Prevalence of mental distress and use of health services in a rural district in Vietnam. *Global Health Action, 3*(1). doi:10.3402/gha.v3i0.2025

Barbeau, E. M., Krieger, N., & Soobader, M.-J. (2004). Working class matters: socioeconomic disadvantage, race/ethnicity, gender, and smoking in NHIS 2000. *American journal of public health, 94*(2), 269-278.

Bartlett, A. A., Singh, R., & Hunter, R. G. (2017). Anxiety and Epigenetics. In R. Delgado-Morales (Ed.), *Neuroepigenomics in Aging and Disease* (pp. 145-166). Cham: Springer International Publishing.

Beldo, S., Morseth, B., Christoffersen, T., Halvorsen, P., Hansen, B., Furberg, A., . . . Horsch, A. (2019). Prevalence of accelerometer-measured physical activity in adolescents. The Tromsø Study: Fit Futures. *Research Square*. doi: 10.21203/rs.2.12691/v1.

Bickham, D. S., Hswen, Y., & Rich, M. (2015). Media use and depression: exposure, household rules, and symptoms among young adolescents in the USA. *International journal of public health, 60*(2), 147-155.

Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British journal of sports medicine, 45*(11), 886-895.

Biddle, S. J., Atkin, A. J., Cavill, N., & Foster, C. (2011). Correlates of physical activity in youth: a review of quantitative systematic reviews. *International Review of Sport and Exercise Psychology, 4*(1), 25-49.

Biddle, S. J., & Mutrie, N. (2007). *Psychology of physical activity: Determinants, well-being and interventions* (2 ed.). London and New York: Routledge.

Biddle, S. J., Whitehead, S. H., O'Donovan, T. M., & Nevill, M. E. (2005). Correlates of participation in physical activity for adolescent girls: a systematic review of recent literature. *Journal of Physical Activity and Health, 2*(4), 423-434.

Birkeland, M. S., Torsheim, T., & Wold, B. (2009). A longitudinal study of the relationship between leisure-time physical activity and depressed mood among adolescents. *Psychology of Sport and Exercise, 10*(1), 25-34.

Blazer, D. G., Kessler, R. C., McGonagle, K. A., & Swartz, M. S. (1994). The prevalence and distribution of major depression in a national community sample: the National Comorbidity Survey. *The American Journal of Psychiatry, 151*(7), 979–986.

Brand, S., Gerber, M., Beck, J., Hatzinger, M., Pühse, U., & Holsboer-Trachsler, E. (2010). High exercise levels are related to favorable sleep patterns and psychological functioning in adolescents: a comparison of athletes and controls. *Journal of Adolescent Health, 46*(2), 133-141.

Bray, N. W., Smart, R. R., Jakobi, J. M., & Jones, G. R. (2016). Exercise prescription to reverse frailty. *Applied physiology, nutrition, and metabolism, 41*(10), 1112-1116.

Carter, T., Morres, I. D., Meade, O., & Callaghan, P. (2016). The effect of exercise on depressive symptoms in adolescents: a systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry, 55*(7), 580-590.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports, 100*(2), 126-131.

Chapman, D. P., Whitfield, C. L., Felitti, V. J., Dube, S. R., Edwards, V. J., & Anda, R. F. (2004). Adverse childhood experiences and the risk of depressive disorders in adulthood. *Journal of affective disorders, 82*(2), 217-225.

Chastin, S., Dontje, M. L., Skelton, D. A., Čukić, I., Shaw, R. J., Gill, J. M., . . . Der, G. (2018). Systematic comparative validation of self-report measures of sedentary time against an objective measure of postural sitting (activPAL). *International Journal of Behavioral Nutrition and Physical Activity, 15*(21). doi:https://doi.org/10.1186/s12966-018-0652-x

Cheng, H. G., & Phillips, M. R. (2014). Secondary analysis of existing data: opportunities and implementation. *Shanghai archives of psychiatry, 26*(6), 371-375. doi:10.11919/j.issn.1002-0829.214171

Chisholm, D., Sweeny, K., Sheehan, P., Rasmussen, B., Smit, F., Cuijpers, P., & Saxena, S. (2016). Scaling-up treatment of depression and anxiety: a global return on investment analysis. *The Lancet Psychiatry, 3*(5), 415-424.

Conn, V. S. (2010). Depressive Symptom Outcomes of Physical Activity Interventions: Meta-analysis Findings. *Annals of Behavioral Medicine, 39*(2), 128-138. doi:10.1007/s12160-010-9172-x

Cummings, C. M., Caporino, N. E., & Kendall, P. C. (2014). Comorbidity of anxiety and depression in children and adolescents: 20 years after. *Psychological Bulletin, 140*(3), 816-845. doi:10.1037/a0034733

Dalton, V. S., Kolshus, E., & McLoughlin, D. M. (2014). Epigenetics and depression: return of the repressed. *Journal of affective disorders, 155*, 1-12. doi:https://doi.org/10.1016/j.jad.2013.10.028

de Wit, L., van Straten, A., Lamers, F., Cuijpers, P., & Penninx, B. (2011). Are sedentary television watching and computer use behaviors associated with anxiety and depressive disorders? *Psychiatry research, 186*(2), 239-243.

Dev, R. O., & Rahman, A. R. A. (2016). Influence of emotional intelligence as the mediator between physical activity and mental health (distress) among malaysian university students. *International E-Journal of Advances in Social Sciences, 2*(5), 492-500.

Dhillon, R., & Hafiz, S. (2018). Relationship of Self Esteem, Personality and Social Support with Psychological Distress in Adolescents. *Journal of Psychosocial Research, 13*(1), 43.

DiLorenzo, T. M., Stucky-Ropp, R. C., Vander Wal, J. S., & Gotham, H. J. (1998). Determinants of exercise among children. II. A longitudinal analysis. *Preventive medicine, 27*(3), 470-477.

Dunn, V., & Goodyer, I. M. (2006). Longitudinal investigation into childhood-and adolescence-onset depression: Psychiatric outcome in early adulthood. *British Journal of Psychiatry, 188*(3), 216-222. doi:10.1192/bjp.188.3.216

Dwyer, J. J., Allison, K. R., Goldenberg, E. R., & Fein, A. J. (2006). Adolescent girls' perceived barriers to participation in physical activity. *Adolescence, 41*(161), 75-89.

Elias, S. M. S. (2018). Prevalence of loneliness, anxiety, and depression among older people living in long-term care: A review. *International Journal Of Care Scholars, 1*(1), 39-43.

Elmesmari, R., Martin, A., Reilly, J. J., & Paton, J. Y. (2018). Comparison of accelerometer measured levels of physical activity and sedentary time between obese and non-obese

children and adolescents: a systematic review. *BMC Pediatrics, 18*(1), 106. doi:10.1186/s12887-018-1031-0

Ezzati, M., Lopez, A. D., Rodgers, A., Vander Hoorn, S., & Murray, C. J. L. (2002). Selected major risk factors and global and regional burden of disease. *The Lancet, 360*(9343), 1347-1360. doi:10.1016/S0140-6736(02)11403-6

Fairchild, A. J., & McDaniel, H. L. (2017). Best (but oft-forgotten) practices: mediation analysis. *The American Journal of Clinical Nutrition, 105*(6), 1259-1271. doi:10.3945/ajcn.117.152546

Farrahi, V., Niemelä, M., Kangas, M., Korpelainen, R., & Jämsä, T. (2019). Calibration and validation of accelerometer-based activity monitors: A systematic review of machine-learning approaches. *Gait & Posture, 68*, 285-299. doi:https://doi.org/10.1016/j.gaitpost.2018.12.003

Fergusson, D. M., Horwood, L. J., Ridder, E. M., & Beautrais, A. L. (2005). Subthreshold Depression in Adolescence and Mental Health Outcomes in Adulthood. *JAMA Psychiatry, 62*(1), 66-72. doi:10.1001/archpsyc.62.1.66

Fergusson, D. M., & Woodward, L. J. (2002). Mental Health, Educational, and Social Role Outcomes of Adolescents With Depression. *JAMA Psychiatry, 59*(3), 225-231. doi:10.1001/archpsyc.59.3.225

Fløtnes, I. S., Nilsen, T. I. L., & Augestad, L. B. (2011). Norwegian adolescents, physical activity and mental health: The Young-HUNT study. *Norsk epidemiologi, 20*(2). doi:https://doi.org/10.5324/nje.v20i2.1336

Freedson, P., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and science in sports and exercise, 30*(5), 777-781.

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Medicine and science in sports and exercise, 37*(11), 523-530. doi:10.1249/01.mss.0000185658.28284.ba

Fryers, T., Melzer, D., & Jenkins, R. (2003). Social inequalities and the common mental disorders. *Social Psychiatry and Psychiatric Epidemiology, 38*(5), 229-237.

Goodman, E., Slap, G. B., & Huang, B. (2003). The public health impact of socioeconomic status on adolescent depression and obesity. *American journal of public health, 93*(11), 1844-1850.

Gordon-Larsen, P., Nelson, M. C., & Popkin, B. M. (2004). Longitudinal physical activity and sedentary behavior trends: Adolescence to adulthood. *American Journal of*

Preventive Medicine, 27(4), 277-283. doi:https://doi.org/10.1016/j.amepre.2004.07.006

Haavet, O. R., Sirpal, M. K., Haugen, W., & Christensen, K. S. (2010). Diagnosis of depressed young people in primary health care—a validation of HSCL-10. *Family Practice, 28*(2), 233-237. doi:10.1093/fampra/cmq078

Hagmayer, Y., Sloman, S. A., Lagnado, D. A., & Waldmann, M. R. (2007). Causal reasoning through intervention. In A. Gopnik & L. Schulz (Eds.), *Causal learning: Psychology, philosophy, and computation* (pp. 86-100). Oxford: Oxford University Press.

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet, 380*(9838), 247-257.

Haller, S. P. W., Cohen Kadosh, K., Scerif, G., & Lau, J. Y. F. (2015). Social anxiety disorder in adolescence: How developmental cognitive neuroscience findings may shape understanding and interventions for psychopathology. *Developmental Cognitive Neuroscience, 13*, 11-20. doi:https://doi.org/10.1016/j.dcn.2015.02.002

Hallgren, M., Dunstan, D. W., & Owen, N. (2020). Passive Versus Mentally Active Sedentary Behaviors and Depression. *Exercise and Sport Sciences Reviews, 48*(1), 20-27. doi:10.1249/jes.0000000000000211

Hansen, B. H., Kolle, E., Steene-Johannessen, J., Dalene, K. E., Ekelund, U., & Anderssen, S. A. (2019). Monitoring population levels of physical activity and sedentary time in Norway across the lifespan. *Scandinavian Journal of Medicine & Science in Sports, 29*(1), 105-112. doi:10.1111/sms.13314

Harter, S. (1988). *Manual for the Self-Perception Profile for Adolescents*. Denver: University of Denver Press.

Harvey, S. B., Hotopf, M., Øverland, S., & Mykletun, A. (2010). Physical activity and common mental disorders. *The British Journal of Psychiatry, 197*(5), 357-364.

Hasin, D. S., Sarvet, A. L., Meyers, J. L., Saha, T. D., Ruan, W. J., Stohl, M., & Grant, B. F. (2018). Epidemiology of Adult DSM-5 Major Depressive Disorder and Its Specifiers in the United States. *JAMA Psychiatry, 75*(4), 336-346. doi:10.1001/jamapsychiatry.2017.4602

Haugen, T., Johansen, B. T., & Ommundsen, Y. (2014). The role of gender in the relationship between physical activity, appearance evaluation and psychological distress. *Child and Adolescent Mental Health, 19*(1), 24-30.

Haugen, T., Säfvenbom, R., & Ommundsen, Y. (2011). Physical activity and global self-worth: The role of physical self-esteem indices and gender. *Mental Health and Physical Activity, 4*(2), 49-56.

Haugen, T., Säfvenbom, R., & Ommundsen, Y. (2013). Sport Participation and Loneliness in Adolescents: The Mediating Role of Perceived Social Competence. *Current Psychology, 32*(2), 203-216. doi:10.1007/s12144-013-9174-5

Hayes, A. F. (2017). *Introduction to Mediation, Moderation, and Conditional Process Analysis A Regression-Based Approach* (2 ed.). New York: Guildford Press.

Hayes, G., Dowd, K. P., MacDonncha, C., & Donnelly, A. E. (2019). Tracking of Physical Activity and Sedentary Behavior From Adolescence to Young Adulthood: A Systematic Literature Review. *Journal of Adolescent Health, 65*(4), 446-454. doi:https://doi.org/10.1016/j.jadohealth.2019.03.013

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., & Owen, N. (2008). Objectively measured sedentary time, physical activity, and metabolic risk. *Diabetes care, 31*(2), 369-371.

Hecht, A., Ma, S., Porszasz, J., & Casaburi, R. (2009). Methodology for using long-term accelerometry monitoring to describe daily activity patterns in COPD. *COPD: Journal of Chronic Obstructive Pulmonary Disease, 6*(2), 121-129.

Helsedirektoratet. (2014). Rapport: Anbefalinger om kosthold, ernæring og fysisk aktivitet. In Helsedirektoratet (Ed.): Helsedirektoratet Oslo.

Hoare, E., Milton, K., Foster, C., & Allender, S. (2016). The associations between sedentary behaviour and mental health among adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 108. doi:10.1186/s12966-016-0432-4

Hoegh Poulsen, P., Biering, K., & Andersen, J. H. (2015). The association between leisure time physical activity in adolescence and poor mental health in early adulthood: a prospective cohort study. *BMC Public Health, 16*, 3. doi:10.1186/s12889-015-2658-5

Huang, Y., Li, L., Gan, Y., Wang, C., Jiang, H., Cao, S., & Lu, Z. (2020). Sedentary behaviors and risk of depression: a meta-analysis of prospective studies. *Translational Psychiatry, 10*(1), 26. doi:10.1038/s41398-020-0715-z

Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R. (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventive Medicine, 95*, 14-25. doi:https://doi.org/10.1016/j.ypmed.2016.11.027

Hume, C., Timperio, A., Veitch, J., Salmon, J., Crawford, D., & Ball, K. (2011). Physical activity, sedentary behavior, and depressive symptoms among adolescents. *Journal of Physical Activity and Health, 8*(2), 152-156.

IBMCorp. (2017). IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.

Irons, C., & Gilbert, P. (2005). Evolved mechanisms in adolescent anxiety and depression symptoms: the role of the attachment and social rank systems. *Journal of Adolescence, 28*(3), 325-341. doi:https://doi.org/10.1016/j.adolescence.2004.07.004

Jablonska, B., & Lindberg, L. (2007). Risk behaviours, victimisation and mental distress among adolescents in different family structures. *Social Psychiatry and Psychiatric Epidemiology, 42*(8), 656-663. doi:10.1007/s00127-007-0210-3

Janssen, I. (2007). Physical activity guidelines for children and youth. *Applied Physiology, Nutrition, and Metabolism, 32*(2), 109-121.

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 40.

Jeon, C. Y., Lokken, R. P., Hu, F. B., & van Dam, R. M. (2007). Physical Activity of Moderate Intensity and Risk of Type 2 Diabetes. *Diabetes care, 30*(3), 744. doi:10.2337/dc06-1842

Johnson, D., Dupuis, G., Piche, J., Clayborne, Z., & Colman, I. (2018). Adult mental health outcomes of adolescent depression: A systematic review. *Depression and Anxiety, 35*(8), 700-716. doi:10.1002/da.22777

Johnson, K. E., & Taliaferro, L. A. (2011). Relationships between physical activity and depressive symptoms among middle and older adolescents: A review of the research literature. *Journal for Specialists in Pediatric Nursing, 16*(4), 235-251.

Joiner Jr, T. E. (1997). Shyness and low social support as interactive diatheses, with loneliness as mediator: Testing an interpersonal-personality view of vulnerability to depressive symptoms. *Journal of abnormal psychology, 106*(3), 386.

Jones, R. A., Hinkley, T., Okely, A. D., & Salmon, J. (2013). Tracking physical activity and sedentary behavior in childhood: a systematic review. *American Journal of Preventive Medicine, 44*(6), 651-658.

Jozefiak, T., & Backer-Grøndahl, A. (2019). Måleegenskaper ved den norske versjonen av Self-Perception Profile for Adolescents (SPPA). *PsykTestBarn, 1*(1). doi:10.21337/0060

Katzmarzyk, P. T., Lee, I. M., Martin, C. K., & Blair, S. N. (2017). Epidemiology of Physical Activity and Exercise Training in the United States. *Progress in Cardiovascular Diseases, 60*(1), 3-10. doi:https://doi.org/10.1016/j.pcad.2017.01.004

Kelly, L. A., McMillan, D. G. E., Anderson, A., Fippinger, M., Fillerup, G., & Rider, J. (2013). Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC Medical Physics, 13*(1), 5. doi:10.1186/1756-6649-13-5

Kempfer, S. S., Fernandes, G. C. M., Reisdorfer, E., Girondi, J. B. R., Sebold, L. F., Porporatti, A. L., & Canto, G. D. L. (2017). Epidemiology of depression in low income and low education adolescents: a systematic review and meta-analysis. *Grant Med J, 2*(04), 67-77.

Kendler, K. S., Gatz, M., Gardner, C. O., & Pedersen, N. L. (2006). A Swedish National Twin Study of Lifetime Major Depression. *American Journal of Psychiatry, 163*(1), 109-114. doi:10.1176/appi.ajp.163.1.109

Kessler, R. C. (2003). Epidemiology of women and depression. *Journal of affective disorders, 74*(1), 5-13.

Kessler, R. C., Amminger, G. P., Aguilar-Gaxiola, S., Alonso, J., Lee, S., & Ustün, T. B. (2007). Age of onset of mental disorders: a review of recent literature. *Current Opinion in Psychiatry, 20*(4), 359-364. doi:10.1097/YCO.0b013e32816ebc8c

Kessler, R. C., & Bromet, E. J. (2013). The epidemiology of depression across cultures. *Annual review of public health, 34*, 119-138. doi:10.1146/annurev-publhealth-031912-114409

Kieling, C., Baker-Henningham, H., Belfer, M., Conti, G., Ertem, I., Omigbodun, O., . . . Rahman, A. (2011). Child and adolescent mental health worldwide: evidence for action. *The Lancet, 378*(9801), 1515-1525. doi:https://doi.org/10.1016/S0140-6736(11)60827-1

Kleppang, A. L., Hartz, I., Thurston, M., & Hagquist, C. (2018). The association between physical activity and symptoms of depression in different contexts – a cross-sectional study of Norwegian adolescents. *BMC Public Health, 18*(1), 1368. doi:10.1186/s12889-018-6257-0

Korczak, D. J., Madigan, S., & Colasanto, M. J. P. (2017). Children's physical activity and depression: a meta-analysis. *Pediatrics, 139*(4). doi:https://doi.org/10.1542/peds.2016-2266

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of Wearable Monitors for Assessing Sedentary Behavior. *Medicine & Science in Sports & Exercise, 43*(8).

Lamblin, M., Murawski, C., Whittle, S., & Fornito, A. (2017). Social connectedness, mental health and the adolescent brain. *Neuroscience & Biobehavioral Reviews, 80*, 57-68.

Larun, L., Nordheim, L., Ekeland, E., Hagen, K., & Heian, F. (2006). Exercise in prevention and treatment of anxiety and de-pression among children and young people. *Cochrane Database of Systematic Reviews, 4*.

Lee, A., & Hankin, B. L. (2009). Insecure Attachment, Dysfunctional Attitudes, and Low Self-Esteem Predicting Prospective Symptoms of Depression and Anxiety During Adolescence. *Journal of Clinical Child & Adolescent Psychology, 38*(2), 219-231. doi:10.1080/15374410802698396

Lee, J. H., & Huber Jr, J. (2011). *Multiple imputation with large proportions of missing data: How much is too much?* Paper presented at the United Kingdom Stata Users' Group Meetings 2011.

Leitzmann, M. F., Park, Y., Blair, A., Ballard-Barbash, R., Mouw, T., Hollenbeck, A. R., & Schatzkin, A. (2007). Physical Activity Recommendations and Decreased Risk of Mortality. *JAMA Internal Medicine, 167*(22), 2453-2460. doi:10.1001/archinte.167.22.2453

Longbottom, J.-L., Grove, J. R., & Dimmock, J. A. (2010). An examination of perfectionism traits and physical activity motivation. *Psychology of Sport and Exercise, 11*(6), 574-581.

MacAuley, D. (1994). A history of physical activity, health and medicine. *Journal of the Royal Society of Medicine, 87*(1), 32-35.

Mammen, G., & Faulkner, G. (2013). Physical Activity and the Prevention of Depression: A Systematic Review of Prospective Studies. *American Journal of Preventive Medicine, 45*(5), 649-657. doi:http://dx.doi.org/10.1016/j.amepre.2013.08.001

Mathers, M., Canterford, L., Olds, T., Hesketh, K., Ridley, K., & Wake, M. (2009). Electronic media use and adolescent health and well-being: cross-sectional community study. *Academic pediatrics, 9*(5), 307-314.

Maturo, C. C., & Cunningham, S. A. (2013). Influence of Friends on Children's Physical Activity: A Review. *American journal of public health, 103*(7), e23-e38. doi:10.2105/AJPH.2013.301366

McLeod, G. F. H., Horwood, L. J., & Fergusson, D. M. (2016). Adolescent depression, adult mental health and psychosocial outcomes at 30 and 35 years. *Psychological medicine, 46*(7), 1401-1412. doi:10.1017/S0033291715002950

McMahon, E. M., Corcoran, P., O'Regan, G., Keeley, H., Cannon, M., Carli, V., . . . Apter, A. (2017). Physical activity in European adolescents and associations with anxiety, depression and well-being. *European child & adolescent psychiatry, 26*(1), 111-122.

Merikangas, K. R., & Avenevoli, S. (2002). Epidemiology of mood and anxiety disorders in children and adolescents. *Textbook in psychiatric epidemiology, 2*, 657-704.

Merikangas, K. R., He, J. P., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., . . . Swendsen, J. (2010). Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(10), 980-989. doi:https://doi.org/10.1016/j.jaac.2010.05.017

Moeller, R. W., & Seehuus, M. (2019). Loneliness as a mediator for college students' social skills and experiences of depression and anxiety. *Journal of Adolescence, 73*, 1-13.

National Institute of Mental Health. (2018). Mental Health Information: Anxiety Disorders. Retrieved from https://www.nimh.nih.gov/health/topics/anxiety-disorders/index.shtml

Ndahimana, D., & Kim, E.-K. (2017). Measurement Methods for Physical Activity and Energy Expenditure: a Review. *Clinical Nutrition Research, 6*(2), 68-80.

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., . . . Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*(9), 1094.

Oliver, M., Badland, H. M., Schofield, G. M., & Shepherd, J. (2011). Identification of accelerometer nonwear time and sedentary behavior. *Research quarterly for exercise and sport, 82*(4), 779-783.

Ommundsen, Y., Page, A., Ku, P.-W., & Cooper, A. R. (2008). Cross-cultural, age and gender validation of a computerised questionnaire measuring personal, social and environmental associations with children's physical activity: the European Youth Heart Study. *International Journal of Behavioral Nutrition and Physical Activity, 5*(1), 29.

Orben, A., & Przybylski, A. K. (2019). The association between adolescent well-being and digital technology use. *Nature Human Behaviour, 3*(2), 173.

Ortega, F. B., Konstabel, K., Pasquali, E., Ruiz, J. R., Hurtig-Wennlöf, A., Mäestu, J., . . . Labayen, I. (2013). Objectively measured physical activity and sedentary time during childhood, adolescence and young adulthood: a cohort study. *PloS one, 8*(4).

