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Psykisk hälsa och fysisk aktivitet under ungdomsåren

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DOKTORSAVHANDLING | Karlstad University Studies | 2018:32
Mental health and physical activity in adolescence

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Faculty of Health, Science and Technology
Public Health Science

DOCTORAL THESIS | Karlstad University Studies | 2018:32
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Karlstad University Studies | 2018:32

urn:nbn:se:kau:diva-68646

ISSN 1403-8099

ISBN 978-91-7063-865-7 (print)


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Distribution:
Karlstad University
Faculty of Health, Science and Technology
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SE-651 88 Karlstad, Sweden
+46 54 700 10 00

Print: Universitetstryckeriet, Karlstad 2018
ABSTRACT

Background: In 2017, the World Health Organization (WHO) reported that half of all mental health disorders in adulthood appear to start by age 14, but most cases are undetected. In Norway, an increasing number of adolescents are reporting mental health problems. Supporting young people at this formative and critical stage of transition is important. Although physical activity is often suggested to play an important role in the prevention and promotion of adolescent mental health, research carried out to date presents a somewhat mixed picture.

The majority of studies addressing the relationship between physical activity and mental health have been cross-sectional. Longitudinal studies in young people – including linkage studies that make use of national registers – have been more rarely used. How physical activity frequency, volume and context (sports club, gym, exercise independently and other organized physical activities) might relate to symptoms of depression is, in particular, still unclear, especially among adolescents. When investigating social interactions in connection to physical activity, most previous research has focused on the team sport context. There is, therefore, a pressing need for further studies that explore the aforementioned gaps in the research field.

Aim: The overall aim of this thesis is to examine the association between physical activity and mental health among Norwegian adolescents aged 15-16 years.

Method: This thesis is based on four studies. Study I and II used data retrieved from the Norwegian Youth Health Study (NYHS) conducted by the Norwegian Institute of Public Health in Hedmark County. In 2001, the students completed a paper and pencil self-administered questionnaire at school; in 2009 students completed a web-based questionnaire at school. Altogether, 3311 adolescents participated (aged 15-16), 1975 in 2001 and 1336 in 2009. In study I the psychometric properties of the Hopkins symptoms checklist-10 (HSCL-10) were analyzed using Rasch Measurement Theory. In study II changes in
physical activity and psychological distress were studied. Multinomial regression analysis was used to analyze the association between physical activity, screen-based sedentary behavior and psychological distress. Study III was based on information retrieved from the NYHS conducted in five counties (Hedmark, Oppland, Troms, Finnmark and Oslo) between 2000 and 2003 (10711 participants) and linked to prescription data from the Norwegian Prescription Database (NorPD, 2004-2013) which covers the entire Norwegian population. Multinomial regression analysis was used to investigate the association between physical activity and subsequent use of antidepressant and hypnotic drug use. The data in this study were patients’ unique personal identity number (encrypted), drug information (ATC code, the amount dispensed in defined daily doses [DDDs]), gender and age. Study IV is based on cross-sectional data retrieved from the Ungdata surveys conducted in municipalities by Norwegian Social Research (NOVA) in cooperation with regional centres for drug rehabilitation (KoRus). Ungdata is financed by the Norwegian Directorate of Health, The Ministry of Children, Equality and Social Inclusion, and the Ministry of Justice and Public Security. A web-based questionnaire was administered anonymously at school during a school hour with a teacher present. Binomial logistic regression analysis was used to study the association between different types of physical activity taking place in different context (sports club, gym, exercise independently and other organized physical activities) and symptoms of depression in Norwegian adolescents.

**Results:** Study I: The Rasch analysis of HSCL-10 indicated good reliability and, overall, the items worked well. However, the item ‘sleeping difficulties’ misfit according to the Rasch model. Some items worked differently between years of investigations and for girls and boys. The targeting of the scale could be improved. Study II: Self-reported psychological distress among the students increased between 2001 and 2009, the proportion of girls reporting distress being twice as large as the proportion of boys. The proportion of students being physically active ≥11 h per week and sedentary behavior ≥6 h per week increased in the same period. Physical activity (≥11h) and sedentary behavior (≥6h) after school were associated with psychological distress.
Study III: Physical activity did not indicate any associations with later use of antidepressants. A significant association with incident hypnotic drug use was found for the short time follow-up period only and disappeared on longer term follow-up. Study IV: Participation in a sports club was associated with significantly fewer symptoms of depression.