Oweis, P., & Spinks, W. (2001). Biopsychological, affective and cognitive responses to acute physical activity. *Journal of sports medicine and physical fitness, 41*(4), 528-538.

Park, H., & Kim, N. (2008). Predicting Factors of Physical Activity in Adolescents: A Systematic Review. *Asian Nursing Research, 2*(2), 113-128. doi:https://doi.org/10.1016/S1976-1317(08)60035-3

Pearson, N., Braithwaite, R. E., Biddle, S. J. H., Sluijs, E. M. F., & Atkin, A. J. (2014). Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis. *Obesity Reviews, 15*(8), 666-675. doi:doi:10.1111/obr.12188

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Current Opinion in Psychiatry, 18*(2), 189-193.

Phillips, J. A., & Young, D. R. (2009). Past-year sports participation, current physical activity, and fitness in urban adolescent girls. *Journal of Physical Activity and Health, 6*(1), 105-111.

Physical Activity Guidelines Advisory Committee (PAGAC). (2008). *Physical Activity Guidelines Advisory Committee Report*. Washington, DC

Pickett, K., Yardley, L., & Kendrick, T. (2012). Physical activity and depression: A multiple mediation analysis. *Mental Health and Physical Activity, 5*(2), 125-134. doi:https://doi.org/10.1016/j.mhpa.2012.10.001

Polanczyk, G., Salum, G., Sugaya, L., Caye, A., & Rohde, L. (2015). Annual Research Review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *Journal of Child Psychology and Psychiatry, 56*(3), 345-365. doi:10.1111/jcpp.12381

Porta, M. (2014). *A dictionary of epidemiology* (5 ed.). Oxford: Oxford university press.

Primack, B. A., Swanier, B., Georgiopoulos, A. M., Land, S. R., & Fine, M. J. (2009). Association between media use in adolescence and depression in young adulthood: a longitudinal study. *Archives of general psychiatry, 66*(2), 181-188.

Qin, X., Wang, S., & Hsieh, C.-R. (2018). The prevalence of depression and depressive symptoms among adults in China: Estimation based on a National Household Survey.

China Economic Review, 51, 271-282. doi:https://doi.org/10.1016/j.chieco.2016.04.001

Qualter, P., Brown, S. L., Munn, P., & Rotenberg, K. J. (2010). Childhood loneliness as a predictor of adolescent depressive symptoms: an 8-year longitudinal study. *European child & adolescent psychiatry, 19*(6), 493-501. doi:10.1007/s00787-009-0059-y

Rao, A. L., & Hong, E. S. (2016). Understanding depression and suicide in college athletes: emerging concepts and future directions. *BMJ Sport and Exercise Medicine, 50*(3), 136-137.

Raudsepp, L., & Neissaar, I. (2012). Brief report: relationships between physical activity and depressive symptoms in adolescent girls. *Journal of Adolescence, 35*(5), 1399-1402.

Rothon, C., Edwards, P., Bhui, K., Viner, R. M., Taylor, S., & Stansfeld, S. A. (2010). Physical activity and depressive symptoms in adolescents: a prospective study. *Bmc Medicine, 8*(1), 32.

Ruiz, J. R., Ortega, F. B., Martínez-Gómez, D., Labayen, I., Moreno, L. A., De Bourdeaudhuij, I., . . . Molnar, D. (2011). Objectively measured physical activity and sedentary time in European adolescents: the HELENA study. *American journal of epidemiology, 174*(2), 173-184.

Sabiston, C. M., O'Loughlin, E., Brunet, J., Chaiton, M., Low, N. C., Barnett, T., & O'Loughlin, J. (2013). Linking depression symptom trajectories in adolescence to physical activity and team sports participation in young adults. *Preventive Medicine, 56*(2), 95-98. doi:http://dx.doi.org/10.1016/j.ypmed.2012.11.013

Sagelv, E. H., Ekelund, U., Pedersen, S., Brage, S., Hansen, B. H., Johansson, J., . . . Hopstock, L. A. (2019). Physical activity levels in adults and elderly from triaxial and uniaxial accelerometry. The Tromsø Study. *PloS one, 14*(12).

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and science in sports and exercise, 32*(5), 963-975.

Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. *Health Psychology, 22*(2), 178-188. doi:10.1037/0278-6133.22.2.178

Salvy, S.-J., Roemmich, J. N., Bowker, J. C., Romero, N. D., Stadler, P. J., & Epstein, L. H. (2008). Effect of Peers and Friends on Youth Physical Activity and Motivation to be Physically Active. *Journal of pediatric psychology, 34*(2), 217-225. doi:10.1093/jpepsy/jsn071

Sawka, K. J., McCormack, G. R., Nettel-Aguirre, A., Hawe, P., & Doyle-Baker, P. K. (2013). Friendship networks and physical activity and sedentary behavior among youth: a systematized review. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 130. doi:10.1186/1479-5868-10-130

Schuch, F. B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P., Reichert, T., . . . Stubbs, B. (2017). Physical activity and sedentary behavior in people with major depressive disorder: A systematic review and meta-analysis. *Journal of affective disorders, 210*, 139-150. doi:https://doi.org/10.1016/j.jad.2016.10.050

Schuch, F. B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P. B., Silva, E. S., . . . Stubbs, B. (2018). Physical Activity and Incident Depression: A Meta-Analysis of Prospective Cohort Studies. *American Journal of Psychiatry, 175*(7), 631-648. doi:10.1176/appi.ajp.2018.17111194

Schuch, F. B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P. B., & Stubbs, B. (2016). Exercise as a treatment for depression: A meta-analysis adjusting for publication bias. *Journal of psychiatric research, 77*, 42-51. doi:https://doi.org/10.1016/j.jpsychires.2016.02.023

Sciamanna, C. N., Smyth, J. M., Doerksen, S. E., Richard, B. R., Kraschnewski, J. L., Mowen, A. J., . . . Yang, C. (2017). Physical activity mode and mental distress in adulthood. *American Journal of Preventive Medicine, 52*(1), 85-93.

Selig, J. P., & Preacher, K. J. (2009). Mediation models for longitudinal data in developmental research. *Research in Human Development, 6*(2-3), 144-164.

Sheeber, L., Hops, H., & Davis, B. (2001). Family Processes in Adolescent Depression. *Clinical Child and Family Psychology Review, 4*(1), 19-35. doi:10.1023/A:1009524626436

Sherar, L. B., Esliger, D. W., Baxter-Jones, A. D. G., & Tremblay, M. S. (2007). Age and Gender Differences in Youth Physical Activity: Does Physical Maturity Matter? *Medicine & Science in Sports & Exercise, 39*(5), 830-835. doi:10.1249/mss.0b013e3180335c3c

Silverman, M. N., & Deuster, P. A. (2014). Biological mechanisms underlying the role of physical fitness in health and resilience. *Interface focus, 4*(5), 20140040. doi:10.1098/rsfs.2014.0040

Sivertsen, B., Harvey, A. G., Lundervold, A. J., & Hysing, M. (2014). Sleep problems and depression in adolescence: results from a large population-based study of Norwegian

adolescents aged 16–18 years. *European child & adolescent psychiatry, 23*(8), 681-689.

Slootmaker, S. M., Schuit, A. J., Chinapaw, M. J., Seidell, J. C., & Van Mechelen, W. (2009). Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. *International Journal of Behavioral Nutrition and Physical Activity, 6*(1), 17.

Smith, A. L., Ullrich-French, S., Walker, E., & Hurley, K. S. (2006). Peer relationship profiles and motivation in youth sport. *Journal of Sport and Exercise Psychology, 28*(3), 362-382.

Smith, M. M., Vidovic, V., Sherry, S. B., Stewart, S. H., & Saklofske, D. H. (2018). Are perfectionism dimensions risk factors for anxiety symptoms? A meta-analysis of 11 longitudinal studies. *Anxiety, Stress, & Coping, 31*(1), 4-20. doi:10.1080/10615806.2017.1384466

Sollerhed, A.-C., Apitzsch, E., Råstam, L., & Ejlertsson, G. (2008). Factors associated with young children's self-perceived physical competence and self-reported physical activity. *Health Education Research, 23*(1), 125-136.

Stavrakakis, N., Roest, A., Verhulst, F., Ormel, J., De Jonge, P., & Oldehinkel, A. (2013). Physical activity and onset of depression in adolescents: A prospective study in the general population cohort TRAILS. *Journal of psychiatric research, 47*(10), 1304-1308.

Steene-Johannessen, J., Anderssen, S., Bratteteig, M., Dalhaug, E., Andersen, I., Andersen, O., & Dalene, K. (2019). Kartlegging av fysisk aktivitet, sedat tid og fysisk form blant barn og unge 2018 (ungKan3). *Norges Idrettshøgskole*.

Stiglic, N., & Viner, R. M. (2019). Effects of screentime on the health and well-being of children and adolescents: a systematic review of reviews. *BMJ open, 9*(1), e023191. doi:10.1136/bmjopen-2018-023191

Strand, B. H., Dalgard, O. S., Tambs, K., & Rognerud, M. (2003). Measuring the mental health status of the Norwegian population: a comparison of the instruments SCL-25, SCL-10, SCL-5 and MHI-5 (SF-36). *Nordic journal of psychiatry, 57*(2), 113-118.

Strong, W. B., Malina, R. M., Blimkie, C. J. R., Daniels, S. R., Dishman, R. K., Gutin, B., . . . Trudeau, F. (2005). Evidence Based Physical Activity for School-age Youth. *The Journal of Pediatrics, 146*(6), 732-737. doi:https://doi.org/10.1016/j.jpeds.2005.01.055

Sund, A. M., Larsson, B., & Wichstrøm, L. (2011). Role of physical and sedentary activities in the development of depressive symptoms in early adolescence. *Social Psychiatry and Psychiatric Epidemiology, 46*(5), 431-441.

Swami, V., Weis, L., Barron, D., & Furnham, A. (2018). Positive body image is positively associated with hedonic (emotional) and eudaimonic (psychological and social) well-being in British adults. *The Journal of Social Psychology, 158*(5), 541-552. doi:10.1080/00224545.2017.1392278

Swartz, J. R., Hariri, A. R., & Williamson, D. E. (2017). An epigenetic mechanism links socioeconomic status to changes in depression-related brain function in high-risk adolescents. *Molecular Psychiatry, 22*(2), 209-214. doi:10.1038/mp.2016.82

Tammelin, T., Näyhä, S., Hills, A. P., & Järvelin, M.-R. (2003). Adolescent participation in sports and adult physical activity. *American Journal of Preventive Medicine, 24*(1), 22-28. doi:https://doi.org/10.1016/S0749-3797(02)00575-5

Tappe, M. K., Duda, J. L., & Ehrnwald, P. M. (1989). Perceived barriers to exercise among adolescents. *Journal of school health, 59*(4), 153-155.

Teigen, K. H. (2015). *Psykologiens Historie* (2 ed.). Bergen: Fagbokforlaget

Tergerson, J. L., & King, K. A. (2002). Do perceived cues, benefits, and barriers to physical activity differ between male and female adolescents? *Journal of school health, 72*(9), 374-380.

Toseeb, U., Brage, S., Corder, K., Dunn, V. J., Jones, P. B., Owens, M., . . . Goodyer, I. M. (2014). Exercise and depressive symptoms in adolescents: A longitudinal cohort study. *JAMA Pediatrics, 168*(12), 1093-1100. doi:10.1001/jamapediatrics.2014.1794

Trinh, L., Wong, B., & Faulkner, G. E. (2015). The independent and interactive associations of screen time and physical activity on mental health, school connectedness and academic achievement among a population-based sample of youth. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 24*(1), 17.

Trost, S. G., Pate, R. R., Sallis, J. F., Freedson, P. S., Taylor, W. C., Dowda, M., & Sirard, J. (2002). Age and gender differences in objectively measured physical activity in youth. *Medicine and science in sports and exercise, 34*(2), 350-355.

Tudor-Locke, C., Camhi, S. M., & Troiano, R. P. (2012). A catalog of rules, variables, and definitions applied to accelerometer data in the National Health and Nutrition Examination Survey, 2003-2006. *Preventing chronic disease, 9*, E113-E113. doi:10.5888/pcd9.110332

Ueno, K. (2005). The effects of friendship networks on adolescent depressive symptoms. *Social Science Research, 34*(3), 484-510. doi:https://doi.org/10.1016/j.ssresearch.2004.03.002

Ullrich-French, S., & Smith, A. L. (2009). Social and motivational predictors of continued youth sport participation. *Psychology of Sport and Exercise, 10*(1), 87-95.

Van Dijk, M. L., Savelberg, H. H. C. M., Verboon, P., Kirschner, P. A., & De Groot, R. H. M. (2016). Decline in physical activity during adolescence is not associated with changes in mental health. *BMC Public Health, 16*(1), 300. doi:10.1186/s12889-016-2983-3

Van Droogenbroeck, F., Spruyt, B., & Keppens, G. (2018). Gender differences in mental health problems among adolescents and the role of social support: results from the Belgian health interview surveys 2008 and 2013. *BMC Psychiatry, 18*(1), 6. doi:10.1186/s12888-018-1591-4

Van Hecke, L., Loyen, A., Verloigne, M., van der Ploeg, H. P., Lakerveld, J., Brug, J., . . . on behalf of the, D. c. (2016). Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 70. doi:10.1186/s12966-016-0396-4

Van, K. D. H., Paw, M. J., Twisk, J. W., Van, W. M. J. M., sports, s. i., & exercise. (2007). A brief review on correlates of physical activity and sedentariness in youth. *39*(8), 1241-1250.

Van Zalk, N., Van Zalk, M., Kerr, M., & Stattin, H. (2011). Social Anxiety as a Basis for Friendship Selection and Socialization in Adolescents' Social Networks. *Journal of Personality, 79*(3), 499-526. doi:10.1111/j.1467-6494.2011.00682.x

Vanhelst, J., Béghin, L., Drumez, E., Coopman, S., & Gottrand, F. (2017). Awareness of wearing an accelerometer does not affect physical activity in youth. *BMC Medical Research Methodology, 17*, 99. doi:10.1186/s12874-017-0378-5

Veed, G. J., McGinley, M., & Crockett, L. J. (2019). Friendship network influence on the development of internalizing symptoms during adolescence. *Journal of Applied Developmental Psychology, 60*, 157-165. doi:https://doi.org/10.1016/j.appdev.2018.09.002

Wen, L. M., Rissel, C., & He, G. (2015). The effect of early life factors and early interventions on childhood overweight and obesity. *Journal of obesity, 2015*.

Whalen, D. J., Sylvester, C. M., & Luby, J. L. (2017). Depression and Anxiety in Preschoolers: A Review of the Past 7 Years. *Child and Adolescent Psychiatric Clinics, 26*(3), 503-522. doi:10.1016/j.chc.2017.02.006

Wichstrøm, L. (1995). Harter's Self-Perception Profile for Adolescents: Reliability, validity, and evaluation of the question format. *Journal of personality assessment, 65*(1), 100-116.

Wiklund, M., Malmgren-Olsson, E.-B., Öhman, A., Bergström, E., & Fjellman-Wiklund, A. (2012). Subjective health complaints in older adolescents are related to perceived stress, anxiety and gender–a cross-sectional school study in Northern Sweden. *BMC Public Health, 12*(1), 993.

Willey, J. Z., Gardener, H., Caunca, M. R., Moon, Y. P., Dong, C., Cheung, Y. K., . . . Wright, C. B. (2016). Leisure-time physical activity associates with cognitive decline: The Northern Manhattan Study. *Neurology, 86*(20), 1897-1903.

Wolanin, A., Gross, M., & Hong, E. (2015). Depression in Athletes: Prevalence and Risk Factors. *Current Sports Medicine Reports, 14*(1), 56-60. doi:10.1249/jsr.0000000000000123

World Health Organisation. (2010). *Global Recommendations on Physical Activity for Health*. World Health Organization.

World Health Organisation (Producer). (2018, February 23rd). Physical activity. [Fact sheet] Retrieved from https://www.who.int/news-room/fact-sheets/detail/physical-activity

World Health Organisation (Producer). (2018, March 30th). Mental health: strengthening our response. [Fact sheet] Retrieved from https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response

World Health Organisation (Producer). (2019, November 28th). Mental disorders. [Fact sheet] Retrieved from https://www.who.int/news-room/fact-sheets/detail/mental-disorders

World Health Organisation (Producer). (n.d., 2020, April 10th). What is Moderate-intensity and Vigorous-intensity Physical Activity? [Information] Retrieved from https://www.who.int/dietphysicalactivity/physical_activity_intensity/en/

World Health Organization (Producer). (2018, January 30th). Depression [Fact sheet] Retrieved from https://www.who.int/en/news-room/fact-sheets/detail/depression

Yang, B., Kelly, A.-F., Pedro, F. S.-M., Gregory, J. W., & Norma, C. (2018). Evaluation of Youth Enjoyment Toward Physical Activity and Sedentary Behavior. *Pediatric exercise science, 30*(2), 273-280. doi:10.1123/pes.2017-0101

Zahl, T., Steinsbekk, S., & Wichstrøm, L. (2017). Physical Activity, Sedentary Behavior, and Symptoms of Major Depression in Middle Childhood. *Pediatrics, 139*(2), e20161711.

Zhao, W., Young, R. E., Breslow, L., Michel, N. M., Flett, G. L., & Goldberg, J. O. (2015). Attachment style, relationship factors, and mental health stigma among adolescents. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement, 47*(4), 263-271. doi:10.1037/cbs0000018

Zimmer, P., Stritt, C., Bloch, W., Schmidt, F.-P., Hübner, S. T., Binnebößel, S., . . . Oberste, M. (2016). The effects of different aerobic exercise intensities on serum serotonin concentrations and their association with Stroop task performance: a randomized controlled trial. *European Journal of Applied Physiology, 116*(10), 2025-2034. doi:10.1007/s00421-016-3456-1

Zisook, S., Lesser, I., Stewart, J. W., Wisniewski, S. R., Balasubramani, G., Fava, M., . . . Nierenberg, A. A. (2007). Effect of age at onset on the course of major depressive disorder. *American Journal of Psychiatry, 164*(10), 1539-1546.

PAPER 1

Opdal et al. BMC Public Health (2019) 19:916
https://doi.org/10.1186/s12889-019-7271-6

BMC Public Health

RESEARCH ARTICLE Open Access

Change in physical activity is not associated with change in mental distress among adolescents: the Tromsø study: Fit Futures

Ida Marie Opdal[1*], Bente Morseth[2], Bjørn Helge Handegård[3], Kjersti Lillevoll[1], Helga Ask[4], Christopher Sivert Nielsen[4], Alexander Horsch[5], Anne-Sofie Furberg[6], Simon Rosenbaum[7,8] and Kamilla Rognmo[1]

Abstract

Background: Previous research shows that physical activity has a protective effect on mental distress in adults, but the relationship is less researched and seems more ambiguous for adolescents. Studies in this field have typically been cross-sectional by design and based on self-reported physical activity measures, which are known to be vulnerable to response bias. The aim of this study was to investigate the relationship between change in objectively assessed physical activity as measured by accelerometer and change in mental distress among adolescents using longitudinal data from The Tromsø Study: Fit Futures.

Method: This study was based on data from 676 upper-secondary school students (mean age 16.23 years at baseline, 45.26% boys) from The Tromsø Study: Fit Futures. Physical activity, mental distress and covariates were measured at baseline (T1) and follow-up (T2) 2 years later. Physical activity was objectively measured with an ActiGraph GT3X accelerometer over 7 days. Mental distress was measured with the Hopkins Symptom Checklist-10 (HSCL-10). Change score variables were computed as the difference between T1 and T2 in number of steps, number of minutes of moderate to vigorous physical activity (MVPA) and mental distress between T1 and T2, and analyzed using linear regression analysis.

Results: Changes in steps per day were not associated with changes in mental distress in neither the crude, partially, nor fully adjusted model. Neither was changes in minutes of MVPA per day. Interaction effects between change in both steps per day and minutes of MVPA and gender were also not statistically significant, nor was the interaction effects between baseline levels of mental distress and physical activity.

Conclusion: The results of our study indicate that for adolescents in the sample, change in physical activity is unrelated to change in mental distress over a two-year period.

Keywords: Adolescence, Youth, Physical activity, Mental distress, Depression, Anxiety, Fit futures, Accelerometry

More than one in ten children and adolescents suffer from a mental disorder [1]. As the median age of onset for experiencing a mental disorder is during the teenage years [2], adolescence may be a crucial period for preventing the development of mental health problems.

Physical activity seems to be related to mental health problems, such as anxiety and depression [3]. The relationship may be explained by low levels of physical activity among individuals with high levels of mental distress, whereas another possible explanation is that physical activity elicits physiological responses that enhance mood, such as higher levels of norepinephrine, endorphins and serotonin, and lower hormonal responses from stress [4, 5]. High intensity and frequent physical activity of young athletes compared to non-athletes has been shown to be associated with lower anxiety and fewer depressive symptoms, and may serve as an indication that some of the effect of physical activity on mental distress is explained by physiological factors associated with increased hormonal responses at higher levels of intensity of

* Correspondence: ida.m.opdal@uit.no
[1]Department of Psychology, UiT The Arctic University of Norway, Tromsø, Norway
Full list of author information is available at the end of the article

exercise [6–9]. A psychological explanation for the relationship may be that physical activity causes feelings of mastery and control [4], influences self-esteem [10], body composition [11], acts as a distractor from stressors, negative thoughts and rumination [4], and may provide an arena for the individual to learn social skills [12] and get a social network [4, 13]. For example, single bouts of exercise were found to impact positively on mood and rumination among other factors in inpatients with mental disorders [14]. The context in which activity is performed may also be of importance, as participation in organized sports has been found to be associated with lower odds of depressive symptoms [15].

The relationship between physical activity and mental health among adults is well established, however, less studies have investigated the relationship among adolescents. The majority of the studies in the field are cross-sectional [16], with the overall result indicating that higher levels of physical activity are related to lower levels of depressive symptoms [17]. However, the strength of the relationship is small to moderate, and the validity and reliability of the results are limited by methodological weaknesses relating to measurement and study design as a majority of the studies has relied on single-item self-report measures of physical activity [17]. In addition, results from cross-sectional studies are not informative regarding changes in the relationship over time. In general, physical activity levels seem to decrease over time during adolescence [18], whereas the prevalence of mental disorders increases [19]. It also seems that recent cohorts of girls experience an increase in internalizing symptoms compared with older cohorts [20], indicating a change in the cohorts, making interpretation from cross-sectional studies difficult. Longitudinal studies are therefore required to investigate if change in physical activity is associated with change in mental distress.

The results of existing longitudinal studies on the relationship seem to depend upon the type of measurement of physical activity. Longitudinal studies using self-report measures tend to find a relationship between physical activity and mental health problems over time [4, 21–24], although not consistently [25, 26]. However, the few studies using objective measurements of physical activity, e.g. step counter or accelerometer, have not found a significant relationship [27, 28]. Objectively measured physical activity and self-reported physical activity are not equivalent, as accelerometers accurately measures the movement in physical activity behaviors and self-reported measurements often aim at measuring the normal level of physical activity in reported time-periods [29]. Whilst self-reported data is based on subjective opinion and recall of past experiences, objective measured data collect the overall total physical activity during a specified time period. The use of self-reported physical activity is subject to recall and response bias [30], and research show that adolescents tend to over-report time spent in moderate and vigorous physical activity compared to objective accelerometer data [31]. Whilst the results of the longitudinal studies using self-report data tend to show significant effects of physical activity, a recent meta-analysis shows that the overall effect of physical activity on depressive symptoms is small [32].