Conclusions: The results reported in this thesis indicate only a weak association between physical activity and mental health among adolescents when volume and frequency are used to measure physical activity. A more distinct pattern appears when not just the frequency and volume, but also the context of the physical activity is taken into account. Participating in a sports club was associated with significantly fewer symptoms of depression compared to no regular exercise, and after controlling for socio-economic conditions, specific health-related behaviours as well as other background variables. Hence, the results underline the need for broader approaches in studies of the association between physical activity and mental health in general and specifically in relation to adolescents. Both physical activity and mental health are complex phenomena and need to be operationalised as such in research exploring the relationship between the two. How mental health is operationalised and measured may have an impact on its relationship with physical activity, for example, when different sample groups are compared. The Rasch analysis of the psychometric properties of the HSCL-10 also adds to the research field. Because of the designs of the studies included in the thesis, no firm conclusions about causality can be made.
Sammendrag

Bakgrunn: I 2017 rapporterte Verdens Helseorganisasjon (WHO) at halvparten av alle psykiske lidelser hos voksne ser ut til å starte i 14 års alderen, og at de fleste tilfellene er uoppdaget. I Norge har det blitt rapportert om en økning i psykiske helseproblemer hos ungdommer. Det er viktig å støtte unge mennesker på dette formative og kritiske stadium i overgangen fra ungdom til voksne. Selv om fysisk aktivitet vanligvis antas å spille en viktig rolle i forebygging og helsefremming av ungdoms psykisk helse, har forskning på området hittil vist et noe blandet resultat.

De fleste studier som har undersøkt assosiasjonen mellom fysisk aktivitet og psykisk helse har vært tverrsnitts studier. Longitudinelle studier gjennomført blant unge - inkludert koblingsstudier mellom nasjonale registre - er det få som har gjennomført. Hvordan fysisk aktivitet, frekvens, volum og kontekst (idrettslag, treningsstudio, selvstendig trening og andre organiserte idretter) kan relateres til depresjonssymptomer er fortsatt uklart, særlig blant ungdommer. Når sosiale aspekter ved fysisk aktivitet har blitt undersøkt, har mye av den tidligere forskningen fokusert på lagspill. Det er et behov for studier som ser nærmere på disse gapene i forskningen.

Mål: Det overordnete målet med denne avhandlingen er å undersøke assosiasjonen mellom fysisk aktivitet og psykisk helse blant Norske ungdommer i alderen 15-16 år.


CONTENT

ABSTRACT ...................................................................................................................... 1
SAMMENDRAG ............................................................................................................ 4
CONTENT ..................................................................................................................... 7
LIST OF PAPERS ....................................................................................................... 9
AUTHOR CONTRIBUTIONS ................................................................................. 10
ABBREVIATIONS ..................................................................................................... 11
INTRODUCTION ....................................................................................................... 12
Mental health and physical activity in adolescence as a public health concern ...................................................................................................................... 12
Adolescence ............................................................................................................ 13
  Mental disorders ................................................................................................... 15
  Psychological distress ........................................................................................... 16
Mental health in adolescence ................................................................................ 17
  Measuring mental health ..................................................................................... 19
  Trends in adolescents’ mental health .................................................................. 21
Physical activity in adolescence .......................................................................... 22
  Sedentary behavior in adolescence .................................................................... 24
  Measuring physical activity ............................................................................... 26
  Trends in adolescents’ physical activity ............................................................... 27
Physical activity, sedentary behaviour and mental health .................................. 29
  Other factors associated with mental health ....................................................... 32
  Gender .................................................................................................................. 32
  Social inequalities ............................................................................................... 33
  Overall conclusion ............................................................................................. 34
OVERALL AIM .......................................................................................................... 35
MATERIAL AND METHODS ............................................................................. 36
  Data collection, study design and participants .................................................. 36
    Table. Method summery of studies I-IV .......................................................... 39
  Data analysis ...................................................................................................... 40
  Ethical considerations ......................................................................................... 44
RESULTS .................................................................................................................. 45
  Study I .................................................................................................................. 45
  Study II .................................................................................................................. 47
  Study III ............................................................................................................... 48
  Study IV ............................................................................................................... 49
DISCUSSION ........................................................................................................... 50
Methodological discussion – strengths and weaknesses ............ 60

CONCLUSIONS AND IMPLICATIONS ................................................................. 64
FUTURE STUDIES .......................................................................................... 65
ACKNOWLEDGEMENTS .............................................................................. 66
REFERENCE .................................................................................................. 68
LIST OF PAPERS


IV. Annette Løvheim Kleppang, Ingeborg Hartz, Miranda Thurston and Curt Hagquist. The association between physical activity and symptoms of depression in different contexts – a cross-sectional study of Norwegian adolescents (Submitted)

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AUTHOR CONTRIBUTIONS

Study I
Annette Løvheim Kleppang participated in the design of the study, conducted the statistical analysis and interpretation of data and drafted the manuscript. Curt Hagquist participated in the design of the study, participated in the data analysis and helped to draft the manuscript. All authors read and approved the final manuscript.