To the best of our knowledge, only two longitudinal studies have used objective measures of physical activity to investigate the association between physical activity and mental health problems among adolescents. Van Dijk et al. [28] found that change in objectively measured physical activity was not associated with change in mental health among 158 adolescents aged 13 years over a one-year period. Overall, physical activity declined by 15.3%, and depressive symptoms by 12.1% between baseline and one-year follow up. Toseeb et al. [27] also found no longitudinal association between objectively measured physical activity at baseline and the development of symptoms of depression during a three-year period for 736 adolescents in the UK aged 14.5 years at baseline. Data on change in physical activity was not available from the Toseeb et al. study, however they found a small decrease in depressive symptoms (5.7% decrease in total score) and an increase in major depression diagnoses by 57% between baseline and the three-year follow up study.

As the measurement method seems to impact the results of the studies investigating the longitudinal relationship between physical activity and mental health outcomes, it is imperative that more studies using objective measurements are performed, in order to increase the knowledge regarding this relationship and shed light upon the apparent discrepancy in results of studies using different methodology. The current study aims to investigate the degree to which change in objectively measured physical activity is related to change in mental distress, operationalized as change in symptoms of anxiety and depression, among adolescents, by using data from The Tromsø study: Fit Futures. As the studies based on objective measurements report different findings than the studies based on self-report, hypothesizing regarding the results of the present study is difficult. However, as most previous studies have shown a relationship over time, and as the biological and psychological explanatory models provide a solid foundation for the mechanisms involved, we hypothesize that change in physical activity is inversely related to change in mental distress over a two-year period. We also hypothesize that the participants with the highest levels of mental distress at baseline benefit more from a change in physical activity between baseline and follow-up than the less mentally distressed individuals, and that higher levels of change in physical activity over time are related to greater change in mental distress.

Method

Study design and sample

In 2010–11, all first-level upper secondary school students in two municipalities in the county of Troms in Northern Norway were invited to participate in the general health study The Tromsø study: Fit Futures 1 (T1), described previously [33]. The study was conducted during school hours, and participants were transported to the research site at the Clinical Research Unit, University Hospital of North Norway, Tromsø.

In total, 1,117 students were invited to participate in T1, out of which 1,038 (92.9%) agreed. In 2012–13, all attendees in T1 and all students at the third level of the same upper secondary schools as in T1, were invited to participate in The Tromsø study: Fit Futures 2 (T2). In total, 1,129 students were invited to T2, out of which 870 (77%) agreed. 694 (67%) students who participated in T1 also participated in T2, and 676 of these are included in the current study after multiple imputation. The majority of the participating sample was 15–17 years old in T1 and 17–19 years old in T2.

Both T1 and T2 included a web-based questionnaire, a clinical examination and interview performed by trained research nurses at the study site. The participants filled in a web-based general questionnaire (Questback) about family, lifestyle, health and disease, and received an ActiGraph GT3X accelerometer and wearing instructions. Height and weight were measured according to standardized procedures. Information about diagnosis of any chronic disease was obtained from the interview. All participants provided written informed consent; participants younger than age 16 also provided written informed consent from a guardian.

Measurements

Physical activity

Physical activity was measured using the ActiGraph GT3X accelerometer. The validity of the ActiGraph GT3X has been well established and is superior to self-reported physical activity as assessed by self-report questionnaire [30, 34], although it tends to underestimate cycling and unstructured activity [31]. The subjects were instructed to wear the ActiGraph on their dominant hip for 7 days, and to only take it off when sleeping, showering or swimming. Participants with at least 10 h wear-time for at least four out of the 7 days were considered to have valid data due to the possible variation in physical activity in the period of measurement.

ActiLife software provided by the manufacturer (ActiGraph, LLC, Pensacola, USA) was used for ActiGraph device initialization and data downloaded as 10-s time intervals (epochs). The further data processing was done with the Quality Control & Analysis Tool (QCAT). The data was aggregated to epochs of 60 s duration for the analysis. This was considered reasonable for the basic variables related to volume, intensity and duration of physical activity used in this study. For wear-time calculation we used the triaxial algorithm described by Hecht et al. [35] as it conforms to previous research definition of non-wear time [36].

ActiGraph variables of interest in this study are number of steps on 10-s time intervals (epochs) and minutes in moderate to vigorous physical activity (MVPA) per valid day, based on uniaxial cut-points by Freedson et al. [37]. Change score variables for steps (steps per valid day at T2 minus steps per valid day at T1) and MVPA (minutes MVPA per valid day at T2 minus minutes MVPA per valid day at T1) were calculated and served as predictor variables in the analyses. Change score for steps per valid day estimates the overall physical activity level, while minutes in MVPA per valid day was included to investigate the impact of change in intensity of physical activity over time in change in mental distress. To make it easier to visualize the change, the total number of steps per valid day was divided by 1000. In order to see if the degree of change from T1 to T2 was related to change in mental distress, steps per day was categorized into four groups, a high negative change (more than 3000 steps reduction at T2), a small negative change (0 to 3000 reduction in steps at T2), a small positive change (0–3000 steps increase at T2), and a high positive change (more than 3000 steps increase at T2). This variable was used in supplemental, interaction analyses.

Mental distress

Mental distress was measured by the Hopkins Symptom Checklist-10 (HSCL-10) in the general questionnaire. HSCL-10 is a well-validated instrument measuring symptoms of anxiety (4 items) and depression (6 items) during the previous 7 days [38]. Response categories were “none” (1), “slightly”, “much” and “very much” (4). The average score of the 10 items was calculated for T1 and T2, and a difference score variable (T2 mental distress minus T1 mental distress) was created and served as the outcome variable in the analyses. In addition, interaction analyses were conducted in order to examine if the relationship between change in physical activity and change in mental distress is dependent upon mean baseline levels of mental distress.

Covariates

A number of variables may impact change in physical activity and change in mental distress, and accordingly we have included demographic variables (e.g. socioeconomic status [39], sex and age [40]), social level variables (e.g. social network [41]), and health or lifestyle related variables (e.g. smoking [42], chronic pain [43], BMI [44] and sleep [45, 46]) as covariates in the analyses. Change

in variables that were measured at both T1 and T2 were included as covariates, in addition to baseline levels of the same variables.

Demography Sex (female = 0, male = 1) was included as a possible confounder in the analyses. At T1, the respondents were asked to indicate the highest level of completed education of their mother and father, which served as a proxy for socioeconomic status (high/low, with low including education up to and including secondary vocational education) in the analyses. As season of the year might significantly impact the level of physical activity, especially in regions north of the Arctic Circle, a seasonal variable indicating the time of ActiGraph measurement at T1 and T2 was included in the analyses to control for measurements during summertime (May to June and September to October, value = 0), or wintertime (November to April, value = 1).

Social network and school motivation Considered quitting or taking a break from school in T1 (yes/no) was included as a possible confounder. Social network was measured at T1 and T2 by five items asking about the degree to which the respondents find it hard to make friends, have many friends, feel accepted among his/her peers, feel liked among peers, and feel popular among peers. Change in social network between T1 to T2 was calculated (T2-T1) and used as a covariate in the analyses, as was baseline social network.

Health and lifestyle related variables In the interview in T1, the respondents were asked if they had any chronic or persistent diseases, and if they reported that they did, they were asked to specify up to five diagnoses. A dichotomous variable was created and coded as follows: 0 = no chronic disease present, 1 = one or more chronic diseases present. The respondents also reported if they suffered from chronic pain (yes/no). Weight and height were measured at the examination site and BMI was calculated by dividing the participants weight by their height squared. In order to take into account body growth, BMI at baseline was categorized in age and sex specific categories with cut-offs defined by previous research [47], and used as a covariate in the analyses. Baseline levels and change in self-reported health between T1 and T2, measured by a five-point Likert type scale, were also included as covariates. Furthermore, smoking was assessed in the questionnaire at T1 ("no", "sometimes", "daily"), and was dichotomized into no and sometimes/daily.

In the general questionnaire in T1, sleep delay was measured by asking the respondents to indicate how long they normally lie awake before falling asleep (sleep onset latency) on weekdays and weekends. Response categories ranged from "30 minutes or less" to "three hours or more". A sleep onset latency over 30 min on more than 3 days per week is considered a clinical marker for insomnia [48]; consequently, a dichotomous variable was created, with a cut-off at spending more than 30 min falling asleep. The respondents were also asked about how many hours of sleep they normally get per night. Response categories ranged from "four hours or less" to "12 hours or more". At last, the degree to which the respondent felt like they get enough sleep was measured, and the response categories were "yes, absolutely enough", "yes, normally enough", "no, somewhat insufficient", "no, clearly insufficient" and "no, far from sufficient". The responses were dichotomized into "yes" (the two first response categories) and "no" (the three last response categories).

Questions asking about the number of times a week the participants consumed unhealthy food such as pizza, hamburger or hot dogs, chocolate or sweets, snacks and soft drinks with sugar, or healthy food such as fat fish, lean fish, fruit, vegetables, cod liver oil and vitamin or mineral supplements were included in the questionnaires at T1 and T2. The response categories ranged from "rarely/never" to "every day". Two variables were created – one average score variable based on the four unhealthy diet items and one average score variable based on the six healthy diet items. Change scores between unhealthy and healthy diet at T1 and T2 were calculated and served as covariates in the analyses, in addition to unhealthy and healthy diet at T1.

Treatment of missing data

In order to increase power to detect an effect, as well as reduce possible bias due to missing values, Multiple imputation (IBM SPSS 25 for windows) was used to impute T1 and T2 ActiGraph data and parental education. It was set a requirement prior to the imputations that only missing ActiGraph and socioeconomic data of participants who had questionnaire data from both T1 and T2 were to be imputed due to their representation of a high proportion of the missing data. Participants who had missing data were not significantly different from those with complete data, and the observed values were perceived as good predictors for the multiple imputation. At T1, 608 (58.6% of total number of participants) had valid ActiGraph data, whereas 420 (48.3% of total number of participants) had valid ActiGraph data at T2. A predictive model consisting of all variables included in the analyses, including T1 and T2 steps per valid day and minutes in MVPA per valid day, was used to create 50 imputed datasets that subsequently were pooled and analyzed. After imputations, 35.2% of the data on steps per day, 35.1% of MVPA, 25% of socioeconomic status of mother and 29.3% of socioeconomic status

of father were imputed. After imputation, 676 participants had complete data on all the variables used in the analyses.

Data analysis

This study investigates the assumption that the difference between T1 and T2 levels of the dependent variable is due to change in levels of physical activity, and thus, change scores between T1 and T2 were calculated for the predictor variables steps per valid day and minutes in MVPA per valid day, and the outcome variable mental distress. Analysis on change scores gives unique information on the relationship between change in the independent and dependent variable over two time points, and is preferred over other longitudinal methods in this study due to the specific research question that we wish to address and due to the robustness of multiple imputation in estimating missing values. Two sets of stepwise linear regression analyses were conducted, using the statistical software SPSS version 25.0 (IBM Corporation, Armonk NY, USA) for Windows® [49]. In the first model, change in steps was the predictor of change in mental distress. In the second model, change in minutes in MVPA was the predictor of change in mental distress. The analyses were run both unadjusted and adjusted by several potentially influential confounders. In the first block of the analyses, change in steps was entered alone, in order to estimate the crude effect. Next, in block two, the demographic variables were entered: sex, age, socioeconomic status of the mother and father, season of actigraphy measurement. In block three, the social level variables social network (change between T1 and T2 and baseline levels) and having considered dropping out of school were entered. Finally, health and lifestyle related variables were included in block four, including chronic disease, chronic pain, sleep onset latency, hours of sleep, sufficient amounts of sleep, baseline BMI, self-reported health (change between T1 and T2 and baseline levels), healthy and unhealthy diet (change between T1 and T2 and baseline levels) and smoking. Interaction effects of change in physical activity and sex, as well as change in physical activity and baseline levels of mental distress were investigated in the fully adjusted model in separate analyses. In addition, an analysis of covariance was performed in order to see if a high negative change in steps per day from T1 to T2 was related to change in mental distress, compared to a high positive change adjusted for sex, age, socioeconomic status, BMI, season, and sleep onset latency.

The analyses were also run on complete cases. Since there were no differences in the results, only results from the analyses based on multiply imputed data are reported.

Results

Descriptive statistics

Descriptive statistics are shown in Table 1 and Table 2. Most of the participant's physical activity was tested during wintertime, and a majority of the participants reported that their mother and father had low levels of education (see Table 1). Mean levels of steps per day and MVPA were also relatively stable from T1 to T2, although somewhat lower at T2 than at T1. The mean levels of MVPA at T1 and T2 were lower than the recommended 60 min of MVPA per day [50].

The relationship between change in physical activity and change in mental distress

Change in steps per valid day showed no statistically significant relationship with mental distress neither in the crude, partially or fully adjusted analyses (Table 3).

Table 1 Frequencies and percentages of T1 subject characteristics. The Tromsø Study – Fit Futures

	All (*N* = 676)
Sex	
Boys	306 (45.3%)
Chronic disease T1	
No	474 (70.1%)
Yes, one or more	202 (29.9%)
Chronic pain T1	
No	512 (75.7%)
Yes	164 (24.3%)
SES mother T1	
Low	391.1 (57.8%)
High	284.9 (42.2%)
SES father T1	
Low	433.7 (64.2%)
High	242.3 (35.8%)
Feeling of enough sleep T1	
No	389 (57.5%)
Yes	287 (42.5%)
Sleep onset latency (30 min) T1	
No	429 (63.4%)
Yes	247 (36.6%)
Using the ActiGraph in the winter	
T1	552 (81.6%)
T2	555 (82.1%)
Considering dropping out of school T1	
No	575 (85%)
Yes	101 (15%)
Smoking T1	
No	545 (80.6%)
Yes	131 (19.4%)

Table 2 Descriptive characteristics of the participants. The Tromsø Study – Fit Futures

	All (*N* = 676)		Difference scores T2-T1 *Mean (SD)*
	T1 *Mean (SD)*	T2 *Mean (SD)*	
Age (years)	16.23 (0.91)	18.33 (0.91)	
HSCL-10	1.51 (0.53)	1.57 (0.60)	0.06 (0.52)
Steps per day / 1000	8.01 (3.61)	7.30 (2.98)	−0.712 (4.33)
MVPA (minutes per day)	44.66 (17.97)	36.46 (20.34)	−8.19 (25.33)
BMI (kg/m^2)	22.27 (3.95)	23.19 (4.30)	
Hours of sleep	6.92 (2.26)	6.64 (2.41)	
Self-reported health (1–5)	3.92 (0.83)	3.89 (0.82)	
Unhealthy diet (times in a week)	2.51 (0.58)	2.36 (0.59)	
Healthy diet (times in a week)	2.62 (0.62)	2.66 (0.62)	
Social network (1–4)	3.30 (0.48)	3.23 (0.52)	

Change in minutes in MVPA per valid day did not show any statistically significant association with change in mental distress (Table 4).

The interaction effects between change in steps per valid day or minutes in MVPA per valid day and sex were not statistically significant, nor were the interaction effects between change in steps per valid day or minutes in MVPA per valid day and baseline levels of mental distress (low, moderate and high baseline mental distress). Finally, the analysis of covariance of high negative to high positive change in steps per day on change in mental distress was not significant either.

Discussion

When controlling for relevant covariates, the present study shows that change in steps per valid day and minutes in MVPA were unrelated to change in mental distress from the first to the third level of upper secondary school. This suggests that a change in physical activity is not related to change in mental distress among adolescents, regardless of the baseline levels of mental distress and levels of change in physical activity between baseline and follow-up.

The non-significant relationship between physical activity and mental distress contradicts several longitudinal studies based on self-reported physical activity [4, 21–24],

Table 3 The predictive effect of change in steps per valid day on change in mental distress from the Tromsø Study – Fit Futures 1 and 2

	B	95% CI	*p*
Crude model			
Change in steps per day/1000	−.005	−.021/.011	.538
Adjusted model Block 2[a]			
Change in steps per day/1000	−.005	−.021/.011	.571
Adjusted model Block 3[b]			
Change in steps per day/1000	−.004	−.019/.012	.640
Adjusted model Block 4[c]			
Change in steps per day/1000	−.003	−.018/.013	.751

[a] Block 1: Model adjusted by demography: sex, age, socioeconomic status mother and father (T1), season of actigraphy measurement (T1 and T2)
[b] Block 2: Model adjusted by variables in block 1 and social level variables: considering dropping out of school (T1), social network (T1) and change in social network (T2 –T1)
[c] Block 3: Model adjusted by variables in block 1, block 2 and health and lifestyle related variables: chronic disease (T1), BMI (T1), sufficient sleep (T1), delayed sleep onset latency (T1), mean hours of sleep per night (T1), self-reported health (T1), change in self-reported health (T2-T1), junk food diet (T1), change in junk food diet (T2-T1), healthy diet (T1), change in healthy diet (T2-T1), chronic pain (T1) and smoking (T1)

Table 4 The predictive effect of change in minutes in MVPA per valid day on change in mental distress from the Tromsø Study – Fit Futures 1 and 2

	B	95% CI	*P*
Crude model			
Change in minutes in MVPA per day	−.001	−.003/.001	.543
Adjusted model Block 2[a]			
Change in minutes in MVPA per day	−.001	−.003/.002	.577
Adjusted model Block 3[b]			
Change in minutes in MVPA per day	−.001	−.003/.002	.616
Adjusted model Block 4[c]			
Change in minutes in MVPA per day	.000	−.002/.002	.656

[a] Block 1: Model adjusted by demography: sex, age, socioeconomic status mother and father (T1), season of actigraphy measurement (T1 and T2)
[b] Block 2: Model adjusted by variables in block 1 and social level variables: considering dropping out of school (T1), social network (T1) and change in social network (T2 –T1)
[c] Block 3: Model adjusted by variables in block 1, block 2 and health and lifestyle related variables: chronic disease (T1), BMI (T1), sufficient sleep (T1), delayed sleep onset latency (T1), mean hours of sleep per night (T1), self-reported health (T1), change in self-reported health (T2-T1), junk food diet (T1), change in junk food diet (T2-T1), healthy diet (T1), change in healthy diet (T2-T1), chronic pain (T1) and smoking (T1)

but is in agreement with results from longitudinal studies based on objective measurements of physical activity [27, 28]. This discrepancy in results based on methodology may be crucial. In a study by Slootmaker et al. [51], adolescents on average reported having spent over 9 h more in moderate physical activity per week and almost 3 h more in vigorous activity per week than was assessed by accelerometer. Thus, the validity of self-reported physical activity among adolescents is questionable, and inferences made by analyzing data based on self-report may also be invalid. One can also suspect that depressed individuals tend to underreport positive behaviors, like physical activity, compared to more optimistic individuals, and in this way construct a negative, spurious relationship between mental health and physical activity. This is a weakness of self-report data that does not occur in accelerometer measurements. However, accelerometer measurements also have some limitations, and these are discussed in the section of methodological considerations below.

Compared to the present study, the follow-up period was shorter (1 year) in the longitudinal study of Van Dijk et al. [28] and longer (3 years) in the longitudinal study by Toseeb et al. [27]. Van Dijk and colleagues argued that the short follow-up period might have affected the results, as effects of changes in physical activity on mental health may take some time. Body composition changes are not immediate, neither are mastery and skill acquisition of sports or other kinds of physical activities. In our study, the mean number of months between T1 and T2 was 24.34, but for some of the participants the follow-up period was considerably shorter. Thus, the time between T1 and T2 may not have been sufficient for positive effects of physical activity to have occurred, and consequently not have had an impact on mental distress. However, as similar results were found in the study by Toseeb [27], with a follow-up period of 3 years, it suggests that the lack of significant effects is not due to short follow-up time. A limitation of our study as well as the study by Van Dijk et al. [28] and Toseeb et al. [27] is that the relationship was investigated over two time points only. Future studies should explore the relationship over multiple time points, in order to get a better understanding of the covariance between physical activity and mental distress.

The change in mean levels of physical activity in our study between baseline and follow-up was very small, as was the change in mean levels of mental distress. Thus, the lack of a significant effect of change in physical activity on change in mental distress could have been explained by a lack of significant change in activity between baseline and follow-up. The same could be true for the results of the Van Dijk et al. [28] study, as they also observed only a small change in physical activity and depressive symptoms over time. In order to see if the low mean change in activity disguised an effect among the adolescents who in fact did experience significant change between baseline and follow-up (a change in +/− 3000 steps), an analysis of covariance was performed. The effects were not significant. There is also a possibility that change in physical activity is not linearly related to change in mental distress, although at this point this is only speculation. However, several studies have shown that adolescents who are highly involved in (competitive) strenuous physical activity are at increased risk to suffer from symptoms of burnout and depression [52, 53]. Some individuals with high positive change in physical activity levels may have higher scores on mental distress, thus, counterbalancing the possible preventive effect of physical activity on mental distress.

The relatively large standard deviations of the change in steps, minutes in MVPA and mental distress (as shown in Table 2), suggest that there is variability in change over the 2 years between data collection. However, as discussed above, we do not know the timing at which the change occurred, or the duration of the change in physical activity levels. Recent changes in activity may not have lasted long enough to have been able to bring about change in mental health related factors. This means that more recent change may have watered down the effects of more long-lasting change in physical activity on mental distress.

As the effect of physical activity on mental health seems to be present in adulthood, but not in adolescence, this could indicate that physical activity serves another function for adolescents than for adults. A large part of the physical activity of adolescents is accrued through organized sports participation [54], but the adolescent period is also the period where dropout from organized sports mainly occurs [55]. Naturally, during the period before an individual decides to quit organized sports, exercising and being physically active may have negative connotations for the individual. A decline in physical activity between T1 and T2 for these individuals may thus have had a positive effect on mental health, and in that way cancelled out the negative effect on mental distress of a decline in physical activity between T1 and T2 for other participants.

There is also a possibility that other factors may play a more significant role in the association with mental distress than physical activity. It has been suggested that hormones that emerge in this period are partially to blame for the increased risk of affective disorders [56], but other risk factors may also have played a part. One study found that adolescents who participated in organized sports, showed lower odds for depressive symptoms than participants who reported that they kept fit independently (swimming, cycling or running) [15]. The

current study fails to control for sport participation and physical activity performed in a social setting, and this is also true for other potentially influential factors, such as, self-esteem [57] and body image [58].

It is, however, necessary to point out that the majority of the previous studies on the relationship among adults have also been based on self-reporting as mentioned in the review by Mammen and Faulkner [59]. More research using objective measures of physical activity are needed both in adult and adolescent samples, in order to determine the degree to which physical activity may prevent the development of mental distress over time.

Some specific mental disorders often emerge in the adolescent years where physical activity is a key factor. Disordered eating or eating disorders, such as anorexia nervosa, are related to anxiety and depression [60] and typically develop in adolescence [61]. Disordered eating is common among adolescents (between 14 and 22% prevalence rates) [62], and one of the core features of disordered eating is excessive physical activity, in order to increase energy expenditure and lose weight. Exercise in young women with disordered eating has been found to be related to negative affect [63]. Disordered eating was not assessed in the present study, whereas the presence of any chronic disorders, such as eating disorders, were registered at T1, but not at T2. As we were unable to account for disordered eating and only to a small extent able to adjust for eating disorders, this may have affected our results. Future studies should include measures of disordered eating or motives for exercise in order to account for the variance explained by this factor.

It is also worth mentioning that intervention studies comparing the effects of physical activity interventions to control conditions have found physical activity to significantly reduce symptoms of depression among adolescents [64], which suggests that physical activity may be an effective component in treating existing depression. This may also suggest that the most mentally distressed individuals at T1 may profit more from a positive change in physical activity. However, the moderating effect of level of mental distress at T1 on the relationship between change in physical activity on change in mental distress was also non-significant. This means that change in physical activity was not related to change in mental distress even among the most highly distressed individuals at T1. Despite this result, we strongly recommend further explorations into how physical activity is related to change in mental distress among the individuals suffering from high levels of symptoms of anxiety and depression, as effectiveness and efficacy studies show that physical activity may benefit this group in terms of lower symptomatology [65].

Methodological considerations

The major strength of this study is that physical activity was measured objectively and longitudinally in a relatively large sample, and that we were able to adjust for several potential confounders. Nonetheless, the results should be interpreted in light of certain methodological limitations.

Although objectively measured physical activity via accelerometer is considered more accurate and unbiased than self-reported physical activity, there are also validity issues concerning these methods that may have affected the results. Accelerometers have a weakness in the ability to reliably register different types of activities, such as cycling and weight lifting, because of its static position on the hip. In addition, the algorithms used to assess the physical activity levels are not fully explained by the cooperation behind the devices, and thus, the resulting physical activity levels are difficult to validate. It is also possible that the short period of wear time (7 days) was not representative for the person's typical level of physical activity, as it may lead to over –or underestimation of the respondent's normal levels of physical activity. There may have been issues both causing the levels of activity to increase and decrease, relative to normal levels. MVPA regressed towards the mean as its levels had a sharper decline for active participants in T1, compared to inactive participants (results not shown), and this regression may partially be explained by over – or underestimation of activity at either time point. However, research done on blinded and non-blinded groups show that the awareness of wearing an accelerometer has no effect on pattern of physical activity in adolescents [66]. We used uniaxial accelerometer measurements, and triaxial measurements may provide higher PA values, although not necessarily more accurate [67].

A relatively large amount of the data was imputed, due to a high percentage of missing values. This could potentially have introduced bias in the estimates. For multiple imputations to produce unbiased estimates, missing data must be missing at random. As we do not know the reason for why data is missing, there is always a chance that data is not missing at random. However, the degree to which the participants with missing data differ from the participants with valid data may provide an indication regarding a pattern in the reason for missingness. In our case, the respondents with missing data did not differ from the respondents with valid data. Although this does not guarantee that data is missing at random, it suggests a higher probability of it. Provided that data is missing at random, multiple imputation provides unbiased estimates, even with high proportions of missing values [68].

In addition, the results cannot be generalized to the Norwegian population of adolescents as a whole as the participants were selected from only two municipalities. Mental health was measured by self-reporting symptoms

the last week prior to the study, and the period for the measurement may be too short to be able to measure the typical behavior. It is also possible that, in a sample where very few adolescents experience change in their mental health, it is difficult to find effects of change in activity levels. Finally, although the sample size is relatively large, the study may have benefitted from collecting data from an even larger sample. A larger sample could also have enabled the investigation of subgroups in which the relationship between physical activity and mental distress may differ.

Conclusions

This study of adolescents from the general population found no significant longitudinal relationship between change in physical activity and change in mental distress over the period of upper-secondary school. These findings are in agreement with the two existing studies based on the same, sound methodology.

We recommend that future studies in the field investigate the relationship using objective measurements over multiple time points, but also include measures of other factors, such as motives for physical activity, context of activity, self-esteem and levels of mental distress, that may be important for gaining a better understanding of the possible relationship between physical activity and mental distress among adolescents.

Abbreviations

BMI: Body Mass Index; HSCL-10: Hopkins Symptom Checklist – 10; MVPA: Moderate to vigorous physical activity

Acknowledgments

The authors are grateful to the study participants, the participating schools in Tromsø and Balsfjord, the staff at the Clinical Research Unit, University Hospital of North Norway, and the Fit Futures administration.

Authors' contributions

Study concept and design: IMO, KR, BM. Analyzing and interpreting of data: IMO, KR, BM. Drafting of the manuscript: IMO. Critical revision of the manuscript for important intellectual content: IMO, KR, BM, KL, HA, CSN, AH, SR, ASF. Study supervision: KR. All authors read and approved the final manuscript.

Funding

The Northern Norway Regional Health Authority (Norwegian: Helse Nord) funded the research when a layout of the project was approved by their committee December 2016. The Tromsø Study Fit Futures is a collaborative study between the University Hospital of North Norway, UiT The Arctic University of Norway, and the Norwegian Institute of Public Health. Actigraph instruments were funded by the Simon F Hartmann family fund.

Availability of data and materials

The dataset supporting the articles findings is available through application directed to the Tromsø Study by following the steps presented on their online page: https://en.uit.no/forskning/forskningsgrupper/sub?p_document_id=453582&sub_id=71247.

Ethics approval and consent to participate

Norwegian Data Inspectorate and the Regional Committee for Medical and Health Research Ethics for Northern-Norway (REK-Nord) have approved Fit Futures – part of The Tromsø Study. The Tromsø Study collected the written informed consent from participants/guardians.

The present project has received a specific approval from REK-Nord (Project number: 2016/987/REK nord).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Psychology, UiT The Arctic University of Norway, Tromsø, Norway. [2]School of Sports Sciences, UiT The Arctic University of Norway, Tromsø, Norway. [3]Regional Centre for Child and Youth Mental Health and Child Welfare, UiT The Arctic University of Norway, Tromsø, Norway. [4]Norwegian Institute of Public Health, Oslo, Norway. [5]Department of Computer Sciences, UiT The Arctic University of Norway, Tromsø, Norway. [6]Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Norway. [7]School of psychiatry, University of New South Wales, Sydney, Australia. [8]Black Dog Institute, Sydney, Australia.

Received: 25 March 2019 Accepted: 1 July 2019
Published online: 09 July 2019

References

1. Polanczyk Guilherme V, Salum Giovanni A, Sugaya Luisa S, Caye A, Rohde LA. Annual research review: a meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. J Child Psychol Psychiatry. 2015;56(3):345–65.
2. Kessler RC, Bromet EJ. The epidemiology of depression across cultures. Annu Rev Public Health. 2013;34:119–38.
3. Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, Silva ES, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. Am J Psychiatr. 2018;175(7):631–48.
4. Birkeland MS, Torsheim T, Wold B. A longitudinal study of the relationship between leisure-time physical activity and depressed mood among adolescents. Psychol Sport Exerc. 2009;10(1):25–34.
5. Oweis P, Spinks W. Biopsychological, affective and cognitive responses to acute physical activity. J Sports Med Phys Fitness. 2001;41(4):528–38.
6. Brand S, Gerber M, Beck J, Hatzinger M, Pühse U, Holsboer-Trachsler E. High exercise levels are related to favorable sleep patterns and psychological functioning in adolescents: a comparison of athletes and controls. 2010; 46(2):133–141.
7. Zimmer P, Stritt C, Bloch W, Schmidt F-P, Hübner ST, Binnebößel S, et al. The effects of different aerobic exercise intensities on serum serotonin concentrations and their association with Stroop task performance: a randomized controlled trial. Eur J Appl Physiol. 2016;116(10):2025–34.
8. Silverman MN, Deuster PA. Biological mechanisms underlying the role of physical fitness in health and resilience. Interface focus. 2014;4(5):20140040.
9. Brand S, Kalak N, Gerber M, Clough P, Lemola S, Sadeghi Bahmani D, et al. During early to mid adolescence, moderate to vigorous physical activity is associated with restoring sleep, psychological functioning, mental toughness and male gender. J Sports Sci. 2016;35:426–34.
10. Dhillon R, Hafiz S. Relationship of self esteem, personality and social support with psychological distress in adolescents. J Psychosoc Res. 2018;13(1):43.
11. Swami V, Weis L, Barron D, Furnham A. Positive body image is positively associated with hedonic (emotional) and eudaimonic (psychological and social) well-being in British adults. J Soc Psychol. 2018;158(5):541–52.
12. Haller SPW, Cohen Kadosh K, Scerif G, Lau JYF. Social anxiety disorder in adolescence: how developmental cognitive neuroscience findings may shape understanding and interventions for psychopathology. Dev Cogn Neurosci. 2015;13:11–20.
13. Zhao W, Young RE, Breslow L, Michel NM, Flett GL, Goldberg JO. Attachment style, relationship factors, and mental health stigma among adolescents. Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement. 2015;47(4):263–71.
14. Brand S, Colledge F, Ludyga S, Emmenegger R, Kalak N, Sadeghi Bahmani D, et al. Acute bouts of exercising improved mood, rumination and social interaction in inpatients with mental disorders. Front Psychol. 2018;9:249.
15. Kleppang AL, Hartz I, Thurston M, Hagquist C. The association between physical activity and symptoms of depression in different contexts – a

cross-sectional study of Norwegian adolescents. BMC Public Health. 2018;18(1):1368.
16. Rothon C, Edwards P, Bhui K, Viner RM, Taylor S, Stansfeld SA. Physical activity and depressive symptoms in adolescents: a prospective study. BMC Med. 2010;8(1):32.
17. Johnson KE, Taliaferro LA. Relationships between physical activity and depressive symptoms among middle and older adolescents: a review of the research literature. J Spec Pediatr Nurs. 2011;16(4):235–51.
18. Ruiz JR, Ortega FB, Martínez-Gómez D, Labayen I, Moreno LA, De Bourdeaudhuij I, et al. Objectively measured physical activity and sedentary time in European adolescents: the HELENA study. Am J Epidemiol. 2011; 174(2):173–84.
19. Merikangas KR, He JP, Burstein M, Swanson SA, Avenevoli S, Cui L, et al. Lifetime prevalence of mental disorders in U.S. adolescents: results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). J Am Acad Child Adolesc Psychiatry. 2010;49(10):980–9.
20. Bor W, Dean AJ, Najman J, Hayatbakhsh R. Are child and adolescent mental health problems increasing in the 21st century? A systematic review. Aust N Z J Psychiatry. 2014;48(7):606–16.
21. Stavrakakis N, Roest A, Verhulst F, Ormel J, De Jonge P, Oldehinkel A. Physical activity and onset of depression in adolescents: a prospective study in the general population cohort TRAILS. J Psychiatr Res. 2013; 47(10):1304–8.
22. Raudsepp L, Neissaar I. Brief report: relationships between physical activity and depressive symptoms in adolescent girls. J Adolesc. 2012; 35(5):1399–402.
23. Sabiston CM, O'Loughlin E, Brunet J, Chaiton M, Low NC, Barnett T, et al. Linking depression symptom trajectories in adolescence to physical activity and team sports participation in young adults. Prev Med. 2013;56(2):95–8.
24. Sund AM, Larsson B, Wichstrøm L. Role of physical and sedentary activities in the development of depressive symptoms in early adolescence. Soc Psychiatry Psychiatr Epidemiol. 2011;46(5):431–41.
25. Suetani S, Mamun A, Williams GM, Najman JM, McGrath JJ, Scott JG. The association between adolescent psychopathology and subsequent physical activity in young adulthood: a 21-year birth cohort study. Psychol Med. 2018;48(2):269–78.
26. Suetani S, Mamun A, Williams GM, Najman JM, McGrath JJ, Scott JG. Longitudinal association between physical activity engagement during adolescence and mental health outcomes in young adults: a 21-year birth cohort study. J Psychiatr Res. 2017;94:116–23.
27. Toseeb U, Brage S, Corder K, Dunn VJ, Jones PB, Owens M, et al. Exercise and depressive symptoms in adolescents: a longitudinal cohort study. JAMA Pediatr. 2014;168(12):1093–100.
28. Van Dijk ML, Savelberg HHCM, Verboon P, Kirschner PA, De Groot RHM. Decline in physical activity during adolescence is not associated with changes in mental health. BMC Public Health. 2016;16(1):300.
29. Troiano RP, McClain JJ, Brychta RJ, Chen KY. Evolution of accelerometer methods for physical activity research. Br J Sports Med. 2014;48(13):1019.
30. Santos-Lozano A, Santín-Medeiros F, Cardon G, Torres-Luque G, Bailón R, Bergmeir C, et al. Actigraph GT3X: validation and determination of physical activity intensity cut points. Int J Sports Med. 2013;34(11):975–82.
31. Wetten AA, Batterham M, Tan SY, Tapsell L. Relative validity of 3 accelerometer models for estimating energy expenditure during light activity. J Phys Act Health. 2014;11(3):638–47.
32. Korczak DJ, Madigan S, Colasanto MJP. Children's physical activity and depression: a meta-analysis. Pediatrics. 2017;139(4):e20162266.
33. Christoffersen T, Winther A, Nilsen OA, Ahmed LA, Furberg A-S, Grimnes G, et al. Does the frequency and intensity of physical activity in adolescence have an impact on bone? The Tromsø Study, Fit Futures. BMC Sports Sci Med Rehabil. 2015;7(1):26.
34. Emaus A, Degerstrøm J, Wilsgaard T, Hansen BH, Dieli-Conwright CM, Furberg A-S, et al. Does a variation in self-reported physical activity reflect variation in objectively measured physical activity, resting heart rate, and physical fitness? Results from the Tromsø study. Scand J Public Health. 2010;38(5):105–18.
35. Hecht A, Ma S, Porszasz J, Casaburi R. Methodology for Using Long-Term Accelerometry Monitoring to Describe Daily Activity Patterns in COPD. COPD: J Chron Obstruct Pulmon Dis. 2009;6(2):121–29.
36. Tudor-Locke C, Camhi SM, Troiano RP. A catalog of rules, variables, and definitions applied to accelerometer data in the National Health and Nutrition Examination Survey, 2003–2006. Prev Chronic Dis. 2012;9:E113–E.
37. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Med Sci Sports Exerc. 1998;30(5):777–81.
38. Strand BH, Dalgard OS, Tambs K, Rognerud M. Measuring the mental health status of the Norwegian population: a comparison of the instruments SCL-25, SCL-10, SCL-5 and MHI-5 (SF-36). Nord J Psychiatry. 2003;57(2):113–8.
39. Gispert R, Rajmil L, Schiaffino A, Herdman M. Sociodemographic and health-relatedcorrelates of psychiatric distress in a generalpopulation. Soc Psychiatry Psychiatr Epidemiol. 2003;38(12):677–83.
40. Caspersen CJ, Pereira MA, Curran KMJM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. Med Sci Sports Exerc. 2000;32(9):1601–9.
41. de Wit LM, Fokkema M, van Straten A, Lamers F, Cuijpers P, Penninx BWJH. Depressive and anxiety disorders and the association with obesity, physical, and social activities. Depress Anxiety. 2010;27(11):1057–65.
42. Strine TW, Okoro CA, Chapman DP, Balluz LS, Ford ES, Ajani UA, et al. Health-related quality of life and health risk behaviors among smokers. Am J Prev Med. 2005;28(2):182–7.
43. Wilson AC, Palermo TM. Physical activity and function in adolescents with chronic pain: a controlled study using actigraphy. J Pain. 2012;13(2):121–30.
44. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. J Adolesc Health. 2004;35(5):360–7.
45. Strine TW, Chapman DP. Associations of frequent sleep insufficiency with health-related quality of life and health behaviors. Sleep Med. 2005;6(1):23–7.
46. Baglioni C, Nanovska S, Regen W, Spiegelhalder K, Feige B, Nissen C, et al. Sleep and mental disorders: a meta-analysis of polysomnographic research. Psychol Bull. 2016;142(9):969–90.
47. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000; 320(7244):1240–3.
48. Lichstein K, Durrence H, Taylor D, Bush A, Riedel B. Quantitative criteria for insomnia. Behav Res Ther. 2003;41(4):427–45.
49. IBMCorp. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp; 2017.
50. Organization WH. Global recommendations on physical activity for health. 2010.
51. Slootmaker SM, Schuit AJ, Chinapaw MJ, Seidell JC, Van Mechelen W. Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. Int J Behav Nutr Phys Act. 2009;6(1):17.
52. Gerber M, Best S, Meerstetter F, Isoard-Gautheur S, Gustafsson H, Bianchi R, et al. Cross-sectional and longitudinal associations between athlete burnout, insomnia, and polysomnographic indices in Young elite athletes. J Sport Exerc Psychol. 2018;40(6):312–24.
53. Gerber M, Best S, Meerstetter F, Walter M, Ludyga S, Brand S, et al. Effects of stress and mental toughness on burnout and depressive symptoms: a prospective study with young elite athletes. J Sci Med Sport. 2018;21(12):1200–5.
54. Vilhjalmsson R, Kristjansdottir G. Gender differences in physical activity in older children and adolescents: the central role of organized sport. Soc Sci Med. 2003;56(2):363–74.
55. Sallis JF. Age-related decline in physical activity: a synthesis of human and animal studies. Med Sci Sports Exerc. 2000;32(9):1598–600.
56. Paus T, Keshavan M, Giedd JN. Why do many psychiatric disorders emerge during adolescence? Nat Rev Neurosci. 2008;9(12):947–57.
57. Dale LP, Vanderloo L, Moore S, Faulkner G. Physical activity and depression, anxiety, and self-esteem in children and youth: an umbrella systematic review. Ment Health and Phys Act. 2018;16:66–79.
58. Friedman KE, Reichmann SK, Costanzo PR, Musante GJ. Body image partially mediates the relationship between obesity and psychological distress. Obes Res. 2002;10(1):33–41.
59. Mammen G, Faulkner G. Physical activity and the prevention of depression: a systematic review of prospective studies. Am J Prev Med. 2013;45(5):649–57.
60. Bulik CM. Anxiety, depression and eating disorders. Eating disorders and obesity: A comprehensive handbook. 2002;2(1):193–198.
61. Hoek HW, van Hoeken D, Katzman MA. Epidemiology and cultural aspects of eating disorders. Eat Disord. 2003;6:75–138.
62. Jones JM, Bennett S, Olmsted MP, Lawson ML, Rodin G. Disordered eating attitudes and behaviours in teenaged girls: a school-based study. Can Med Assoc J. 2001;165(5):547–52.

63. Thome J, Espelage DL. Relations among exercise, coping, disordered eating, and psychological health among college students. Eat Behav. 2004;5(4):337–51.
64. Bailey A, Hetrick S, Rosenbaum S, Purcell R, Parker A. Treating depression with physical activity in adolescents and young adults: a systematic review and meta-analysis of randomised controlled trials. Psychol Med. 2018;48(7):1068–83.
65. Rosenbaum S, Tiedemann A, Ward PB. Meta-analysis physical activity interventions for people with mental illness: a systematic review and meta-analysis. J Clin Psychiatry. 2014;75(0):1–11.
66. Vanhelst J, Béghin L, Drumez E, Coopman S, Gottrand F. Awareness of wearing an accelerometer does not affect physical activity in youth. BMC Med Res Methodol. 2017;17:99.
67. Kelly LA, McMillan DGE, Anderson A, Fippinger M, Fillerup G, Rider J. Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. BMC Med Phys. 2013;13(1):5.
68. Lee JH, Huber Jr J, editors. Multiple imputation with large proportions of missing data: How much is too much? United Kingdom Stata Users' Group Meetings 2011; 2011: Stata Users Group.

Publisher's Note

PAPER 2

BMJ Open

Is change in mental distress among adolescents predicted by sedentary behaviour or screen time? Results from the longitudinal population study The Tromsø Study: Fit Futures

Ida Marie Opdal ,[1] Bente Morseth,[2] Bjørn-Helge Handegård,[3] Kjersti R Lillevoll,[1] Wendy Nilsen,[4] Christopher Nielsen,[5] Anne-Sofie Furberg,[6,7] Simon Rosenbaum,[8,9] Kamilla Rognmo[1]

To cite: Opdal IM, Morseth B, Handegård B-H, *et al*. Is change in mental distress among adolescents predicted by sedentary behaviour or screen time? Results from the longitudinal population study The Tromsø Study: Fit Futures. *BMJ Open* 2020;**10**:e035549. doi:10.1136/bmjopen-2019-035549

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-035549).

Received 05 November 2019
Revised 10 January 2020
Accepted 13 January 2020

For numbered affiliations see end of article.

Correspondence to
Ida Marie Opdal;
ida.m.opdal@uit.no

ABSTRACT

Objective There is growing interest in the relationship between sedentary behaviour and mental distress among adolescents, but the majority of studies to date have relied on self-reported measures with poor validity. Consequently, current knowledge may be affected by various biases. The aim of this study was to investigate the cross-sectional and longitudinal association between (1) objectively measured sedentary time and (2) self-reported screen time with mental distress among adolescents participating in The Tromsø Study: Fit Futures, in order to see if the association is dependent on mode of measurement of sedentary behaviour.

Design Prospective study.

Setting Sample drawn from upper secondary school students (mean age 16.3 years at baseline) from two municipalities in Northern Norway participating in The Tromsø Study: Fit Futures 1 and 2.

Participants 686 adolescents (54.5% female), with complete self-reported and accelerometer data after multiple imputation.

Primary outcome measures Mental distress assessed via the Hopkins Symptom Checklist-10 (HSCL-10).

Results Minutes in sedentary behaviour measured by accelerometer showed no significant relationship with mental distress in neither crude, partly adjusted nor multiple adjusted hierarchic linear regression analyses. Self-reported screen time was positively associated with mental distress in all analyses (multiple adjusted, B=0.038, p=0.008, 95% CI 0.010 to 0.066). However, the effect was small.

Conclusions Self-reported screen time was associated with slightly elevated mental distress 2 years later, whereas objectively measured minutes in sedentary behaviour was not, indicating a discrepancy in the results depending on measurement methods.

Strengths and limitations of this study

- Use of both objective measure of sedentary behaviour and self-reported screen time.
- A prospective study design across 2 years in middle and late adolescence.
- Analysis controlled for several relevant covariates, for example, socioeconomic status, social network and physical activity levels.
- No collected self-reported data on total volume and different types of sedentary behaviour other than screen time.
- Sample contains students from two municipalities in, restricting the generalisability of the study.

Mental disorders commonly arise during the teenage years,[1] signifying that adolescence may be a crucial period for preventing the development of mental health problems. The importance of prevention is increasingly emphasised as more than 1 in 10 children and adolescents suffer from a mental disorder.[2] Interestingly, the onset of symptoms of depression and anxiety during the adolescent period coincides with a decrease in physical activity that also occurs during this period.[3]

Physical activity is thought to play a significant role in protecting against poor mental health in adolescents,[4 5] but also in children,[6 7] adults[8] and the elderly.[9] The effect of physical activity is theoretically explained by positive physiological responses, such as higher levels of norepinephrine, endorphins and serotonin, and lower hormonal responses from stress,[10 11] but could also be explained by psychological responses, such as feelings of mastery and control, higher self-esteem, and distracting from stressors, negative thoughts and rumination.[10 12 13] However, a review done by Bailey *et al*[14] concluded that even though there are promising results indicating that physical activity may have a treatment effect

on mental distress, there are methodological weaknesses that obstruct a clear understanding of the association. In addition, other studies have not found an association between physical activity and mental health.[15–17]

If there are physiological and psychological benefits of physical activity, this could indicate that the opposite of engaging in physical activity—sedentary behaviours that involve sitting or resting—could potentially increase symptoms of mental distress. However, high levels of sedentary time do not necessarily correlate with low levels of physical activity, and as such, physical activity and sedentary behaviours are not necessarily mutually exclusive.[18] Because a person may be both physically active and sedentary over a period, adjusting for physical activity is essential when investigating the degree to which sedentary behaviour is an independent risk factor of mental health problems among adolescents.