Study II
Annette Løvheim Kleppang participated in the design of the study, conducted the statistical analysis and interpretation of data and drafted the manuscript. Ingeborg Hartz and Miranda Thurston helped to draft and provided a critical review of the manuscript. Curt Hagquist participated in the design of the study, participated in the data analysis and helped to draft the manuscript. All authors read and approved the final manuscript.

Study III
Annette Løvheim Kleppang participated in the design of the study, conducted the statistical analysis and interpretation of data and drafted the manuscript. Miranda Thurston helped to draft and provided a critical review of the manuscript. Curt Hagquist and Ingeborg Hartz participated in the design of the study, participated in the data analysis and helped to draft the manuscript. All authors read and approved the final manuscript.

Study IV
Annette Løvheim Kleppang participated in the design of the study, conducted the statistical analysis and interpretation of data and drafted the manuscript. Curt Hagquist participated in the design of the study, participated in the data analysis and critically revised the manuscript. Ingeborg Hartz and Miranda Thurston provided a critical review of the manuscript. All authors read and approved the final manuscript.
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>ATC</td>
<td>Anatomical Therapeutic Chemical</td>
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<tr>
<td>C.I</td>
<td>Confidence interval</td>
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<tr>
<td>DIF</td>
<td>Different Item Functioning</td>
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<td>DSM-V</td>
<td>Diagnostic and Statistical Manual V</td>
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<tr>
<td>EVC</td>
<td>Expected values curves</td>
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<tr>
<td>HBSC</td>
<td>Health Behavior in School-aged Children-study</td>
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<td>HSCL-10</td>
<td>Hopkins Symptoms Checklist-10</td>
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<tr>
<td>ICD-10</td>
<td>The International Statistical Classification of Diseases and Related Health Problems</td>
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<td>KoRus</td>
<td>Regional centres for drug rehabilitation</td>
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<tr>
<td>MET</td>
<td>Metabolic equivalent of task</td>
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<tr>
<td>N05A</td>
<td>Antidepressants</td>
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<td>N05C</td>
<td>Hypnotics</td>
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<td>NorPD</td>
<td>Norwegian prescription database</td>
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<td>NOVA</td>
<td>Norwegian Social Research</td>
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<td>NYHS</td>
<td>Norwegian Youth Health study</td>
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<td>PA</td>
<td>Physical activity</td>
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<td>PCA</td>
<td>Principal component analysis</td>
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<td>PSI</td>
<td>Person separation index</td>
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<td>R06AD01</td>
<td>Alimemazine</td>
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<td>SB</td>
<td>Sedentary behavior</td>
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<tr>
<td>UNCRC</td>
<td>The UN Convention on the Rights of a child</td>
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<td>WHO</td>
<td>The World Health Organization</td>
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INTRODUCTION

Mental health and physical activity in adolescence as a public health concern

Historically, the concept of childhood mental illness did not emerge until the late 19th century, and was not seen as distinct from adult mental illness until the early part of the 20th century (Hoagwood, 1997). In more recent times, there are signs in many countries that mental illness among children and young people is increasing. Kieling et al. (2011), reported an overall world-wide prevalence of between 10-20% of children who have one or more mental or behavioral problems. Of note from a public health perspective, is that half of many adult mental health issues appear to start in childhood or adolescence (Kessler et al., 2005). Adolescents who reported an internalizing disorder at both 13 and 15 years, were more likely to report a mental disorder as adults compared to those who reported no internalizing disorder or once, either at age 13 or age 15 (Colman, Wadsworth, Croudace, & Jones, 2007).

In Norway, the mental health of children and young people has been a matter of concern for the Government since the late 1990s (Ådnanes & Halsteinli, 2009). The Norwegian Government has recently published a strategy plan for good mental health (Departementene, 2017). Children and adolescents have received special attention in this document. Two main goals (of five) in this plan are as follows: 1) mental health should be an equal part of public health work and 2) promoting good mental health in children and adolescents. The strategy plan refers to the need for more and better data on children's and young people's mental health, and the need for more clinical research.

In 1953, Morris et al. reported an increased risk of coronary heart disease in bus drivers (sedentary) compared with conductors (physically active) from London. Since then, many studies have shown that a lack of physical activity is a major risk factor for morbidity and premature mortality, particularly in relation to cardiovascular disease but also
more widely. Morris (1994) described physical activity as the ‘best buy’ for public health. A number of countries worldwide have a national physical activity plan or policy plan, despite this, levels of physical activity have not improved (Sallis et al., 2016).