Until recently, research on the association between sedentary behaviour and mental health has been restricted to using self-reported measurements of sedentary behaviour. The majority of the existing studies on the association between sedentary behaviour and mental health have operationalised the term *sedentary behaviour* as hours of self-reported screen time.[19] In general, previous studies based on self-report conclude that there is a moderate positive association between screen time and depressive symptoms.[19–24] A recent study investigating the effects of screen time on adolescent well-being (operationalised as high levels of well-being and low levels of mental health problems) found a significant negative association.[25] However, screen time only accounted for 0.4% of the variance in broadly defined well-being, suggesting that screen time is associated with reductions in well-being only to a very small extent. A recent Norwegian study from 2019 also reported that screen time is associated with slight increases in depression, behaviour problems and alcohol use among adolescents.[26]

Despite screen time being the most common measure of sedentary behaviour, the validity of the measure is questionable. Several studies have shown that screen time is a poor estimate of sedentary behaviour compared with objective measures.[27] This means that the evidence base regarding the relationship between sedentary behaviour and mental distress rests on an unreliable foundation. Hamer *et al*[28] investigated the association between objectively assessed and self-reported sedentary time with mental health in adults, and found that the highest tertile of objectively assessed sedentary behaviour was associated with adverse mental health, but that the context-specific sedentary time, TV viewing, was far less consistently associated. This may indicate that the statistical relationship between sedentary behaviour and mental health may depend on measurement issues, and having both objectively measured and self-report data on sedentary behaviours may provide important insight regarding the association.

The current study aimed to investigate the cross-sectional and longitudinal association between (1) objectively measured sedentary time and (2) self-reported screen time with mental distress among adolescents participating in The Tromsø Study: Fit Futures, in order to see if the association is dependent on mode of measurement of sedentary behaviour. Objectively measured minutes in moderate to vigorous physical activity (MVPA) will serve as a covariate in the analyses, alongside demographic, psychosocial and health-related covariates, to investigate to which the degree sedentary behaviour is an independent risk factor of mental distress among adolescents. In the longitudinal analyses, baseline levels of mental distress will be adjusted for, enabling the coefficients of the analyses to be interpreted as indicators of change in the outcome between baseline and 2 years later.

METHOD

Study design and sample

The present study is based on data from a longitudinal population-based general health study, The Tromsø Study: Fit Futures, conducted in two waves, 2 years apart. In the first wave (T1, baseline) in 2010–2011, all first-level upper secondary school students in two municipalities were invited to participate. In total, 1117 students were invited, and 1038 (92.9%) participated. The second wave (T2, follow-up) was conducted in 2012–2013, where all T1 attendees and all students at the third level of the same upper secondary schools as in T1 were invited to participate. In total, 1129 students were invited, out of which 870 (77%) participated. Of these, 694 (67%) students also participated at T1. The majority of the participating sample was 15–17 years old at T1 (middle adolescence) and 17–19 years old at T2 (late adolescence). The study is described in detail elsewhere.[29 30]

The Fit Futures study included a web-based questionnaire, clinical examinations and interviews performed by trained research nurses at the study site. All participants aged 16 or older provided informed consent, as stated in §17 in the Norwegian Health Research Act; for participants younger than age 16, consent was also given by a guardian.

Patient and public involvement

No patients involved.

Measurements

Sedentary time and physical activity

Percentage of sedentary behaviour per valid day and minutes in MVPA were measured using the ActiGraph GT3X accelerometer at T1. The participants were instructed to wear the ActiGraph on their dominant hip for 8 days, and to only take it off when sleeping, showering or swimming.

The ActiGraph measures acceleration in movement, referred to as 'counts'. The raw accelerometer files was reduced to 10 s epochs using the ActiLife software owned by the manufacturer,[31] the 10 s epochs was further summed to 1 min. Due to the possible variation in physical

activity during the period of measurement, participants with at least 10-hour wear time for at least 4 out of 7 days were considered to have valid data. The activity variables, minutes in sedentary behaviour per valid day and minutes in MVPA per valid day for each participant, were based on the cut-points by Freedson *et al*,[32] sedentary behavior <100 counts per minute and MVPA >1952 counts per minute. The percentage of the day spent in sedentary behaviour was used as the predictor variable, and minutes in MVPA per valid day contributed as a covariate.

Estimated hours spent per day watching a screen (PC, TV and DVD) outside of school time for weekdays and weekends was reported in the general questionnaire ("How many hours per day do you spend by the PC, watching TV, DVD etc outside school during weekdays/weekends?"). The response categories ranged from 'none' to 'about 10 hours or more'. These ordinal variables were recoded in order to approximate a continuous variable and thus facilitate a more appropriate interpretation in the regression analyses ('none' was changed into 0, 'about 0.5 hours' into 0.5, 'about 1 to 1.5 hours' into 1.25, 'about 2 to 3 hours' into 2.5, 'about 4 to 6 hours' into 5, 'about 7 to 9 hours' into 8, and 'about 10 or more hours' into 10).

Mental distress

The Hopkins Symptom Checklist-10 (HSCL-10) was included in the general questionnaire at T1 and T2, and measures symptoms of anxiety (four items) and depression (six items) during the previous 7 days. The internal and external validity and reliability of the HSCL-10 has been found acceptable in a number of studies (eg, previous works[33 34]), and correlates well with depression diagnosed using diagnostic interview.[35] Response categories were 'none' (1), 'slightly' (2), 'much' (3) and 'very much' (4). The average for the scale was then calculated and further standardised, and the standardised score at T2 served as the outcome variable in the analyses. The analysis controlled for the average score at T1.

Covariates

Several variables may have an impact on sedentary behaviour and mental distress, and thus, we have included demographic variables (eg, socioeconomic status,[36] sex and age[37]), health variables (eg, smoking,[38] chronic pain,[39] body mass index (BMI)[40] and sleep[41]) and social variables (eg, social network[42]) as covariates in the analyses.

Demography at T1

Sex was included in the analyses as a possible confounder. Further, the respondents were asked to indicate the highest level of completed education of their mother and father, which served as a proxy for socioeconomic status (high/low, with high education meaning higher than secondary vocational education) in the analyses. As the season of the year might significantly affect the level of physical activity, a seasonal variable indicating the time of ActiGraph measurement at T1 and T2 (summer: May to June and September to October, or winter: November to April) was included in the analyses as a covariate.

Health and psychosocial variables at T1

The respondents reported if they had persistent pain that had lasted 3 months or longer (yes/no), and rated their overall perception of their own health, measured by a five-point Likert type scale. A variable on social network was made by a mean score of five items asking about the degree to which the respondents find it hard to make friends, have many friends, feel accepted among his/her peers, feel liked among peers, and feel popular among peers. Sleep delay was measured by asking the respondents to indicate how long they normally lie awake before falling asleep (sleep onset latency) on weekdays and weekends. Response categories ranged from '30 min or less' to '3 hours or more'. A sleep onset latency over 30 min on more than 3 days per week is considered a clinical marker for insomnia.[43] A dichotomous variable was created, with a cut-off at spending more than 30 min falling asleep (0=sleep onset latency 30 min or less, 1=sleep onset latency over 30 min). Weight and height were measured at the examination site and BMI was calculated by dividing the participants weight in kg by their height in metres squared.

Treatment of missing data

Multiple imputation (IBM SPSS V.25 for windows) was used to impute T1 ActiGraph data and socioeconomic status of participants who had questionnaire data from both T1 and 2 years later at T2. These variables represented a high proportion of the missing data and was imputed in order to maintain power and reduce possible bias due to missing values. Of the participants who had data on both T1 and T2, 464 (67%) had valid ActiGraph data at T1, 505 (71%) had valid data on socioeconomic status based on fathers' education and 529 (74%) had valid data on socioeconomic status based on mothers' education. A predictive model consisting of all variables included in the analyses was used to create 50 imputed datasets that subsequently were pooled and analysed. After imputations, 35% of the data on percentage of sedentary behaviour per valid day, 35% of MVPA, 26% of socioeconomic status of mother and 29% of socioeconomic status of father were imputed. After imputation, 686 participants had complete data on all the variables used in the analyses.

Data analysis

Descriptive statistics and Pearson product-moment correlation analysis between percentage of sedentary behaviour per valid day measured by accelerometer and self-reported screen time, in addition to the hierarchical linear regression analysis, were conducted using the statistical software IBM SPSS V.25.[44] In order to investigate the research questions of interest, two sets of hierarchical linear regression analyses were conducted, analysing the

degree to which percentage of sedentary behaviour (T1) and self-reported screen time (T1) are cross-sectionally (at T1/baseline) or longitudinally (change between T1 and T2) associated with mental distress. In the cross-sectional analyses, percentage of sedentary behaviour or self-reported screen time was entered alone in the first model. In model 2, the demographic variables (sex, age, socioeconomic status and season) were entered, whereas health and psychosocial variables (BMI, sleep onset latency, self-reported health, social network, chronic pain and either percentage of sedentary behaviour or screen time (depending on which serves as the predictor variable in the analysis in question)) were entered as covariates in model 3. The same procedure was followed for the longitudinal analyses; however, in model 1, T1 symptoms of anxiety and depression were included in order to investigate residualised change in mental distress in relation to T1 percentage of sedentary behaviour and screen time. Interaction effects between percentage of sedentary behaviour and self-reported screen time were investigated in the multiple adjusted models to see if the relationship between percentage of sedentary behaviour and mental distress was dependent on levels of screen time, and vice versa, under the assumption that sedentary behaviour and screen time relate to different constructs. Interaction effects between sedentary behaviour/screen time and sex, mental health at T1, MVPA, social network and BMI was also investigated. In addition, the analyses were also conducted on complete cases only.

RESULTS

Descriptive statistics

Descriptive statistics are shown in table 1. 86.6% of the participants at T1 engaged in less MVPA than the recommended 60 min per day.[45] On average, the adolescents reported 4 hours of screen time per day and were sedentary for more than 9 hours per day. Almost 80% of the accelerometer measurements occurred during wintertime. 20.1% of the participants at T1 had a HSCL-10 score over the cut-off of 1.85, identified as a threshold for indicating the presence of an internalising mental disorder among adolescents.[34] At T2, 26.7% had a score over the cut-off. Finally, a majority of the participants reported that their mother and father had a low level of education (see table 1).

The correlation between percentage of sedentary behaviour per valid day measured by accelerometer and self-reported screen time was 0.20, p=0.000.

Cross-sectional analysis

The results of the cross-sectional analyses showed no significant association between objectively measured percentage of sedentary time and mental distress at baseline (table 2). There was a significant relationship between self-reported screen time and mental distress at baseline in the crude, partially and fully adjusted model. Objectively measured percentage of time spent in sedentary behaviour was not significantly related to mental distress at baseline.

Table 1 Frequencies and percentages of T1 subject characteristics

	All (n=686)
Sex	
Boys	312 (45.5%)
Chronic pain T1≥3 months	
Yes	165 (24.1%)
SES mother T1	
High≥Higher education	286 (41.7%)
SES father T1	
High≥Higher education	242 (35.3%)
Sleep onset latency (>30 min) T1	
Yes	249 (36.3%)
Using the ActiGraph in the winter	
T1	546 (79.6%)
HSCL-10 T1	
Over cut-off	138 (20.1%)
HSCL-10 T2	
Over cut-off	183 (26.7%)
MVPA (min/day)	
Under 60 min	594 (86.6%)
Age (years)	16.25 (0.94)
Self-reported mean screen time per day*	4.00 (2.30)
Objectively measured sedentary time per day*	9.58 (2.25)
MVPA (minutes per day)	44.66 (18.06)
BMI (kg/m^2)	22.27 (3.95)
Self-reported health (scale of 1–5)	3.94 (0.83)
Social network (scale of 1–4)	3.30 (0.48)

Time reported in hours per day.
BMI, body mass index; HSCL, Hopkins symptoms checklist; MVPA, Moderate to vigorous physical activity; SES, socioeconomic status; T1, baseline.

The longitudinal relationship between percentage of sedentary behaviour and change in mental distress

Objectively assessed percentage of time in sedentary behaviour at baseline showed no significant relationship with change in mental distress between baseline and follow-up in neither crude, partly adjusted nor multiple adjusted analyses (table 3). Of the covariates, sex, mental distress at baseline, minutes in MVPA, sleep onset latency, chronic pain and screen time were significant predictors of mental distress at T2.

Self-reported screen time at baseline was significantly associated with increased mental distress after 2 years (table 4). Of the covariates, sex, mental distress at baseline, minutes in MVPA, sleep onset latency and chronic pain were significant predictors of mental distress at follow-up.

Table 2 The cross-sectional association between baseline percentage of sedentary behaviour measured by accelerometer/self-reported screen time and standardised HSCL-10 score at T1 investigated by multiple hierarchic linear regression

	Objectively measured percentage of sedentary behaviour*				Self-reported screen time†			
		95% CI				95% CI		
	B	Lower	Upper	P value	B	Lower	Upper	P value
Adjusted model Block 1								
Predictor variable	0.013	−0.001	0.027	0.068	0.052	0.020	0.085	0.002
Adjusted model Block 2								
Predictor variable	0.014	−3.521E-5	0.027	0.051	0.078	0.046	0.110	0.000
Sex	−0.506	−0.654	−0.358	0.000	−0.578	−0.727	−0.429	0.000
Age	0.080	0.004	0.156	0.040	0.081	0.006	0.156	0.034
SES father	0.011	−0.166	0.188	0.902	0.028	−0.145	0.202	0.748
SES mother	−0.008	−0.180	0.163	0.923	0.014	−0.156	0.183	0.872
Season	−0.053	−0.284	0.177	0.648	−0.070	−0.299	0.158	0.546
Adjusted model Block 3								
Predictor variable	0.011	−0.004	0.026	0.143	0.048	0.017	0.079	0.002
Sex	−0.472	−0.612	−0.332	0.000	−0.472	−0.612	−0.332	0.000
Age	0.023	−0.048	0.093	0.526	0.023	−0.048	0.093	0.526
SES father	0.016	−0.146	0.179	0.842	0.016	−0.146	0.179	0.842
SES mother	0.027	−0.130	0.183	0.739	0.027	−0.130	0.183	0.739
Season	−0.047	−0.258	0.164	0.664	−0.047	−0.258	0.164	0.664
MVPA	0.005	0.000	0.009	0.043	0.005	0.000	0.009	0.043
BMI	−0.009	−0.027	0.008	0.294	−0.009	−0.027	0.008	0.294
Sleep onset latency	0.427	0.284	0.571	0.000	0.427	0.284	0.571	0.000
Social network	−0.358	−0.503	−0.212	0.000	−0.358	−0.503	−0.212	0.000
Self-reported health	−0.122	−0.211	−0.034	0.007	−0.122	−0.211	−0.034	0.007
Chronic pain	0.423	0.264	0.583	0.000	0.423	0.264	0.583	0.000
Control variable‡	0.048	0.017	0.079	0.002	0.011	−0.004	0.026	0.143

T1 (baseline) variables: age, SES mother/father (socioeconomic status≥higher education), season (winter), sleep onset latency >30 min, social network, self-reported health, chronic pain>3 months.
*Predictor variable, percentage of day spent in sedentary behavior per valid day.
†Predictor variable, screen time—time reported in hours per day.
‡Screen time for when sedentary time is predictor, and sedentary time when screen time is predictor.
BMI, body mass index; HSCL, Hopkins Symptoms Checklist; MVPA, moderate to vigorous physical activity.

Interaction effects between percentage of sedentary time and self-reported screen time were investigated in the multiple adjusted model in separate analyses, but there were no significant effects. This was also true for the interaction effects independently between percentage of sedentary time/self-reported screen time and sex, mental health at baseline, MVPA, social network and BMI. Additional analyses investigating weekday and weekend screen time as separate predictors of mental distress showed the same result as mean weekday, and consequently, the results are not shown.

Sensitivity analysis on original data

Participants dropping out between T1 and T2 did not differ in terms of percentage of sedentary time, screen time, MVPA or symptoms of anxiety or depression. The results from the analyses on cases with complete data on the variables in question showed no significant association between percentage of sedentary time and change in mental distress, see table 5. No significant association was also found between screen time and change in mental distress. The regression coefficients for percentage of sedentary behaviour per valid day were slightly lower, whereas the coefficients for screen time were slightly higher in Block 2 and 3 in the analyses of the non-imputed data, compared with the imputed data shown in tables 3 and 4.

DISCUSSION

Screen time at baseline (in middle adolescence) was a significant predictor of increasing mental distress from middle to late adolescence, after adjusting for mental distress at baseline, whereas the association between objectively measured percentage of sedentary time at

Table 3 The association between baseline percentage of sedentary time per valid day measured by accelerometer and standardised HSCL-10 score between baseline and T2, controlling for HSCL-10 at baseline, assessed by hierarchic linearly regression

		95% CI				
	B	Lower	Upper	P value	R^2	R change
Adjusted model Block 1					0.341	0.341
Sedentary time*	0.004	−0.007	0.016	0.460		
HSCL-10 T1	1.096	0.980	1.211	0.000		
Adjusted model Block 2					0.354	0.014
Sedentary time*	0.005	−0.007	0.016	0.399		
HSCL-10 T1	1.047	0.927	1.167	0.000		
Sex	−0.233	−0.360	−0.106	0.000		
Age	−0.006	−0.071	0.058	0.848		
SES father	−0.016	−0.163	0.132	0.835		
SES mother	0.044	−0.098	0.187	0.541		
Season	−0.009	−0.198	0.180	0.925		
Adjusted model Block 3					0.388	0.034
Sedentary time*	0.009	−0.004	0.023	0.189		
HSCL-10 T1	0.870	0.732	1.008	0.000		
Sex	−0.289	−0.419	−0.160	0.000		
Age	−0.009	−0.073	0.055	0.779		
SES father	−0.024	−0.170	0.122	0.747		
SES mother	0.046	−0.095	0.186	0.524		
Season	−0.017	−0.206	0.171	0.856		
MVPA	0.005	0.000	0.009	0.032		
BMI	−0.005	−0.021	0.011	0.537		
Sleep onset latency	0.246	0.114	0.379	0.000		
Social network	−0.121	−0.257	0.016	0.084		
Self-reported health	−0.010	−0.092	0.071	0.807		
Chronic pain	0.198	0.050	0.347	0.009		
Screen time	0.038	0.010	0.066	0.008		

T1 (baseline) variables: age, SES mother/father (socioeconomic status≥higher education), season (winter), sleep onset latency>30 min, social network, self-reported health, chronic pain>3 months.
*Percentage of day spent in sedentary behaviour per valid day.
BMI, body mass index; HSCL, Hopkins Symptoms Checklist; MVPA, moderate to vigorous physical activity.

baseline and change in mental distress between middle to late adolescence was not significant. Similar associations were found in the cross-sectional analyses on baseline data, in which a significant relationship was found only between self-reported screen time and mental distress. This indicates that measurement methods may be of importance in the statistical relationship between sedentary behaviour and mental health, and that self-reported screen time may not be a fitting proxy for sedentary behaviour. Researchers should therefore thoroughly assess the validity and reliability of the chosen method of measurement in relation to the concept they wish to investigate.

The discrepancy in the results necessitates a discussion regarding the use of self-reported screen time measurements versus accelerometer measurements of sedentary behaviour. The mean levels of screen time per day (4 hours) and sedentary time (9 hours) reported in the present study reveal a large difference, which nonetheless comply with mean levels shown in previous studies.[46 47] Additionally, less than 15% of the adolescents were sufficiently active, 60 min of MVPA or more,[48] a finding that is also in compliance with results of previous studies.[49 50] Self-reported measurements are prone to report bias, and adolescents have been found to over-report time spent in MVPA[51] as well as to under-report minutes in sedentary behaviour[52] compared with objective measurements. One study found that self-reported screen time correctly measured sedentary time in boys,[53] whereas other studies conclude that self-reported screen time shows poor accuracy compared with objectively measured data.[27] This current study may contribute to the evidence that

Table 4 The association between self-reported screen time at baseline and standardised HSCL-10 score between baseline and follow-up, assessed by hierarchic linearly regression

		95% CI				
	B	Lower	Upper	P value	R^2	R change
Adjusted model Block 1					0.344	0.344
Screen time*	0.027	0.001	0.054	0.045		
HSCL-10 T1	1.088	0.973	1.203	0.000		
Adjusted model Block 2					0.362	0.018
Screen time*	0.042	0.014	0.069	0.003		
HSCL-10 T1	1.024	0.903	1.144	0.000		
Sex	−0.278	−0.408	−0.148	0.000		
Age	−0.003	−0.067	0.061	0.918		
SES father	−0.008	−0.154	0.137	0.911		
SES mother	0.056	−0.086	0.198	0.438		
Season	−0.018	−0.206	0.170	0.852		
Adjusted model Block 3					0.388	0.026
Screen time*	0.038	0.010	0.066	0.008		
HSCL-10 T1	0.870	0.732	1.008	0.000		
Sex	−0.289	−0.419	−0.160	0.000		
Age	−0.009	−0.073	0.055	0.779		
SES father	−0.024	−0.170	0.122	0.747		
SES mother	0.046	−0.095	0.186	0.524		
Season	−0.017	−0.206	0.171	0.856		
MVPA	0.005	0.000	0.009	0.032		
BMI	−0.005	−0.021	0.011	0.537		
Sleep onset latency	0.246	0.114	0.379	0.000		
Social network	−0.121	−0.257	0.016	0.084		
Self-reported health	−0.010	−0.092	0.071	0.807		
Chronic pain	0.198	0.050	0.347	0.009		
Sedentary time	0.009	−0.004	0.023	0.189		

T1 (baseline) variables: age, SES mother/father (socioeconomic status≥higher education), season (winter), sleep onset latency>30 min, social network, self-reported health, chronic pain>3 months, sedentary time—percentage of sedentary behaviour per valid day.
*Time reported in hours per day.
BMI, body mass index; HSCL, Hopkins Symptoms Checklist; MVPA, moderate to vigorous physical activity.

self-reported screen time is not a fitting proxy to sedentary time and that different types of measurements may give different results. This may have implications for further research on sedentary behaviour as researchers should thoroughly assess what type of measurement is suited to measure the behaviour. In addition, clinicians may consider the complexity of the self-reported estimation of sedentary behaviours, such as screen time, as it may be influenced by a number of psychological factors that may include depressive symptoms.

In general, studies of the association between sedentary behaviour and mental distress in adolescents have mainly used self-report measurements for sedentary behaviour, and the results from these studies commonly show sedentary behaviour to predict higher levels of mental distress.[6 19 54–56] A review found only evidence for a significant association between self-reported sedentary time and depression among adolescents, while anxiety and overall psychological distress was considered inconclusive.[5] However, it is important to point out that the effect between screen time and mental health is generally small.[5 25 57 58] This is true also for the present study as supplementary analysis showed that screen time at baseline only accounts for 1.4% of the variance in mental distress 2 years later, before adjustment of possible confounders. Orben and Przybylski[25] have argued that the observed effect of screen time on well-being among adolescents is too small to justify any policy changes.

Our study is one of few who have examined the association between objectively measured sedentary behaviour and mental distress. Likewise, few studies of self-reported or objectively measured physical activity have applied longitudinal designs. The results of the few existing longitudinal studies tend to vary—although most have reported

Table 5 The association between baseline sedentary time measured by accelerometer/self-reported screen time and change in mean score HSCL-10 between T1 and T2—complete cases, assessed by hierarchic linearly regression

	Percentage of sedentary behaviour*			Screen time†		
	B	95% CI	P value	B	95% CI	P value
Adjusted model Block 1‡						
Predictor variable	0.005	−0.009/0.019	0.464	0.020	−0.019/0.060	0.310
Adjusted model Block 2§						
Predictor variable	0.005	−0.008/0.019	0.438	0.027	−0.013/0.067	0.188
Adjusted model Block 3¶						
Predictor variable	0.012	−0.005/0.029	0.151	0.029	−0.013/0.070	0.173

*Percentage of day spent in sedentary behaviour.
†Time reported in hours per day.
‡Block 1: model adjusted by HSCL-10 (T1).
§Block 2: model adjusted by variables in Block 1; demography-related variables: sex, age, socioeconomic status father (>higher education T1), socioeconomic status mother (>higher educationT1), season (Winter T1), MVPA (T1), BMI (T1), sleep onset latency (>30 min T1), social network (T1) and screen time when sedentary time was predictor or sedentary time when screen time was predictor (T1).
¶Block 3: model adjusted by variables in Block 1, Block 2 and health-related variables: self-reported health (T1) and chronic pain (T1).
BMI, body mass index; HSCL, Hopkins Symptoms Checklist; MVPA, moderate to vigorous physical activity; T1, baseline.

a significant, but small effect of self-reported sedentary behaviour (eg, see previous works[22 57 59]). Hamer *et al*[28] compared the association between objectively assessed and self-reported sedentary behaviour with mental distress in adults in a cross-sectional study, and found that sedentary behaviour, independent of assessment method, was associated with adverse mental health. In contrast, a study by Hume *et al*[17] investigating the association between sedentary behaviour as measured by accelerometer, self-reported time spent watching TV and depressive symptoms in adolescent boys and girls found no significant association between sedentary behaviour or time spent watching TV and depressive symptoms in neither a cross-sectional nor a longitudinal design. However, girls who were depressed at baseline spent significantly more time watching TV at follow-up. As studies on adults[28 60] show a relationship between objectively measured sedentary behaviour and mental distress, as opposed to the current study and the study by Hume *et al*,[17] it is reasonable to question whether sedentary behaviour may have different psychological impact on adults and adolescents. A study by Zahl *et al*[7] found that objectively measured sedentary time among Norwegian children was not associated with depression 2 years later, further pointing to the potential age-dependent effect of sedentary behaviour on mental distress.

It is possible that the association between sedentary behaviour and mental distress is more complex than what our study was able to investigate. We lack information regarding the context in which the adolescent is sedentary, for instance, if he/she is alone or with friends, playing online games with other players and so on. This social component of sedentary behaviour may impact the relationship with mental distress. Mentally active sedentary behaviour, such as office work or knitting/sewing, shows a potential positive effect on mental well-being in adults compared with passive sedentary behaviour.[61] Hallgren *et al*[62] found a 5% decreased risk of major depressive disorder if 30 min of passive sedentary behaviour was replaced with equal amounts of mentally active sedentary behaviour. Future studies should aim to identify how specific modes of sedentary behaviour, such as time spent with friends, school classes or screen time, relates to mental distress. Studies that provide knowledge on adolescents' sedentary behaviour patterns and possible effect modifiers such as self-esteem and well-being are also required to fully understand the association between sedentary behaviour and mental distress.

Methodological considerations

The results are based on data from a relatively large sample with repeated measurements, making it possible to investigate the association between sedentary behaviour and mental distress over time. A major strength is that the study contains information on sedentary behaviour both from accelerometer data and from self-reported screen time. This enabled investigation of the effect of measurement method on the relationship to mental distress, as well as the validity of screen time as a proxy measure of sedentary behaviour. In addition, the study included adjustment for several potential confounders.

Despite these strengths, the results should be interpreted in light of certain methodological limitations. Even though objective measurements of physical activity and sedentary behaviour is considered more accurate and unbiased than self-report, there are still some validity issues that may have had an impact on the results. One issue is that accelerometers lack the ability to reliably register different types of activities such as rowing and cycling because of its static position on the hip. In addition, hip worn accelerometers have difficulty differentiating between postures, such as standing, sitting or

lying down.[63] In the current study, the inclinometer was not included because of the validity issues, but including posture in the analyses may have had a slight impact on the results, although it is unlikely to be a great source of bias. Reliably differentiating between sedentary time and non-wear time may also be challenging, and potentially lead to underestimation of sedentary time measured by accelerometer.[64] Additionally, the study used data collected over a short period of wear time (7 days), and it is possible that these data are not representative of the participants' typical level of physical activity. Yet, research conducted on blinded and non-blinded participants show that the awareness of wearing an accelerometer has no effect on the pattern of physical activity in youth.[65] Physical activity levels may vary by season, but almost all participants were measured during winter. Preliminary analyses also showed that there was no significant difference in levels of MVPA or sedentary behaviour for participants measured in winter or summer (results not shown). Another limitation of the study is that data on screen time and mental distress were collected through self-report. Self-reported data may be subject to response bias, in that behaviour or characteristics valued as positive may be over-reported, and negative characteristics under-reported. Furthermore, a relatively large amount of data was imputed, due to the high percentage of missing values. To prevent biassed estimations in multiple imputations, missing data must be missing at random. There is always a chance that the missing variables are not missing at random, as we do not know the reason for why the data are missing. However, the degree to which the participants with missing values differ from the participants with valid data may give us an indication for 'the missing pattern'. In the current study, the two groups of participants did not differ significantly from each other, and the results of the hierarchical regression analyses on the sample with complete data were in essence similar to the analyses of the imputed sample. This suggests a higher probability for missing at random and provides confidence that the imputation provided unbiased estimates, even with higher proportions of missing data.[66] The single-item chronic pain assessment in this study was rather high, at 24.1%. Nevertheless, similar results have been shown in other studies.[67 68] The social network variable is not from a validated test battery, and as such, the validity of the measure is uncertain. This needs to be taken into account when interpreting the results. In addition, there may be other potential confounders that the study fail to control for, such as, the difference between passive and mentally active objectively measured sedentary behaviour, as research have shown that mentally active sedentary behaviour may have a positive impact on depression combined with light physical activity for adults.[61 62]

Finally, the findings may not be generalisable to adolescents as a whole, because the participants in this study were collected from only two municipalities in the northern region of Norway. Nevertheless, the findings of percentage of sedentary time and minutes in MVPA resemble those from previous findings from national and European samples, which suggests that the participants are no more or less active or sedentary than other adolescents. Still, Northern Norway's long winter season and polar nights may have affected the results, and caution with generalising the findings is advised.

CONCLUSION

The study indicates a disparity in the results depending on the type of measurement method; self-reported screen time was associated with increased mental distress 2 years later, whereas objectively measured time in sedentary behaviour was not. This calls for a thorough assessment of the validity and reliability of the chosen method of measurement in relation to the concept one wishes to investigate.

Author affiliations
[1]Department of Psychology, UiT Arctic University of Norway, Tromso, Norway
[2]School of Sports Sciences, UiT Arctic University of Norway, Tromso, Norway
[3]Regional Centre for Child and Youth Mental Health and Child Welfare, UiT Arctic University of Norway, Tromso, Norway
[4]Work Research Institute, Oslo Metropolitan University, Oslo, Norway
[5]Chronic Diseases and Ageing, Nasjonalt Folkehelseinstitutt, Oslo, Norway
[6]Department of Community Medicine, UiT Arctic University of Norway, Tromso, Norway
[7]Department of Microbiology and Infection Control, Universitetssykehuset Nord-Norge, Tromso, Norway
[8]School of Psychiatry, University of New South Wales, Sydney, New South Wales, Australia
[9]Black Dog Institute, Randwick, New South Wales, Australia

Contributors Study concept and design: IMO, KR and BM. Analysing and interpreting of data: IMO, KR, BM and B-HH. Drafting of the manuscript: IMO. Critical revision of the manuscript for important intellectual content: IMO, KR, BM, B-HH, KRL, WN, CSN, A-SF and SR. Study supervision: KR. All authors read and approved the final manuscript.

Funding The Northern Norway Regional Health Authority (Norwegian: Helse Nord) funded the research when a layout of the project was approved by their committee December 2016. The Tromsø Study: Fit Futures is a collaborative study between the University Hospital of North Norway, UiT–The Arctic University of Norway and the Norwegian Institute of Public Health. ActiGraph instruments were funded by the Simon F Hartmann family fund.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Norwegian Data Inspectorate and the Regional Committee for Medical and Health Research Ethics for Northern-Norway (REK-Nord) have approved Fit Futures – part of The Tromsø Study. The Tromsø Study collected the written informed consent from participants/guardians. The present project has received a specific approval from REK-Nord (Project number: 2016/987/REK nord).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The dataset supporting the articles findings is available through application directed to the Tromsø Study by following the steps presented on their online page: https://en.uit.no/forskning/forskningsgrupper/sub?p_document_id=453582&sub_id=71247.

ORCID iD
Ida Marie Opdal http://orcid.org/0000-0002-7092-9494

REFERENCES

1 Kessler RC, Bromet EJ. The epidemiology of depression across cultures. *Annu Rev Public Health* 2013;34:119–38.
2 Polanczyk GV, Salum GA, Sugaya LS, *et al*. Annual research review: a meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *J Child Psychol Psychiatry* 2015;56:345–65.
3 Ruiz JR, Ortega FB, Martínez-Gómez D, *et al*. Objectively measured physical activity and sedentary time in European adolescents: the Helena study. *Am J Epidemiol* 2011;174:173–84.
4 Johnson KE, Taliaferro LA. Relationships between physical activity and depressive symptoms among middle and older adolescents: a review of the research literature. *J Spec Pediatr Nurs* 2011;16:235–51.
5 Rodriguez-Ayllon M, Cadenas-Sánchez C, Estévez-López F, *et al*. Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. *Sports Medicine* 2019;49:1383–410.
6 Kremer P, Elshaug C, Leslie E, *et al*. Physical activity, leisure-time screen use and depression among children and young adolescents. *J Sci Med Sport* 2014;17:183–7.
7 Zahl T, Steinsbekk S, Wichstrøm L. Physical activity, sedentary behavior, and symptoms of major depression in middle childhood. *Pediatrics* 2017;139:e20161711.
8 Schuch FB, Vancampfort D, Firth J, *et al*. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry* 2018;175:631–48.
9 Vagetti GC, Barbosa Filho VC, Moreira NB, *et al*. Association between physical activity and quality of life in the elderly: a systematic review, 2000-2012. *Rev. Bras. Psiquiatr.* 2014;36:76–88.
10 Birkeland MS, Torsheim T, Wold B. A longitudinal study of the relationship between leisure-time physical activity and depressed mood among adolescents. *Psychol Sport Exerc* 2009;10:25–34.
11 Oweis P, Spinks W. Biopsychological, affective and cognitive responses to acute physical activity. *J Sports Med Phys Fitness* 2001;41:528–38.
12 Salmon P. Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clin Psychol Rev* 2001;21:33–61.
13 Lubans D, Richards J, Hillman C, *et al*. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics* 2016;138:e20161642.
14 Bailey AP, Hetrick SE, Rosenbaum S, *et al*. Treating depression with physical activity in adolescents and young adults: a systematic review and meta-analysis of randomised controlled trials. *Psychol Med* 2018;48:1068–83.
15 Toseeb U, Brage S, Corder K, *et al*. Exercise and depressive symptoms in adolescents: a longitudinal cohort study. *JAMA Pediatr* 2014;168:1093–100.
16 Rothon C, Edwards P, Bhui K, *et al*. Physical activity and depressive symptoms in adolescents: a prospective study. *BMC Med* 2010;8:32.
17 Hume C, Timperio A, Veitch J, *et al*. Physical activity, sedentary behavior, and depressive symptoms among adolescents. *J Phys Act Health* 2011;8:152–6.
18 Pearson N, Braithwaite RE, Biddle SJH, *et al*. Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis. *Obes Rev* 2014;15:666–75.
19 Hoare E, Milton K, Foster C, *et al*. The associations between sedentary behaviour and mental health among adolescents: a systematic review. *Int J Behav Nutr Phys Act* 2016;13:108.
20 Arbour-Nicitopoulos KP, Faulkner GE, Irving HM. Multiple health-risk behaviour and psychological distress in adolescence. *Journal of the Canadian Academy of Child Adolescent Psychiatry* 2012;21:171.
21 Mathers M, Canterford L, Olds T, *et al*. Electronic media use and adolescent health and well-being: cross-sectional community study. *Acad Pediatr* 2009;9:307–14.
22 Bickham DS, Hswen Y, Rich M. Media use and depression: exposure, household rules, and symptoms among young adolescents in the USA. *Int J Public Health* 2015;60:147–55.
23 Primack BA, Swanier B, Georgiopoulos AM, *et al*. Association between media use in adolescence and depression in young adulthood. *Arch Gen Psychiatry* 2009;66:181–8.
24 Stiglic N, Viner RM. Effects of screentime on the health and well-being of children and adolescents: a systematic review of reviews. *BMJ Open* 2019;9:e023191.
25 Orben A, Przybylski AK. The association between adolescent well-being and digital technology use. *Nat Hum Behav* 2019;3:173–82.
26 Brunborg GS, Burdzovic Andreas J. Increase in time spent on social media is associated with modest increase in depression, conduct problems, and episodic heavy drinking. *J Adolesc* 2019;74:201–9.
27 Chastin SFM, Dontje ML, Skelton DA, *et al*. Systematic comparative validation of self-report measures of sedentary time against an objective measure of postural sitting (activPAL). *Int J Behav Nutr Phys Act* 2018;15:21.
28 Hamer M, Coombs N, Stamatakis E. Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from the health survey for England. *BMJ Open* 2014;4:e004580.
29 Christoffersen T, Winther A, Nilsen OA, *et al*. Does the frequency and intensity of physical activity in adolescence have an impact on bone? The Tromsø study, fit futures. *BMC Sports Sci Med Rehabil* 2015;7:26.
30 Opdal IM, Morseth B, Handegård BH, *et al*. Change in physical activity is not associated with change in mental distress among adolescents: the Tromsø study: fit futures. *BMC Public Health* 2019;19:916.
31 Migueles JH, Cadenas-Sanchez C, Ekelund U, *et al*. Accelerometer data collection and processing criteria to assess physical activity and other outcomes: a systematic review and practical considerations. *Sports Med* 2017;47:1821–45.
32 Freedson PS, Melanson E, Sirard J. Calibration of the computer science and applications, Inc. accelerometer. *Med Sci Sports Exerc* 1998;30:777–81.
33 Haavet OR, Sirpal MK, Haugen W, *et al*. Diagnosis of depressed young people in primary health care—a validation of HSCL-10. *Fam Pract* 2011;28:233–7.
34 Strand BH, Dalgard OS, Tambs K, *et al*. Measuring the mental health status of the Norwegian population: a comparison of the instruments SCL-25, SCL-10, SCL-5 and MHI-5 (SF-36). *Nord J Psychiatry* 2003;57:113–8.
35 Sandanger I, Moum T, Ingebrigtsen G, *et al*. Concordance between symptom screening and diagnostic procedure: the Hopkins symptom Checklist-25 and the composite international diagnostic interview I. *Soc Psychiatry Psychiatr Epidemiol* 1998;33:345–54.
36 Gispert R, Rajmil L, Schiaffino A, *et al*. Sociodemographic and health-related correlates of psychiatric distress in a general population. *Soc Psychiatry Psychiatr Epidemiol* 2003;38:677–83.
37 Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Med Sci Sports Exerc* 2000;32:1601–9.
38 Strine TW, Okoro CA, Chapman DP, *et al*. Health-related quality of life and health risk behaviors among smokers. *Am J Prev Med* 2005;28:182–7.
39 Wilson AC, Palermo TM. Physical activity and function in adolescents with chronic pain: a controlled study using actigraphy. *J Pain* 2012;13:121–30.
40 Janssen I, Katzmarzyk PT, Boyce WF, *et al*. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35:360–7.
41 Strine TW, Chapman DP. Associations of frequent sleep insufficiency with health-related quality of life and health behaviors. *Sleep Med* 2005;6:23–7.
42 de Wit LM, Fokkema M, van Straten A, *et al*. Depressive and anxiety disorders and the association with obesity, physical, and social activities. *Depress Anxiety* 2010;27:1057–65.
43 Lichstein KL, Durrence HH, Taylor DJ, *et al*. Quantitative criteria for insomnia. *Behav Res Ther* 2003;41:427–45.
44 IBMCorp. *Ibm SPSS statistics for windows, version 25.0*. Armonk, NY: IBM Corp, 2017.
45 World Health Organization. Global recommendations on physical activity for health, 2010. Available: https://apps.who.int/iris/bitstream/handle/10665/44399/9789241599979_eng.pdf;jsessionid=952EF2FE7000ECC64D066DFA28FBD1D4?sequence=1
46 Arundell L, Salmon J, Koorts H, *et al*. Exploring when and how adolescents sit: cross-sectional analysis of activPAL-measured patterns of daily sitting time, bouts and breaks. *BMC Public Health* 2019;19:653.
47 Bucksch J, Sigmundova D, Hamrik Z, *et al*. International trends in adolescent Screen-Time behaviors from 2002 to 2010. *J Adolesc Health* 2016;58:417–25.
48 World Health Organisation. © World Health organization 2010, 2010. Available: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf?ua=1
49 McMahon EM, Corcoran P, O'Regan G, *et al*. Physical activity in European adolescents and associations with anxiety, depression and well-being. *Eur Child Adolesc Psychiatry* 2017;26:111–22.

50 Cooper AR, Goodman A, Page AS, *et al*. Objectively measured physical activity and sedentary time in youth: the International children's accelerometry database (ICAD). *Int J Behav Nutr Phys Act* 2015;12:113.
51 Slootmaker SM, Schuit AJ, Chinapaw MJ, *et al*. Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. *Int J Behav Nutr Phys Act* 2009;6:17.
52 Affuso O, Stevens J, Catellier D, *et al*. Validity of self-reported leisure-time sedentary behavior in adolescents. *J Negat Results Biomed* 2011;10:2.
53 Rey-López JP, Ruiz JR, Ortega FB, *et al*. Reliability and validity of a screen time-based sedentary behaviour questionnaire for adolescents: the Helena study. *Eur J Public Health* 2012;22:373–7.
54 Maras D, Flament MF, Murray M, *et al*. Screen time is associated with depression and anxiety in Canadian youth. *Prev Med* 2015;73:133–8.
55 Trinh L, Wong B, Faulkner GE. The independent and interactive associations of screen time and physical activity on mental health, school connectedness and academic achievement among a population-based sample of youth. *J Can Acad Child Adolesc Psychiatry* 2015;24:17–24.
56 Stanczykiewicz B, Banik A, Knoll N, *et al*. Sedentary behaviors and anxiety among children, adolescents and adults: a systematic review and meta-analysis. *BMC Public Health* 2019;19:459.
57 Sund AM, Larsson B, Wichstrøm L. Role of physical and sedentary activities in the development of depressive symptoms in early adolescence. *Soc Psychiatry Psychiatr Epidemiol* 2011;46:431–41.
58 Biddle SJH, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med* 2011;45:886–95.
59 Romer D, Bagdasarov Z, More E. Older versus newer media and the well-being of United States youth: results from a national longitudinal panel. *J Adolesc Health* 2013;52:613–9.
60 Vallance JK, Winkler EAH, Gardiner PA, *et al*. Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005–2006). *Prev Med* 2011;53:284–8.
61 Hallgren M, Owen N, Stubbs B, *et al*. Passive and mentally-active sedentary behaviors and incident major depressive disorder: a 13-year cohort study. *J Affect Disord* 2018;241:579–85.
62 Hallgren M, Nguyen T-T-D, Owen N, *et al*. Cross-sectional and prospective relationships of passive and mentally active sedentary behaviours and physical activity with depression. *Br J Psychiatry* 2019:1–7.
63 Kozey-Keadle S, Libertine A, Lyden K, *et al*. Validation of wearable monitors for assessing sedentary behavior. *Med Sci Sports Exerc* 2011;43:1561–7.
64 Oliver M, Badland HM, Schofield GM, *et al*. Identification of accelerometer nonwear time and sedentary behavior. *Res Q Exerc Sport* 2011;82:779–83.
65 Vanhelst J, Béghin L, Drumez E, *et al*. Awareness of wearing an accelerometer does not affect physical activity in youth. *BMC Med Res Methodol* 2017;17:99.
66 Lee JH, Huber Jr J. *Multiple imputation with large proportions of missing data: how much is too much? United Kingdom Stata users' group meetings 2011*. Stata Users Group, 2011.
67 Sundblad GMB, Saartok T, Engström L-MT, *et al*. Prevalence and co-occurrence of self-rated pain and perceived health in school-children: age and gender differences. *European Journal of Pain* 2007;11:171–80.
68 Perquin CW, Hazebroek-Kampschreur AAJM, Hunfeld JAM, *et al*. Pain in children and adolescents: a common experience. *Pain* 2000;87:51–8.

PAPER 3

Is the association between physical activity and mental distress among adolescents mediated by peer acceptance, perceived barriers and enjoyment of activity? Results from the Tromsø Study: Fit Futures

Ida Marie Opdal[a]*, Bente Morseth[b], Ane Sofie Kokkvoll[c], Alexander Horsch[d], Simon Rosenbaum[e,f] and Kamilla Rognmo[a].

[a] Department of psychology, UiT The Arctic University of Norway

[b] School of sports sciences, UiT The Arctic University of Norway

[c] Department of Paediatrics, Finnmark Hospital Trust, Hammerfest, Norway and Paediatric Research Group, Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway

[d] Department of computer sciences, UiT The Arctic University of Norway

[e] School of psychiatry, University of New South Wales, Australia

[f] Black Dog Institute, Sydney, Australia

*Corresponding author

ABSTRACT

Objective: Adolescents with anxiety or depression tend to be less physically active compared to their peers without symptoms of mental distress. Examining factors that could explain the reduced physical activity levels of adolescents experiencing mental distress is important in order to enable interventions aiming at increasing activity in this population. The aims of the present study are to 1) investigate if mental distress is associated with physical activity and sedentary behavior among adolescents, and 2) explore if the association is mediated by peer acceptance, enjoyment or perceived barriers towards physical activity, tested through a serial multiple mediator model by using data from a health study among adolescents from the general population, the Tromsø Study: Fit Futures.

Design: Cross-sectional study.

Setting: Sample drawn from upper secondary school students (mean age 16.3 years) from two municipalities in Northern Norway, participating in The Tromsø study: Fit Futures 1.

Participants: 582 adolescents (55.5% female), with complete self-reported questionnaire and accelerometer data were included in the analysis.

Primary outcome measure: Objectively measured physical activity assessed via ActiGraph GT3X accelerometers, reported as minutes spent in moderate to vigorous physical activity (MVPA) and minutes in sedentary behavior per day.

Results: The direct effect of mental distress on minutes in MVPA was not significant. The analysis showed a significant indirect effect of mental distress on MVPA through low peer acceptance. The direct effect of the relationship between mental distress and sedentary behavior was also non-significant, and again, low peer acceptance significantly mediated the effect of mental distress on sedentary behavior.

Conclusion: The results of this study indicate that low peer acceptance mediates both the association between mental distress and minutes in MVPA, and the association between mental distress and sedentary behavior. When these mediating effects were taken into account, there were no significant direct effects between mental distress and MVPA or sedentary behavior. However, due to the design of the study, the results are only able to show indications of effects. Longitudinal studies on the relationships are needed.

INTRODUCTION

Adolescents experiencing mental distress, including symptoms of anxiety and depression, are significantly less physically active and more sedentary compared to their peers without symptoms of mental distress [1, 2]. The literature indicates that physical activity could both have a protective and a treatment effect on mental distress, as low levels of physical activity are found to be an important risk factor for depression and anxiety, as well as reducing symptoms related to the disorders [e.g. 3, 4]. A recent meta review of systematic reviews, concluded that interventions aiming at increasing physical activity levels among adolescents were moderately effective in reducing depression [5]. However, observational studies investigating cross-sectional or longitudinal associations between physical activity and symptoms of anxiety or depression reveal more mixed findings, varying between small to non-significant effects [4, 5].

Regardless of the specific effect of physical activity on symptoms of anxiety or depression, increasing physical activity levels among depressed persons is essential. This is because physical activity in adolescence positively impacts many other health related outcomes than mental distress, such as physical activity participation in adulthood [6], increasing bone mass density [7], reducing body fat percentage [8], lowering risk of type 2 diabetes [9], increasing survival rates following coronary heart disease [10] and reducing overall risk of mortality [11].