**Adolescence**

In this thesis, adolescents aged 15-16 years have been studied. The concept ‘adolescent’ is typically used to denote individuals between the ages of 10 and 19 (WHO, 2018b). The UN Convention on the Rights of a child (UNCRC) defines the child chronologically as a member of society under the age of 18 years (United Nations, 1989). The UNCRC was established in 1989 and adopted in Norway in 1991. Blakemore and Mills (2014, p. 188) define adolescence ‘as the period that begins with the physical, cognitive and social changes occurring with the onset of puberty’. Although the timing varies from person to person as well as differences between boys and girls, it is a period when an individual undergoes major psychological, physical and social changes. In this period, there is a formative biological and social transition, and studies have demonstrated that the social cognition and social brain undergo profound development (Blakemore & Mills, 2014). The impact of puberty on the brain in adolescents makes them particularly sensitive to their social environment (Peper & Dahl, 2013), that is to say, the trajectory of development is influenced by the social environment and, in particular, the social experiences mediated through the people in the varying milieu within which their lives develop. The views of peers tend to become more important for adolescents than family members over time; they go through a period of reorienting. The social brain and social cognition undergo a profound period of development in adolescence; it is a period for the processing and acquisition of sociocultural knowledge (Blakemore & Mills, 2014).

Taking a life course perspective reveals that half of all mental health disorders in adulthood appear to start by the age 14, but most of them are undetected and untreated (WHO, 2018a). This suggests that pre-
vention of mental illness and promotion of mental health should be targeted during childhood and adolescence if the adult burden of disease is to be reduced. A life course perspective also gives emphasis to adolescents’ health being affected by early childhood development and the social and biological experiences that accompany puberty, shaped by social determinants and health-related behaviors, and the onset of these behaviors affect the burden of disease in adults (Sawyer et al., 2012). Six domains have been identified as being important in this regard: ‘give every child the best start in life, enable all children, young people and adults to maximize their capabilities and have control over their lives, create fair employment and good work for all, ensure a healthy standard of living for all, create and develop healthy and sustainable places and communities and strengthen the role and impact of ill-health prevention’ (Marmot et al., 2010, p. 22). Processes in one phase both affect and are affected by events later in life. A recent meta-analysis of prospective cohort studies indicated that higher levels of physical activity offer a protective effect on future development of depression for youths, working age adults and elderly people across geographical regions around the world (Schuch et al., 2018).

Adolescence is an important period in life during which the opportunities for good health and the foundations for future patterns of adult health are established (Sawyer et al., 2012). Studying young people at this formative and critical stage of transition is important, not least because of the shifting pattern of youth physical activity. To improve adolescents’ health, it is necessary to focus on factors that are promotive and protective across various health outcomes, and improve their daily lives in their family, among peers and in schools (Viner et al., 2012).

A meta-analysis reported that a gender difference in depression symptoms peaks in adolescents aged 16, with the gender gap in depression diagnoses emerging earlier (aged 12) than previously thought, which represents a major health disparity. However, the gender gap becomes smaller and remains stable in adulthood (Salk, Hyde, & Abramson, 2017).
Mental disorders

Depressive disorders account for more than 44 million years lived with disability, and are the second leading cause of the global burden of illness (Vos et al., 2016). A mental disorder or illness is diagnosed when a pattern of symptoms and signs are identified by a medical practitioner that are associated with social and psychological functioning and which meet criteria for disorders under an accepted system and classification (Gustafsson et al., 2010). In 1948, the WHO inherited the Statistical Classification of Diseases, Injuries and Causes of Death (ICD) from a previous system which used medical classification as a system to denote cause of death. The WHO introduced psychiatric diseases in ICD-6 in 1949, which became ICD-10 in 1992 (10th version). 'Mental disorders', is a concept used to denote a range of mental and behavioral disorders that fall within the International Statistical Classification of Diseases and Related Health Problems (ICD-10) or the Diagnostic and Statistical Manual V (DSM-V). These include disorders that cause a high burden of disease such as, bipolar affective disorder, depression, schizophrenia, intellectual disabilities, anxiety disorders, dementia, substance use disorders, and developmental and behavioral disorders with onset usually occurring in childhood and adolescence, including autism (WHO, 2013).

If symptoms of depression are primarily caused by a poor relationship with a family member, then these problems will not be resolved by the use of antidepressants (Johansson, Jørgensen, Getz, & Moynihan, 2016). ’A more laidback and listening approach from the doctor might favor salutary choices with great importance to health and might represent greater respect for individual autonomy then offering medical choices the patient did not ask for’ (Johansson et al., 2016, p. 3). This is relevant to the issue of using statistics on mental health, i.e., incident use of psychotropic drugs, but also how young people evaluate their own mental health through instruments such as the HSCL-10 and a scale measuring symptoms of depression.
**Psychological distress**

Within the research field, several terms for mood disorders are used. For example, symptoms of depression and anxiety, depression, depressive symptoms, mental distress and psychological distress are used. In the current studies, the term 'psychological distress' is used in order to focus on the literature and studies of symptoms of both depression and anxiety. As such, it has been the focus of many studies that have explored risk and protective factors associated with it. Psychological distress is often used as an indicator of mental health in population-based studies. In this thesis, the most widely accepted definition of psychological distress was used, i.e., 'a state of emotional suffering characterized by symptoms of depression and anxiety' (Mirowsky & Ross, 2002). Thus, it refers to those without a diagnosis but who can be identified from their responses to a survey instrument or scale. Psychological distress is viewed as an emotional disturbance that may impact on the social functioning and day-to-day living of individuals (Wheaton, 2007). It is consistent with a normal emotional reaction to a stressor and viewed as a transient phenomenon (Horwitz, 2007). A major problem with the construct of psychological distress is its different meanings in the scientific literature. All tend to use a combination of symptoms relating to depression and general anxiety, personality traits, functional disabilities and behavioral problems (Drapeau, Marchand, & Beaulieu-Prévost, 2012).

Two important things are observed when investigating psychological distress: the widespread gender difference, and, the variation at different stages of life (Drapeau et al., 2010). Psychological distress is considered a risk factor for developing mental illness and may be used as an indicator in the work with health promotion and disease prevention. Thus, monitoring changes in psychological distress among adolescents over time, and exploring the relationships between psychological distress and physical activity among adolescents is relevant to explore, because it has implications for public health strategies.
Mental health in adolescence

The World Health Organization (WHO) has identified mental health problems in adolescents as a key public health issue. The WHO defined health in 1946 as ‘a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity’ (WHO, 1948, p. 16). This implies health as a final goal, and includes both physical, mental and social well-being (Medin & Alexanderson, 2000). This definition asserts that health is more than the absence of disease or illness, however it has been criticized over the years for being too static; that is to say, it overlooks the dynamic development of health over time and in relation to circumstances (Huber et al., 2011). In Ottawa in 1986 the definition was revised to reflect the view that health was a resource for daily life and not only an objective (WHO, 1986). The Ottawa Charter, produced at the same time (1986) also gave recognition to the social determinants of health. More recently the WHO has developed a distinct definition of mental health as ‘a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community’ (WHO, 2018b).

Mental health problems can appear in many different forms, for example internalizing and externalizing problems. Internalizing problems refer to emotional problems, such as depression and anxiety. These negative emotions are directed inwards towards the person him- or herself rather than outwards towards others. Psychosomatic problems, such as abdominal pain and headache are also often seen as a part of internalizing problems (Gustafsson et al., 2010). Externalizing problems refer to behavioral problems such as hyperactivity, attention deficit, antisocial behavior and conduct disorders. These behavioral problems consist of negative emotions against others, i.e. aggression, anger, fear and frustration (Gustafsson et al., 2010).

Positive aspects of mental health, such as psychological, emotional and social wellbeing are also increasingly recognized as related to mental health: for example self-esteem, self-determination, sense of belonging and quality of life (Rose et al., 2017). Previous studies on mental health
among adolescents have mainly focused on mental disorders and mental health problems (Clarke et al., 2011). Absence of illness, however, does not necessarily mean that people are mentally well. Mental health measurements have traditionally focused on lower levels of illness symptoms as being indicative of wellbeing (Rose et al., 2017). Instruments measuring wellbeing are important in public health science, especially when promoting mental health in adolescents and evaluating the outcome of mental health promotion interventions. A few scales have been developed to measure mental wellbeing among adolescents – see for example, the Warwick Edinburgh Mental Wellbeing Scale (Smith, Alves, Knapstad, Haug, & Aarø, 2017).

Mental health has emerged as a specific concern in public health in recent years, particularly in relation to adolescence. In all societies, mental health accounts for a large proportion of the disease burden in young people, often emerging during youth, although frequently diagnosed later in life (Patel, Flisher, Hetrick, & McGorry, 2007). Psychiatric health problems are estimated to be one of the biggest global health challenges by 2020 (WHO, 2004). Given that there seems to be a general conception that physical activity might affect adolescents’ mental health in a positive way, it could constitute an important protective factor. However, the evidence base presents a rather mixed picture.