Identifying factors related to higher levels of physical activity or lower levels of sedentary behaviors can prove useful for targeted interventions aiming at increasing levels of physical activity among adolescents, in particular among adolescents struggling with mental distress. The term *perceived barriers* has been used to investigate barriers towards health behavior in general, but also for barriers towards specific health behaviors such as physical activity [12]. The most common perceived barrier among the general population is lack of time to be physically active [12, 13]. Other barriers commonly cited are the lack of someone to be active with [14], lack of enjoyment while exercising [13] and inaccessibility of facilities [15]. Adolescents who report more perceived barriers are less likely to be physically active [13, 16, 17], and are more likely to engage in sedentary behaviors [18]. To the best of our knowledge, the degree to which perceived barriers for being physically active is related to mental distress, or contributes to the association between mental distress and physical activity has not been previously investigated.

While barriers may serve to lower levels of physical activity, other factors can be related to higher levels of physical activity. Enjoyment of physical activity and perceived competence are factors that have previously been found to correlate with [17, 19] and predict [20] physical activity levels, although the results are mixed and suffers from a lack of extensive research among adolescents [21]. As far as we know, it is unknown whether adolescents with symptoms of depression and anxiety have different experiences of enjoyment and competence in physical activity, and how this ultimately affect their physical activity levels.

The social environment of the adolescent may also be of importance to the relationship between mental distress and physical activity. Poor peer relations and loneliness are found to predict depression [22-24], and depression may escalate interpersonal problems, causing a further deterioration in peer relations and a feeling of social rejection [25]. Furthermore, in adolescence, peer relations strongly influence physical activity levels [26]. Peer acceptance, defined as how the peer group feels about a specific individual, is an important determinant of sports continuation, perceived competence and enjoyment of activity [27, 28], which all are related to higher levels of physical activity [e.g. 29, 30]. Thus, mental distress may be related to physical activity through peer acceptance, which in turn may impact enjoyment of activity and perceived competence that also may be related to physical activity levels. A similar explanatory model can be conceivable for how perceived barriers may act as a mediator in a serial mediator causal chain: mental distress may impact peer acceptance, which in turn may impact the degree to which one feels there are barriers towards being physically active, such as not having someone to be physically active with, which in turn may cause physical activity levels to drop.

Understanding the role of factors such as perceived barriers, enjoyment, perceived competence and peer acceptance/friendships may provide insight into why adolescents experiencing mental distress may be less physically active, and prove useful for designing interventions and implement strategies aiming at enhancing physical activity among this group. However, existing research on perceived enjoyment and barriers to physical activity suffers from certain methodological weaknesses, including limited sample sizes and the use of self-reported measures of physical activity. Self-reported physical activity is subject to recall and response bias [21], and adolescents tend to over-report time spent in moderate and vigorous physical activity compared to objective accelerometer data [22]. The aims of the present study are to 1) investigate if mental distress is associated with levels of physical

activity and sedentary behavior among adolescents, and 2) explore if the association is mediated by peer acceptance, enjoyment or perceived barriers towards physical activity, by using data from a health study among adolescents from the general population, the Tromsø Study: Fit Futures. This study is inspired by the results from a previous study on the effect of change in physical activity on change in mental distress [31], sparking interest to look at the association between physical activity and mental distress in the Fit Futures sample from a different angle.

METHOD

Study design and sample

This study is based on data from the first wave of the population based general health study The Tromsø Study: Fit Futures (hereafter called Fit Futures), collected in the school year of 2010-2011. All students attending first-level upper secondary school in the municipalities of Tromsø and Balsfjord in northern Norway were invited to participate in the study. In total, 1,117 students were invited to participate, of which 1,038 (92.9%) did. Participants with valid data on all variables were included in the analyses. This resulted in a total number of 582 participants (56% of the participating sample). Using longitudinal data was not possible as only a fraction of the sample had objective physical activity data from two waves of data collection. The majority of the participating sample was 15-17 years old at the time of the study. The Fit Futures study is also described in detail elsewhere [31, 32].

The Fit Futures study collected data through a web-based questionnaire, clinical examinations and interviews performed by trained research nurses at the study site at the University Hospital of Northern Norway. The present study is based on questionnaire data and objective data on physical activity. All participants aged 16 years or more provided informed consent to The Tromsø study before attending, as stated in §17 in the Norwegian Health Research Act; participants younger than 16 years had to have signed consent provided by a guardian.

Measurements

Mental distress. The Hopkins Symptom Checklist – 10 (HSCL-10) assesses symptoms of anxiety (4 items) and depression (6 items) during the previous seven days. The HSCL-10 has been found to have good psychometric properties including internal and

external validity, and reliability [33, 34]. The participants rate the agreement with each of the ten statements on the scale of response categories “none” (1), “slightly” (2), “much” (3) and “very much” (4). The results were then averaged into a mean score variable, and subsequently, dichotomized over/under the cutoff 1.85, which has been identified as a threshold for indicating the presence of an internalized mental disorder among adolescents [33]. The dichotomous variable served as a predictor in the analyses. The term mental distress will be used hereafter.

Sedentary time and physical activity. The Fit Futures study collected objectively measured physical activity data with an ActiGraph GT3X accelerometer. The participants wore the ActiGraph on their dominant hip for eight days, and were instructed to only take it off when sleeping, showering or swimming. The ActiGraph measures acceleration in movement, referred to as “counts”. By using the ActiLife software, owned by the manufacturer, the raw accelerometer files were reduced to 10 second epochs, and further, 10 second epochs were summed to 1 minute. The participants with at least ten hours of wear-time for at least four out of the total seven days were considered to have valid data.

The analysis in this current study used the variables minutes spent in moderate to vigorous physical activity (MVPA) and minutes spent in sedentary behavior as the outcome variables. Threshold values suggested by Freedson et al. [35] were used to define physical activity levels; minutes in sedentary behavior per valid day was defined as minutes in < 100 counts per minute, and minutes in MVPA per valid day was defined as minutes in ≥ 1952 counts per minute. Details of the accelerometer data processing are described elsewhere [36]

Mediators

Enjoyment and perceived competence of activity. Four items based on the research of Ommundsen et al. [37] were included in the questionnaire to measure the extent to which participants experience enjoyment and competence of physical activity. The items measuring enjoyment were, “I have more fun during exercise or physical activity than doing other things”, and “I wish I could do more exercise/physical activity than what I have the opportunity to”. For perceived competence the statements were, “I feel that I am better than most people my age at sports/physical activity”, and “I feel that I can easily keep up with others my age during sports/physical activity”. Originally, the response categories ranged on a scale of 1-5, where 1 = strongly agree and 5 = strongly disagree. For this study, the response categories were recoded to show the rate of agreement in increasing rate (1= strongly

disagree, 5= strongly agree). A Principal Component Factor analysis with oblimin rotation was performed, and two factors were extracted. The item "I wish I could do more exercise/physical activity than what I have the opportunity to" loaded on a separate factor than the other three items. The wording of this item is somewhat unclear, and the phenomenon the item is meant to measure is not evident. Due to this, we chose to not include this item in further analyses. The three remaining items were averaged into a mean score of enjoyment and perceived competence, called "enjoyment" hereafter. The variable serves as a mediator in the regression analyses, but the effect of mental distress on enjoyment is also estimated, as well as the effect of enjoyment on physical activity.

Barriers to physical activity. Experienced barriers to physical activity were measured by asking participants to rate how much they agreed to the eight following statements based on the research of Ommundsen et al. [37] and Deforche et al. [38]: "I don't like to exercise while others are watching", "Access to a private dressing room would make exercising easier", "I get uncomfortably breathless, unpleasantly sweat or bodily pain when exercising", "The exercise lessons at school are organized in a way that I cannot keep up", "I have nobody to exercise with", "I don't have the equipment necessary to do the activity I want to", "I have too many other tasks to have time for exercising (e.g. homework, household work)", and "There is a lack of suitable sports halls, or good outdoor areas to engage in physical activity where I live". A Principle Component Factor analysis with oblimin rotation showed a single factor structure, and consequently the eight items were averaged into a variable called "Perceived barriers". The barrier variables were also originally scaled from one to five, where 1 = strongly agree and 5 = strongly disagree, but for the sake of the present analyses, the scaling was reversed (1= strongly disagree, 5= strongly agree). The perceived barriers variable is used as a mediator in the analyses, but the effect of mental distress and friends on perceived barriers is also estimated, as is the effect of perceived barriers on physical activity.

Low peer acceptance. Social acceptance was assessed using a revised version of the Self-Perception Profile for Adolescents (SPPA). SPPA was originally developed by Harter [39], but Wichstrøm revised this version, in order to be suitable for Norwegian adolescents [40]. The social acceptance scale of the SPPA consists of five items, asking about the degree to which the respondents find it hard to make friends, have many friends, feel accepted among his/her peers, feel liked among peers, and feel popular among peers. The responses were given on four point Likert type scales, ranging from highly incorrect to highly correct. In order to aid the interpretation of the results, positively worded items were reversed, so that a

high score indicates a *low* level of peer acceptance. The Norwegian subscale, social acceptance, has been validated with good results [41]. Low peer acceptance is used as a mediator in the analyses, but as for the other mediators, the effect of mental distress on low peer acceptance, as well as the effect of low peer acceptance on physical activity, will also be estimated.

Covariates

Demographic variables. Sex was included in the analyses as a possible confounder. In addition, a variable indicating what time of the year the physical activity measurement was made, from the date of ActiGraph start wear-time (non-winter: May to June and September to October, or winter: November to April) and included in the analyses as a covariate. As the variation in age was very low in the participating sample, age was not included as a covariate.

BMI. Weight and height were measured at the examination site and BMI was subsequently calculated by dividing the participants weight in kg by their height in meters squared.

Data analysis

All analyses were run using the statistical software IBM SPSS 25 [42]. Pearson product moment correlation analyses were run in order to investigate the bivariate relationship between MVPA and sedentary behavior and peer acceptance, enjoyment and perceived barriers.

In order to explore the effect of mental distress on minutes in MVPA and sedentary behavior, and the degree to which the effect is mediated by peer acceptance, enjoyment and perceived barriers we used the PROCESS macro written by Andrew F. Hayes [43]. PROCESS macro is a custom dialog box available for download to SPSS, making analyzing moderation and mediation effects less time consuming. All effects were estimated by sex, season of measurement of activity and BMI. As the literature suggests that peer acceptance may be predicted by mental distress, and in turn may be a predictor of enjoyment of activity, which in turn may predict physical activity, a serial multiple mediator model was run (model 6 in PROCESS), with low peer acceptance as the first mediator, expected to affect the second mediator and outcome variable in a causal sequence. In this model, a number of effects are estimated, in a sequential order. The effect of the predictor variable on the first mediator is estimated, adjusted by the covariates, as well as the effect of the predictor on the second

mediator, adjusted by the covariates and the effect of the first mediator. The effect of the first mediator on the second mediator is also estimated, adjusted by the predictor and the covariates, as well as the effect of the first mediator and second mediators on the outcome variable, adjusted by each other as well as the covariates. The model also estimates the total effect of the predictor on the outcome variable, which is adjusted only by the covariates, and the direct effect of the predictor on the outcome, adjusted by the covariates and both mediators. Three mediating effects are also estimated, the mediating effect of the first mediator, adjusted by the covariates, the mediating effect of the second mediator, adjusted by the effect of the first mediator and the covariates, and the joint mediating effect of the first and second mediator (the product of the effect of the first and second mediator), adjusted by the covariates. The confidence intervals were bootstrapped to estimate properties of the sampling distribution relatively unaffected by violations of assumption and outliers.

Sensitivity analyses were conducted in order to investigate the degree to which the study sample differed in a significant way to the participants with missing data. Chi square tests were run for the dichotomous variables, HSCL-10 and sex, and one-way analysis of variance were performed for the variables measuring enjoyment for physical activity, perceived barriers for physical activity, low peer acceptance and BMI. It was not possible to investigate if the participating sample differed from the participants with missing values in terms of physical activity levels, as almost all participants with valid ActiGraph data were retained in the study sample.

RESULTS

Descriptive statistics

The descriptive statistics of the participants are shown in Table 1. 18.4% of the participants exceeded the cutoff score of HSCL-10 indicative of a probable diagnosis of anxiety or depression. On average, participants spent almost 45 minutes ± 21.62 minutes per day in MVPA and were sedentary for almost 9.5 hours ± 1.18 hours per day. Mean low peer acceptance was on the lower end of the range of possible scores, indicating that most feel accepted by their peers. Mean score for enjoyment of activity was above the middle value of possible scores. The mean of perceived barriers was near the middle value, and the standard deviation indicates that the variability in scores was somewhat greater on this variable than on the peer acceptance and enjoyment of activity variables.

Table 1: Descriptive statistics of subject characteristics. Mean and standard deviation (SD) for scale variables.

	All (N=582) N (%)
Sex (Boys)	249 (44.5%)
HSCL-10 > 1.85[a]	107 (18.4%)
Season (Winter)	495 (85.1%)
	Mean (*SD*)
MVPA[b]	44.41 (21.62)
Sedentary behavior[c]	566.81 (71.08)
BMI	22.50 (4.09)
Low peer acceptance (1-5)	1.73 (0.49)
Enjoyment (1-5)	3.12 (.89)
Perceived barriers (1-5)	2.72 (1.08)

[a] *Above cutoff at 1.85 indicating symptoms of depression and anxiety*
[b] *Minutes in moderate to vigorous physical activity per valid day*
[c] *Minutes in sedentary behavior per valid day*

As shown in Table 2, low peer acceptance was negatively correlated with physical activity and positively correlated with sedentary behavior. Enjoyment showed an opposite correlation, whereas perceived barriers showed weaker correlations with MVPA and sedentary behavior.

Table 2: Correlations between the outcome variables and the mediation variables, low peer acceptance, enjoyment and perceived barriers, in the study sample Fit Futures 1 study.

	Low peer acceptance	Enjoyment	Barriers
MVPA[a]	-.15***	.12**	-.09*
Sedentary behavior[b]	.15***	-.12**	-01

[a] *Minutes in moderate to vigorous physical activity per valid day*
[b] *Minutes in sedentary behavior per valid day*
*** *p<.00*
** *p<.01*
* *p<.05*

Mediation analyses

The results of the mediation model are seen in Figure 1. There was a significant effect of mental distress on low peer acceptance (*B*=.37, *p*=.000), but not on enjoyment (*B*=-.08, *p*=.452). Low peer acceptance was not a significant predictor of enjoyment (*B*=-.06, *p*=.484). Both low peer acceptance (*B*=-5.41, *p*=.004) and enjoyment (*B*= 2.51, *p*=.010) significantly predicted MVPA. The total effect of mental distress on MVPA was significant (*B*= -6.26, *p*=.007, *CI* = -10.83, -1.69), indicating that adolescents screened positive for mental distress spent significantly less time in moderate and vigorous activity compared to non-distressed adolescents. The direct effect of mental distress, in which the effect of the mediators was taken into account was, however, not significant (*B*=-4.03, *p*=.094, *CI*=-8.75, .69). There was a significant indirect effect of mental distress on MVPA through low peer acceptance (*B*=-1.99, *bootstrapped CI* = -3.52, -.65), indicating that adolescents with mental distress reported lower peer acceptance, which in turn was related to lower MVPA. Enjoyment of activity did not mediate the effect of mental distress on MVPA (*B* =-.19, *bootstrapped CI* = -.91, .39), nor did the joint product of low peer acceptance and enjoyment of activity (*B*=-.05, *bootstrapped CI* = -.28, .10).

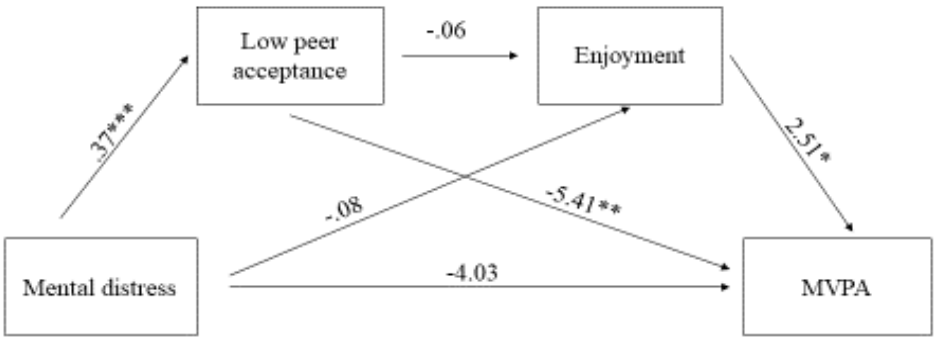


Figure 1: Mediation analyses testing low peer acceptance and enjoyment as mediators of the effect of mental distress on MVPA. Sex, season of measurement of activity and BMI were added as covariates.

The second set of analyses (shown in Figure 2) tested the degree to which the effect of mental distress on MVPA was mediated by low peer acceptance and perceived barriers, and this analysis produced results similar to the previous model. The relationships between mental distress and low peer acceptance and enjoyment are the same in all models, and consequently

will not be commented upon further. Low peer acceptance (*B*=-5.39, *p*=.004) and perceived barriers (*B*=-1.62, *p*=.049) significantly predicted MVPA. The total effect of mental distress was significant (*B*=-6.26, *p*=.007), whereas the direct effect was not (*B*=-3.91, *p*=.106). Low peer acceptance significantly mediated the effect of mental distress on MVPA (*B*=-1.98, *bootstrapped CI*=-3.57, -.64), whereas perceived barriers (*B*=.32, *bootstrapped CI*=-.96, .05) and the joint effect of low peer acceptance and barriers (*B*=-.06, *bootstrapped CI*=-.24, .06) did not.

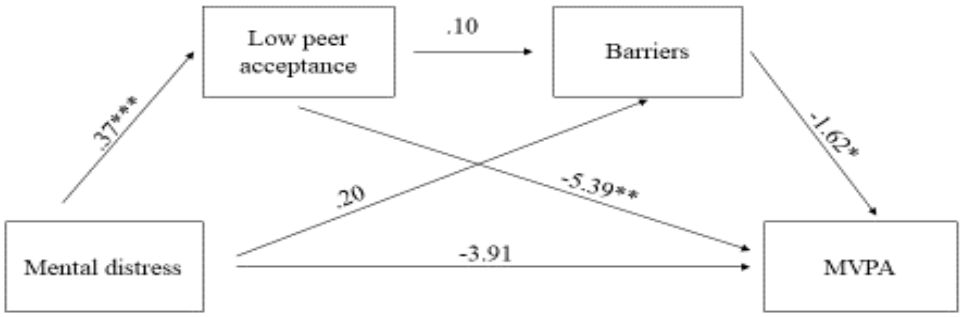


Figure 2: Mediation analyses testing low peer acceptance and barriers as mediators of the effect of mental distress on MVPA. Sex, season of measurement of activity and BMI were added as covariates.

In Figure 3, the results of the mediation analysis of low peer acceptance and enjoyment as mediators of the effect of mental distress on sedentary behavior can be seen. Low peer acceptance (*B*=20.91, *p*=.001) positively predicted sedentary behavior, whereas enjoyment of activity negatively predicted the behavior (*B*=-9.84, *p*=.003). The total effect (*B*=10.50, *p*=.176) and direct effect (*B*=1.86, *p*=.815) of mental distress on sedentary behavior were non-significant. Peer acceptance significantly mediated the effect of mental distress on sedentary behavior (*B*=7.68, *bootstrapped CI*=2.87, 13.65), meaning that individuals experiencing mental distress were significantly more likely to experience low peer acceptance, which in turn was related to higher levels of sedentary behavior. Enjoyment (*B*=.75, *bootstrapped CI*=-1.39, 3.42) and the product of peer acceptance and enjoyment (*B*=.20, *bootstrapped CI*=-.39, .99) did not.

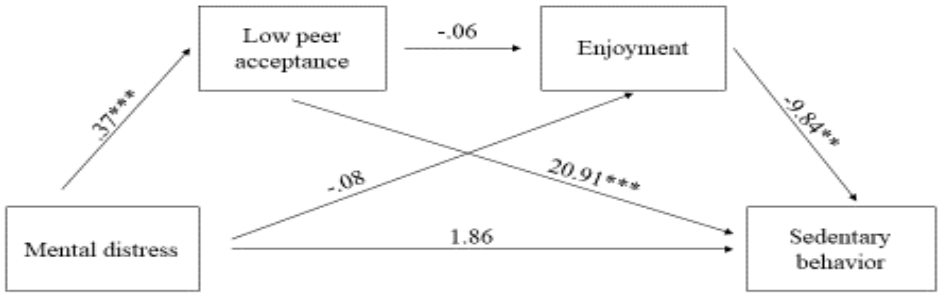


Figure 3: Mediation analyses testing low peer acceptance and enjoyment as mediators of the effect of mental distress on sedentary behavior. Sex, season of measurement of activity and BMI were added as covariates.

Finally, the results of the mediation model testing if low peer acceptance and perceived barriers were mediators of the effect of mental distress on sedentary behavior are displayed in Figure 4. As in the previous models, low peer acceptance significantly, positively predicted sedentary behavior (*B*=21.45, *p*=.001). Barriers did not (*B*=.08, *p*=.978). The total (*B*=10.50 *p*=.176) and direct effect (*B*=2.60, *p*=.746) of mental distress on sedentary behavior were non-significant. Once again, the only significant mediator of the relationship was peer acceptance (*B*=7.88, *bootstrapped CI*=2.86, 13.90), whereas perceived barriers (*B*=0.01, *bootstrapped CI*=-1.28, 1.35) and the joint effect of peer acceptance and perceived barriers (*B*=-0.00, *bootstrapped CI*=-.31, .31) were non-significant.

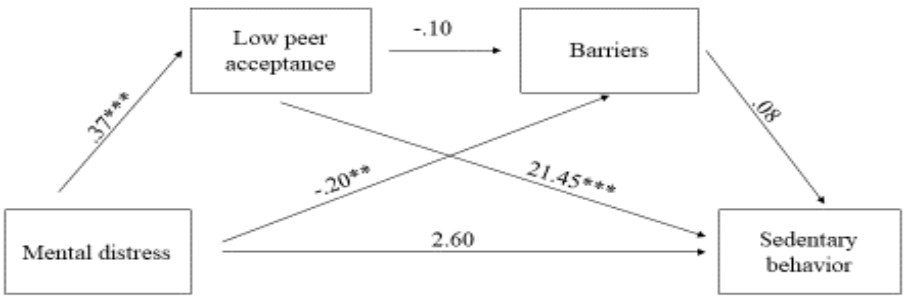


Figure 3: Mediation analyses testing low peer acceptance and barriers as mediators of the effect of mental distress on sedentary behavior. Sex, season of measurement of activity and BMI were added as covariates.

Sensitivity analysis between the study sample and the participants with missing data

Participants who had valid data did not differ in terms of HSCL-10 score compared to those who were not included in the study sample. Nor were there any differences in terms of mean score of enjoyment, barriers towards physical activity or BMI between the groups. There was a significant difference between valid data sample and the non-valid regarding sex, as it was found that more girls had valid data compared with boys (chi square = 22.80, p= .000). There was also found a difference between low peer acceptance between the groups (F = 7.49, p=.006). However, the difference between the means was small (mean for participants with valid data = 1.73, mean for participants with missing data = 1.64). This is interpreted as of no practical significance.

DISCUSSION

This study aimed to investigate if mental distress was associated with levels of physical activity and sedentary behavior among adolescents, and further, if the association was mediated by peer acceptance, enjoyment or perceived barriers towards physical activity. The results showed that the total effect of mental distress on MVPA was significant, but that this effect is due to the mediating role of peer acceptance. This means that mental distress is significantly related to perceived low acceptance by peers, which in turn is negatively related to levels of physical activity. Mental distress was not significantly related to sedentary behavior, but there was an indirect effect of mental distress through low peer acceptance, indicating that mental distress is related to low peer acceptance, which in turn is related to higher levels of sedentary behavior. Enjoyment and perceived barriers did not mediate the effect of mental distress on MVPA nor sedentary behavior, but both had a significant relationship with physical activity, whereas only enjoyment significantly predicted sedentary behavior.

In this study, mediation was investigated using cross-sectional data. This has been considered inappropriate until recent years, because by definition mediation models are causal models, in which the predictor is causally related to the mediator and the mediator is causally related to the outcome. In order to establish causality, temporal precedence of predictor variables (the predictor and the mediator) relative to the outcome variables (the mediator and the outcome) needs to be established, and this can only be determined by having data from a at least three time points. However, there are a number of reasons why this view may pose too

strict criteria for investigating mediation. Hayes, the developer of the PROCESS macro used for the analyses in the present study [43] states that this view places too much emphasis on the answers provided by statistical analyses, and that the degree to which a relationship between two variables is expected to be causal should be evaluated by existing theory, current literature and logical reasoning, and not the results of statistical analyses. In regards to the mediation models examined in the present study, previous research shows that mental distress is related to lower peer acceptance [25], but also that lower peer acceptance is related to higher levels of mental distress [23]. Thus, mental distress may be both a predictor and a mediator in this particular case. However, as our main aim was to try to understand mechanisms behind the relationship between mental distress and physical activity, mental distress needs to be considered as a predictor of low peer acceptance, although we admit that for some of the individuals, the causal arrow may point the other way around. The key finding is that there is a relationship between mental distress and low peer acceptance, and that the joint effect of these two factors may impact upon physical activity levels. Mental distress may negatively influence social relations measured as low peer acceptance, and lead to decreased physical activity levels, possibly due to drop out from organized sports. A recent study from Brazil found adolescents with a negative perception of their friendships were more likely to drop out of organized sports and physical activity [44]. Other explanations for the lower levels of MVPA and higher levels of sedentary behavior of adolescents with mental distress explained by low peer acceptance, may be less opportunity to be active, through lower social support for activity, or lower levels of social influencing of engaging in physical activity, as demonstrated in a number of previous studies [45-47].

As the relationships between mental distress and perceived barriers to and enjoyment of activity have not previously been investigated, previous research could not help us determine the probable temporal precedence of barriers and enjoyment relative to mental distress. However, as anhedonia is a core symptom of depression, it is reasonable to believe that experiencing mental distress may impact the degree to which physical activity may impact enjoyment, rather than the other way around. The same line of arguments may be applied to the temporal precedence of perceived barriers. It seems probable that mental distress may impact the degree to which one experiences the barriers towards activity to increase, whereas the other way around - that perceived barriers towards physical activity is a predictor of mental distress - seems somewhat less probable. Thus, previous research and logical reasoning suggests that the temporal precedence of the variables used in our models is

appropriate, and as such, using cross-sectional data to investigate the mediation models is appropriate. Statistical methods are not used to make causal inferences, establishing cause and effect is more of a problem in research design and logical reasoning than in data analysis [43].

As the literature suggests an interrelationship between several of the variables defined as mediator variables, a serial mediator model was investigated, with low peer acceptance delineated as the first mediator, and enjoyment or perceived barriers as subsequent mediators of the effect of mental distress on physical activity. We did, however, not find support for these serial mediating effects, as low peer acceptance was neither a significant predictor of enjoyment or perceived barriers. Enjoyment and perceived barriers were significantly associated with MVPA, but only enjoyment was associated with sedentary behaviour. Overall, these findings are in line with results from previous research [17, 19, 20]. However, in contrast to other studies [13, 16, 17], this study did not find an association between perceived barriers and sedentary behaviors.

In mediation analyses using the causal steps approach proposed by Baron and Kenny [48], the total effect needs to be significant for mediation to occur, meaning that the indirect effect of low peer acceptance on the effect of mental distress on sedentary behavior would not be considered valid. However, this principle is flawed; the size of the total effect does not determine or limit the size of the indirect effect, as there are several cases that may produce a non-significant total effect and a significant indirect effect. One example is a positive direct effect of X on Y and a negative indirect effect, which may cancel each other out resulting in a total effect close to zero [43]. Thus, the indirect effect of mental distress via low peer acceptance on sedentary behavior should be considered as a credible indirect effect.

Methodological considerations

The results from this study are based on the data collected through The Tromsø Study: Fit Futures, which offers a unique opportunity to study objectively measured physical activity in a relatively large, generalizable sample of adolescents from the general population. There are, however, several limitations in this study that the reader should be aware of. Foremost, this study is the first study to investigate the mediating effect of peer acceptance, enjoyment and barriers for physical activity on the relationship between mental health and physical activity that we know of. Thus, comparison with previous studies is limited.

The reported experienced barriers and enjoyment of physical activity are only based on a few selected items from the questionnaire presented by Ommundsen et al. [37] and

Deforche et al. [38], and these measurements of perceived personal, social and environmental influences are difficult to measure in adolescents [49]. Therefore, the validity may be questionable when using only a few items. Furthermore, the literature has confirmed a gender difference on the perceived barriers to, and enjoyment of physical activity, where boys score higher on enjoyment of physical activity [50, 51] and girls higher on perceived barriers for physical activity [52, 53]. Unfortunately, our sample was not sufficiently large to investigate moderation effects of gender. The physical activity variables were collected through accelerometers worn on the hip. Due to this static placement, the device is unable to reliably register different types of activities such as rowing and cycling. Accelerometers are also limited when it comes to reliably differentiating between sedentary time and non-wear time adequately, as this potentially could lead to underestimation of sedentary time measured by accelerometer [54, 55]. Accelerometer data was collected for only seven days and there is a possibility that the data is not representative of the participants' typical level of physical activity. However, results from blind and non-blind test concluded that the awareness of wearing an accelerometer has no effect on the pattern of physical activity among youth [56]. The potential effect should, nevertheless, be considered.

Access to data from several time points would have been preferable, but as only a fraction of the baseline sample had accelerometer data from the follow-up study, and as PROCESS does not accept multiply imputed datasets, imputation of missing variables was disregarded as there were no suitable variables to impute the missing data from. However, as the present study is the first to estimate the mediating effects of peer acceptance, enjoyment and perceived barriers on the relationship between mental distress and physical activity and sedentary behavior, we believe the use of cross-sectional data adds to the research literature in a significant way.

Conclusions

This study show that low peer acceptance mediate both the association between mental distress and minutes in MVPA and the association between mental distress and sedentary behavior. When the mediating effect was taken into account, there were no significant direct association between mental distress and minutes in MVPA or mental distress and sedentary behavior. However, due to the design of the study, the results are only able to point towards an indication of effect in the population. Longitudinal studies are essential.

DECLARATIONS

Ethics approval and consent to participate

Norwegian Data Inspectorate and the Regional Committee for Medical and Health Research Ethics for Northern-Norway (REK-Nord) have approved Fit Futures – part of The Tromsø Study. The Tromsø Study collected the written informed consent from participants/guardians. The present project has received a specific approval from REK-Nord (Project number: 2016/987/REK nord).

Consent for publication

Not applicable.

Funding

The Northern Norway Regional Health Authority (Norwegian: Helse Nord) funded the research when a layout of the project was approved by their committee December 2016. The Tromsø Study Fit Futures is a collaborative study between the University Hospital of North Norway, UiT - The Arctic University of Norway, and the Norwegian Institute of Public Health. Actigraph instruments were funded by the Simon F Hartmann family fund.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Study concept and design: IMO, KR, BM. Analyzing and interpreting of data: KR, IMO. Drafting of the manuscript: IMO. Critical revision of the manuscript for important intellectual content: IMO, KR, BM, AH, ASK, SR. Study supervision: KR. All authors read and approved the final manuscript.

Data sharing statement

The dataset supporting the articles findings is available through application directed to the Tromsø Study by following the steps presented on their online page: https://en.uit.no/forskning/forskningsgrupper/sub?p_document_id=453582&sub_id=71247.

Acknowledgements

The authors are grateful to the study participants, the participating schools in Tromsø and Balsfjord, the staff at the Clinical Research Unit, University Hospital of North Norway, and the Fit Futures administration.

REFERENCES

1. Kremer P, Elshaug C, Leslie E, Toumbourou JW, Patton GC, Williams J. Physical activity, leisure-time screen use and depression among children and young adolescents. Journal of science and medicine in sport. 2014;17(2):183-7.
2. Schuch F, Vancampfort D, Firth J, Rosenbaum S, Ward P, Reichert T, et al. Physical activity and sedentary behavior in people with major depressive disorder: A systematic review and meta-analysis. Journal of Affective Disorders. 2017;210:139-50.
3. Bailey A, Hetrick S, Rosenbaum S, Purcell R, Parker A. Treating depression with physical activity in adolescents and young adults: a systematic review and meta-analysis of randomised controlled trials. Psychological medicine. 2018;48(7):1068-83.
4. Rodriguez-Ayllon M, Cadenas-Sanchez C, Estevez-Lopez F, Muñoz NE, Mora-Gonzalez J, Migueles JH, et al. Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. Sports medicine. 2019:1-28.
5. Biddle SJ, Ciaccioni S, Thomas G, Vergeer I. Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. Psychology of Sport and Exercise. 2019;42:146-55.
6. Hallal PC, Victora CG, Azevedo MR, Wells JC. Adolescent physical activity and health. Sports medicine. 2006;36(12):1019-30.
7. Khan K, McKay HA, Haapasalo H, Bennell KL, Forwood MR, Kannus P, et al. Does childhood and adolescence provide a unique opportunity for exercise to strengthen the skeleton? Journal of science and medicine in sport. 2000;3(2):150-64.
8. Twisk JW. Physical activity guidelines for children and adolescents. Sports medicine. 2001;31(8):617-27.
9. Jeon CY, Lokken RP, Hu FB, van Dam RM. Physical Activity of Moderate Intensity and Risk of Type 2 Diabetes. Diabetes Care. 2007;30(3):744.
10. Moholdt T, Lavie CJ, Nauman J. Sustained Physical Activity, Not Weight Loss, Associated With Improved Survival in Coronary Heart Disease. Journal of the American College of Cardiology. 2018;71(10):1094.
11. Leitzmann MF, Park Y, Blair A, Ballard-Barbash R, Mouw T, Hollenbeck AR, et al. Physical Activity Recommendations and Decreased Risk of Mortality. JAMA Internal Medicine. 2007;167(22):2453-60.
12. Tappe MK, Duda JL, Ehrnwald PM. Perceived barriers to exercise among adolescents. Journal of School Health. 1989;59(4):153-5.

13. Biddle SJ, Whitehead SH, O'Donovan TM, Nevill ME. Correlates of participation in physical activity for adolescent girls: a systematic review of recent literature. Journal of Physical Activity and Health. 2005;2(4):423-34.
14. Tergerson JL, King KA. Do perceived cues, benefits, and barriers to physical activity differ between male and female adolescents? Journal of school health. 2002;72(9):374-80.
15. Dwyer JJ, Allison KR, Goldenberg ER, Fein AJ. Adolescent girl's perceived barriers to participation in physical activity. Adolescence. 2006;41(161):75.
16. Allison KR, Dwyer JJM, Makin S. Perceived Barriers to Physical Activity among High School Students. Preventive Medicine. 1999;28(6):608-15.
17. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Medicine and science in sports and exercise. 2000;32(5):963-75.
18. Salmon J, Owen N, Crawford D, Bauman A, Sallis JF. Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. Health Psychology. 2003;22(2):178-88.
19. Yang B, Kelly A-F, Pedro FS-M, Gregory JW, Norma C. Evaluation of Youth Enjoyment Toward Physical Activity and Sedentary Behavior. Pediatric Exercise Science. 2018;30(2):273-80.
20. DiLorenzo TM, Stucky-Ropp RC, Vander Wal JS, Gotham HJ. Determinants of Exercise among Children. II. A Longitudinal Analysis. Preventive Medicine. 1998;27(3):470-7.
21. Biddle SJ, Atkin AJ, Cavill N, Foster C. Correlates of physical activity in youth: a review of quantitative systematic reviews. International Review of Sport and Exercise Psychology. 2011;4(1):25-49.
22. Joiner Jr TE. Shyness and low social support as interactive diatheses, with loneliness as mediator: Testing an interpersonal-personality view of vulnerability to depressive symptoms. Journal of Abnormal Psychology. 1997;106(3):386.
23. Ueno K. The effects of friendship networks on adolescent depressive symptoms. Social Science Research. 2005;34(3):484-510.
24. Moeller RW, Seehuus M. Loneliness as a mediator for college students' social skills and experiences of depression and anxiety. Journal of Adolescence. 2019;73:1-13.
25. Nolan SA, Flynn C, Garber J. Prospective relations between rejection and depression in young adolescents. Journal of personality and social psychology. 2003;85(4):745.
26. Fitzgerald A, Fitzgerald N, Aherne C. Do peers matter? A review of peer and/or friends' influence on physical activity among American adolescents. Journal of adolescence. 2012;35(4):941-58.
27. Smith AL, Ullrich-French S, Walker E, Hurley KS. Peer relationship profiles and motivation in youth sport. Journal of Sport and Exercise Psychology. 2006;28(3):362-82.
28. Ullrich-French S, Smith AL. Social and motivational predictors of continued youth sport participation. Psychology of sport and exercise. 2009;10(1):87-95.
29. Phillips JA, Young DR. Past-year sports participation, current physical activity, and fitness in urban adolescent girls. Journal of physical activity and health. 2009;6(1):105-11.
30. Sollerhed A-C, Apitzsch E, Råstam L, Ejlertsson G. Factors associated with young children's self-perceived physical competence and self-reported physical activity. Health Education Research. 2008;23(1):125-36.

31. Opdal IM, Morseth B, Handegård BH, Lillevoll K, Ask H, Nielsen CS, et al. Change in physical activity is not associated with change in mental distress among adolescents: the Tromsø study: Fit Futures. BMC Public Health. 2019;19(1):916.
32. Christoffersen T, Winther A, Nilsen OA, Ahmed LA, Furberg A-S, Grimnes G, et al. Does the frequency and intensity of physical activity in adolescence have an impact on bone? The Tromsø Study, Fit Futures. BMC Sports Science, Medicine and Rehabilitation. 2015;7(1):26.
33. Strand BH, Dalgard OS, Tambs K, Rognerud M. Measuring the mental health status of the Norwegian population: a comparison of the instruments SCL-25, SCL-10, SCL-5 and MHI-5 (SF-36). Nordic journal of psychiatry. 2003;57(2):113-8.
34. Haavet OR, Sirpal MK, Haugen W, Christensen KS. Diagnosis of depressed young people in primary health care—a validation of HSCL-10. Family practice. 2010:cmq078.
35. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Medicine and science in sports and exercise. 1998;30(5):777-81.
36. Sagelv EH, Ekelund U, Pedersen S, Brage S, Hansen BH, Johansson J, et al. Physical activity levels in adults and elderly from triaxial and uniaxial accelerometry. The Tromsø Study. PloS one. 2019;14(12).
37. Ommundsen Y, Page A, Ku P-W, Cooper AR. Cross-cultural, age and gender validation of a computerised questionnaire measuring personal, social and environmental associations with children's physical activity: the European Youth Heart Study. International Journal of Behavioral Nutrition and Physical Activity. 2008;5(1):29.
38. Deforche BI, De Bourdeaudhuij IM, Tanghe AP. Attitude toward physical activity in normal-weight, overweight and obese adolescents. Journal of adolescent health. 2006;38(5):560-8.
39. Harter S. Self-perception profile for adolescents: University of Denver; 1988.
40. Wichstraum L. Harter's Self-Perception Profile for Adolescents: Reliability, validity, and evaluation of the question format. Journal of personality assessment. 1995;65(1):100-16.
41. Jozefiak T, Backer-Grøndahl A. Måleegenskaper ved den norske versjonen av Self-Perception Profile for Adolescents (SPPA). 2019.
42. IBMCorp. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp; 2017.
43. Hayes AF. Introduction to Mediation, Moderation, and Conditional Process Analysis A Regression-Based Approach. 2 ed. New York: Guildford Press; 2017.
44. Silva DRPd, Werneck AO, Collings P, Fernandes RA, Ronque ERV, Sardinha LB, et al. Identifying children who are susceptible to dropping out from physical activity and sport: a cross-sectional study. Sao Paulo Medical Journal. 2019;137:329-35.
45. Cheng LA, Mendonça G, Farias Júnior JCd. Physical activity in adolescents: analysis of the social influence of parents and friends. Jornal de Pediatria. 2014;90(1):35-41.
46. Beets MW, Vogel R, Forlaw L, Pitetti KH, Cardinal BJ. Social support and youth physical activity: the role of provider and type. American Journal of Health Behavior. 2006;30(3):278-89.

47. Edwardson CL, Gorely T. Parental influences on different types and intensities of physical activity in youth: A systematic review. Psychology of Sport and exercise. 2010;11(6):522-35.
48. Baron RM, Kenny DA. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of personality and social psychology. 1986;51(6):1173.
49. Motl RW, Dishman RK, Trost SG, Saunders RP, Dowda M, Felton G, et al. Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity among adolescent girls. Preventive medicine. 2000;31(5):584-94.
50. Carroll B, Loumidis J. Childrenís Perceived Competence and Enjoyment in Physical Education and Physical Activity Outside School. European Physical Education Review. 2001;7(1):24-43.
51. Fairclough S. Physical Activity, Perceived Competence and Enjoyment During High School Physical Education. European Journal of Physical Education. 2003;8(1):5-18.
52. Robbins LB, Sikorskii A, Hamel LM, Wu T-Y, Wilbur J. Gender comparisons of perceived benefits of and barriers to physical activity in middle school youth. Research in Nursing & Health. 2009;32(2):163-76.
53. Wu T-Y, Pender N, Noureddine S. Gender differences in the psychosocial and cognitive correlates of physical activity among taiwanese adolescents: A structural equation modeling approach. International Journal of Behavioral Medicine. 2003;10(2):93-105.
54. Oliver M, Badland HM, Schofield GM, Shepherd J. Identification of accelerometer nonwear time and sedentary behavior. Research quarterly for exercise and sport. 2011;82(4):779-83.
55. Syed S, Morseth B, Hopstock LA, Horsch A. Evaluating the performance of raw and epoch non-wear algorithms using multiple accelerometers and electrocardiogram recordings. Scientific Reports. 2020;10(1):1-18.
56. Vanhelst J, Béghin L, Drumez E, Coopman S, Gottrand F. Awareness of wearing an accelerometer does not affect physical activity in youth. BMC Medical Research Methodology. 2017;17:99.

APPENDIX

Approval from Regional Committee for Medical and Health Research Ethics (REK)

Written agreement between project leader and the Tromsø study

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK nord			08.06.2016	2016/987/REK nord
			Deres dato:	Deres referanse:
			03.05.2016	

Vår referanse må oppgis ved alle henvendelser

Kamilla Rognmo
Postboks 6050 Langnes

2016/987 Fysisk aktivitet og depresjon blant ungdom

Forskningsansvarlig: UiT Norges Arktiske Universitet
Prosjektleder: Kamilla Rognmo

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK nord) i møtet 26.05.2016. Vurderingen er gjort med hjemmel i helseforskningsloven (hfl.) § 10, jf. forskningsetikkloven § 4.

Prosjektleders prosjektomtale
Forebygging av depresjon blant ungdom kan være av stor betydning for folkehelsen. For å kunne forebygge er det viktig med kunnskap om kausale sammenhenger og underliggende mekanismer. Blant voksne foreligger det god indikasjon på at fysisk aktivitet kan forebygge depresjon, mens evidensgrunnlaget er langt tynnere for ungdom. Det finnes langt færre studier på den forebyggende effekten av fysisk aktivitet, og resultatene er blandet. Videre har de fleste studier benyttet selv-rapporterte data på fysisk aktivitet, med lav validitet. Vi planlegger å undersøke sammenhengen mellom objektivt målt fysisk aktivitet og depresjon hos ungdom ved bruk av data fra Fit Futures 1 og 2 (FF1 og FF2). FF1 ble samlet inn i 2010-11 og FF2 i 2012-13 blant utvalgte videregående skoler i Tromsø og Balsfjord kommune. 685 elever deltok i både FF1 og FF2, og objektive malinger av fysisk aktivitet ble gjort ved hjelp av akselerometer. Depresjon ble målt ved selvrapport.

Vurdering av om det avgitte samtykket er dekkende for studien
Det fremgår av informasjonsskrivet at et av fokusområdene for studien er fysisk aktivitet og vekt, personlighet og helseatferd. Det er således påregnelig at det vil bli forsket på disse data.

Samtykkeskrivet ansees som dekkende for studien.

Vedtak
Med hjemmel i helseforskningsloven §§ 2 og 10 godkjennes prosjektet.

Sluttmelding og søknad om prosjektendring
Prosjektleder skal sende sluttmelding til REK nord på eget skjema senest 30.06.2020, jf. hfl. § 12. Prosjektleder skal sende søknad om prosjektendring til REK nord dersom det skal gjøres vesentlige endringer i forhold til de opplysninger som er gitt i søknaden, jf. hfl. § 11.

Klageadgang
Du kan klage på komiteens vedtak, jf. forvaltningsloven § 28 flg. Klagen sendes til REK nord. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK nord, sendes klagen videre til

Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

May Britt Rossvoll
sekretariatsleder

Kopi til: ingunn.skre@uit.no

UIT
NORGES
ARKTISKE
UNIVERSITET

Tromsø-
undersøkelsen

Avtale

mellom

Tromsøundersøkelsen, Institutt for samfunnsmedisin, UiT Norges arktiske universitet

og

Kamilla Rognmo, Institutt for psykologi, UiT Norges arktiske universitet

om utvidelse av periode for rettigheter til forskningsdata fra Tromsøundersøkelsen

Prosjekttittel:

Physical activity and depression among adolescents: Results from Fit Futures

Viser til den opprinnelige avtalen, **24.2.2017, prosjektnummer 2620.00032,** mellom Tromsøundersøkelsen og **Kamilla Rognmo, UiT**. Avtalen bygger på skriftlig søknad med prosjektbeskrivelse og publikasjonsplan, samt godkjenning i Data og Publikasjonsutvalget for Tromsøundersøkelsen. Det forutsettes at arbeidet med data skjer i henhold til *Retningslinjer for tilgang til forskningsdata fra Tromsøundersøkelsen*, datert 6.2.2013.

Prosjektleder **Kamilla Rognmo, UiT** kan la samarbeidspartnere som er nevnt i prosjektsøknaden få analysere data, så fremt arbeidet holder seg innenfor rammen for prosjektbeskrivelsen og publikasjonsplanen. Prosjektleder har ansvar for datasikkerheten og at data oppbevares forsvarlig i hht lover og forskrifter.

Retten til data gjelder til **31.12.2021**. Når analysene er fullført, skal datasettet slettes og bekreftelse om dette sendes skriftlig til Tromsøundersøkelsen. Dette skal ikke skje senere enn **31.12.2021** med mindre ny avtale om forlengelse er inngått. Eventuelle nye data skal tilbakeføres til Tromsøundersøkelsen, jfr. pkt. 10 i retningslinjene.

Sted, dato

Tromsø, 9.12.2019

Prosjektleder

Sted, dato

Tromsø, 28.11.2019

For Tromsøundersøkelsen