A minority of Norwegian adolescents with symptoms of depression and anxiety (quite distressed group) seek help from parents, other adults, friends or professionals (Moen & Hall-Lord, 2018). Even among the ten percent who have the worst problems, only one in four seeks help and most often this is from general practitioners. (Zachrisson, Rödje, & Mykletun, 2006). A study of 18-19 year olds in Hedmark and Oslo found that 12-13% of girls and 4% of boys reported experiencing problems that they sought help for during the last year (Folkehelseinstituttet, 2014).

Studies have indicated negative effects of internalizing problems on academic achievement (Fletcher, 2008; Patel et al., 2007), and young people experiencing depression or anxiety disorder are less likely to complete secondary school (Bowman, McKinstry, & McGorry, 2017). However, both mental disorders and somatic conditions are more
significant predictors of dropout among girls than among boys (Mikkonen, Moustgaard, Remes, & Martikainen, 2018).

Instead of giving people a diagnosis, it is possible to assess the type and severity of symptoms using instruments or scales or indexes to measure mental health (Mirowsky & Ross, 2002).

**Measuring mental health**

Self-reported data are often used in large-scale population-based surveys. Many different scales and instruments are used, especially in epidemiological studies. Many studies are actually measuring mental illness, for example, anxiety and depression of psychological distress, rather than mental health in a ‘wellbeing’ sense.

A large number of studies have explored the relationship between various risk and protective factors and psychological distress. However, the results range from convincing, to conflicting. The discrepancies between findings from different studies can sometimes be attributed to variation in the design of the studies and the specific instrument used to measure psychological distress. Psychological distress is assessed with self-administered instruments, scales or through clinician interview. Several instruments and scales have been developed to measure psychological distress, for example: Hopkins Symptom Checklist (HSCL) (Derogatis, Lipman, Rickels, Uhlenhuth, & Covi, 1974), The General Health Questionnaire (GHQ) (French & Tait, 2004), The Kessler scales and Hospital Anxiety and Depression Scale (HADS) (Kessler et al., 2002).

The prevalence of psychological distress among youth is difficult to assess due to the variety of instruments used and the cut off-points applied to dichotomize the score of psychological distress (Drapeau et al., 2012). The development of an instrument designed to measure psychological distress is a lengthy process. For example, the Hopkins Symptom Checklist-10 (HSCL-10) has been used as a scored instrument in several epidemiological studies among adolescents (Sagatun, Kolle,
Anderssen, Thoresen, & Sogaard, 2008). Haavet, Sirpal, Haugen, and Christensen (2011) confirmed that the HSCL-10 is a valid instrument for the identification of depression in adolescents in epidemiological research within this age group. However, the instrument has not been psychometrically examined with respect to invariance across years of investigation using Rasch Measurement Theory. A fundamental feature of the Rasch model is that it provides measurement that does not depend on the distribution of the people involved, given that the data fit the Rasch model (David Andrich, 1988). This enables invariant comparisons across the latent variable as well as across different sample groups. Some items of the scales used to assess psychological distress are more frequently endorsed by women than by men but this difference in item functioning does not appear to account completely for the gender difference in psychological distress (Drapeau et al., 2010). This shows the importance of having validated instruments and scales to measure psychological distress, and of psychometric testing of instruments and scales among adolescents.

In this thesis (study III) the incident use of psychotropic drugs has been used as an indicator of diagnosed mental illness. Incident use of psychotropic drugs using the Norwegian prescription database (NorPD) is an outcome that can help us understand if physical activity has a role in preventing future mental health issues. In children and adolescents, the use of psychotropic drugs for the treatment of psychiatric disorders has increased considerably in the last two decades in Western countries (Steinhausen, 2015; Thomas, Conrad, Casler, & Goodman, 2006). The majority of psychotropic drugs are not formally approved for use in adolescence, which results in an off-label (Pagsberg & Thomsen, 2017), meaning that the drugs are used outside the authority-approved specification regarding indication, dose, age and route of administration and duration of treatment (Nielsen et al., 2017). In this thesis the incident use of antidepressants and hypnotics was used as a mental health measure in order to explore the relationship between physical activity and mental health.
Trends in adolescents’ mental health

Monitoring population trends in mental health problems is important if preventive efforts and mental health services are to be appropriately targeted (Collishaw, 2015). In recent years policy makers in many Western developed countries have expressed increasing concern about young people’s mental health and wellbeing. Depressive symptoms in adolescents are an important public health issue in Norway and in most Western countries. Although trends are complex (Collishaw, 2015; Sweeting, West, Young, & Der, 2010) there is some agreement that, there has been an increase in mental health problems among young people (Bor, Dean, Najman, & Hayatbakhsh, 2014; Collishaw, 2015), together with an earlier age of onset for mood and anxiety disorders (Lijster et al., 2017), with three-quarters of mental disorders starting by the mid-20s (Kessler et al., 2007). Psychological distress has been identified as a risk factor for the development of later mental disorders.

Large nationwide register-based studies (Norwegian and Danish), reported high and increasing rates of off-label use of hypnotic and sedatives, that was largely driven by the hypnotic drug melatonin (Hartz, Furu, Bratlid, Handal, & Skurtveit, 2012; Nielsen et al., 2017). Psychotropic drug use has increased in adolescents, attributed mainly to stimulants and hypnotics/sedatives. There is a higher level of psychotropic drug use in adolescent girls compared to boys (Hartz, Skurtveit, Steffenak, Karlstad, & Handal, 2016). An increasing use of antidepressants among 0–17 year olds is observed in Denmark between 1995 and 2011 (Pottegård, Zoëga, Hallas, & Damkier, 2014). A study reported that incident use of psychotropic drugs before the age of 25 was doubled among adolescents (both genders) age 15-16 years who reported psychological distress, compared with adolescents who reported no psychological distress (Steffenak et al., 2012).

In a systematic review (Bor et al., 2014) that included 19 studies, 17 of these examined internalizing problems among participants aged 18 years and under. They found that internalizing problems increased over time among adolescent girls; however, the findings in boys were mixed. A cohort study (1987-2006) carried out in the West of Scotland
among adolescents aged 15, showed an increase in self-reported psychological distress for both boys and girls, but higher for girls (Sweeting et al., 2010). A Health Behaviour in School-aged Children study (HBSC) analyzed trends from 1994-2010 in multiple recurrent health complaints in adolescents (aged 15 years) in 35 countries. They found that in seven countries (Croatia, Greece, Macedonia, Portugal, Slovenia, Spain and Ukraine) there was a linear decline across cohorts; in five countries (Belgium-Flemish, Denmark, Finland, Greenland and Norway) a linear increase was found. Further, a U-shaped trend was observed in four countries (Austria, Canada, Czech Republic and Scotland); an inverted U-shaped trend was observed in six countries (England, Estonia, Lithuania, Poland, Slovakia, Sweden), and unstable patterns in the remaining counties (Ottová-Jordan et al., 2015). This study indicates a high degree of variation between countries in health complaints among adolescents aged 15.

A Swedish study reported a significant increase in self-reported mental health complaints from 1985 to 2006 among adolescents (15 year), particularly among girls (Hagquist, 2010). Results from a survey from an urban area in Norway (Oslo) indicated an increase in depression and a decline in behavioural problems between 1999 and 2002 (Øia, 2012). A Norwegian trend study showed that the prevalence of high scores on depressive symptoms increased significantly between 1992 and 2002 among adolescent girls and boys, however no significant changes were observed between 2002 and 2010 among either boys or girls (von Soest & Wichstrøm, 2014). These results indicate a need for further studies on changes, trends and gender differences in adolescent’s mental health.

Physical activity in adolescence

Development of new technologies has enabled people to reduce the amount of physical activity needed to accomplish many tasks in their daily lives. Physical activity can be defined as ‘any bodily movement produced by skeletal muscles that result in expenditure of energy, and can be categorized into sports, conditioning, occupational, household
and other activities’ (Caspersen, Powell, & Christenson, 1985, p. 126). The definition has been modified by determining the ratio of the work metabolic expenditure of energy (Metabolic Equivalent of Task, MET). One MET (1 kcal/kg/hour) is the energy expended at rest, and is roughly equivalent to the energy cost of sitting quietly (Ainsworth et al., 2011). The concept of METs is a convenient and useful way to describe the intensity of a variety of physical activities. In 2008, Ridley, Ainsworth, and Olds (2008) developed a compendium of energy expenditures for youth, a constant MET value for each activity provided for all children aged 5–17 years. A new Youth Compendium of Physical Activities has been developed and presents MET values across four groups: age 6–9, 10–12, 13–15, and 16–18 year for 196 activities (Butte et al., 2018).

The term ‘physical activity’ is used variously in the literature, depending on how it is measured and the objectives of the research. In a letter to the editor in the Journal of Autoimmunity Reviews, Budde (2016) commented on a review article written by Rochette, Duché, and Merlin (2015), on the need for differentiating between exercise, physical activity, and training. The review used different terms for physical activity i.e., ‘PA’, ‘exercise’, ‘acute exercise’, ‘chronic exercise’, ‘exercise training’, ‘training’, ‘prolonged training’, ‘physical training’, ‘physical exercise programs’, and ‘physical fitness’. However the review did not provide specific definitions, such that it was difficult to know which studies could be adequately interpreted and compared (Budde, 2016). In this thesis, physical activity have been used and measured by self-report data (hours per week and times per week) and physical activity contexts (times per week).

Recommendations published by the World Health Organization (WHO, 2010), state that children and adolescents should spend at least 60 minutes of moderate- to vigorous physical activity each day. Globally, a substantial proportion of young people fail to meet physical activity guidelines and, moreover, the proportion meeting the guidelines declines during the transition from childhood to adolescence (Corder et al., 2013). In countries with survey data, less than one in every four adolescents meets these guidelines for physical activity. Worldwide, a majority of adolescents (aged 13-15) do not meet the guidelines, with
approximately 80 % being insufficiently active to benefit their health (Hallal et al., 2012). A survey in Norway reported that in 2011-2012, 42 % of girls and 57 % of the boys age 15 followed the Norwegian government’s recommendations (Dalene et al., 2018). The same study showed that from 9–15 years, time spent in moderate- to vigorous physical activity per day reduced by more than 25 %, and time spent being sedentary increased by 20 %.

**Sedentary behavior in adolescence**

Tremblay et al. (2011) defines sedentary behavior as any waking behavior characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture. The term is used differently among researchers, however, depending on their research area. Many researchers from the sport and exercise field describe participants as sedentary because they do not meet the global physical activity guidelines. These different definitions of the term sedentary can lead to confusion when researchers compare results. In this thesis the specific term ‘sedentary leisure screen time’ has been used, which is a part of sedentary behavior and is consistent with Tremblay et al.’s definition. Some countries (Australia, Canada) have developed guidelines/recommendations for sedentary behavior, stating that adolescents should spend no more than 2 hours per day engaging in screen-based activities such as TV viewing (Carson et al., 2016; Tremblay et al., 2011).

In June 2016, Canadian 24-Hour Movement Guidelines for Children and Youth aged 5-17 years, were released. (Tremblay et al., 2016). The guidelines are described as behaviors across the whole day, comprising a combination of sleep, sedentary behaviors and physical activity (light, moderate and vigorous). The guideline includes the following: children and youth should achieve high levels of physical activity (at least 60 min/day with moderate- to high activity. High activity, muscle and bone strengthening should be incorporated at least 3 times a week and several hours of light intensities should be added), low levels of seden-
tary behavior (less than 2 h/day for recreational screen time and limited sitting) and sufficient sleep each day (8-10 hours for those aged 14-17 years) (Tremblay et al., 2016).

A recent study among adolescents aged 15 years, reported that both girls and boys in the 2011-2012 cohort spent more time being sedentary compared to their peers in the 2005-2006 cohort (Dalene et al., 2018). In recent years, sedentary behavior has been the subject of increasing attention (Iannotti & Wang, 2013; Katzmarzyk, 2010; Pearson, Braithwaite, Biddle, Sluijs, & Atkin, 2014). The amount of sedentary behavior among adolescents has increased during the last decade in many parts of Europe and North America (Bucksch et al., 2016).

To a large degree these recommendations have been based on evidence relating to the prevention of chronic non-infectious physical diseases rather than mental health outcomes. It is important that a clear distinction between ’low levels of physical activity’ and ’sedentary behavior’ is made, because evidence indicates that even those meeting the guidelines for physical activity may still accumulate considerable sedentary time, which may be an independent risk factor for mental health (Marshall, Biddle, Sallis, McKenzie, & Conway, 2002; Pearson et al., 2014). Increasingly independent decision-making among young people may influence physical and sedentary behavior, which may also influence their mental health, thus making it an important period to study.

Sedentary behavior such as computer use and TV viewing has tended to be viewed as taking time away from physical activity (the ’displacement hypothesis’), that is to say, one behavior (sedentary) displaces another behavior (physical activity) (Mutz, Roberts, & Vuuren, 1993). However, other studies have not confirmed this theory (Iannotti et al., 2009). There is little association between sedentary behavior and moderate to vigorous physical activity, and it is possible for an individual to accumulate both physical activity and be sedentary in the course of a day (Owen, Healy, Matthews, & Dunstan, 2010). A review concluded that sedentary behavior was inversely associated with physical activity in young people (Pearson et al., 2014), however, the relationship was weak. This means that physical activity and sedentary behavior should not be considered functional opposite. Too little physical activity and
too much sedentary behavior represent separate and distinct risk factors for health outcomes, and there is no real competition between them (Tremblay, Colley, Saunders, Healy, & Owen, 2010).

Measuring physical activity

For practical reasons, self-report via a questionnaire is the most commonly used method to measure physical activity in large epidemiological surveys. There are several limitations with self-report: recall bias, cross-cultural differences and misinterpretation of questions. The use of accelerometers for the objective measurement of physical activity in international studies has become more common, because they theoretically allow the elimination of these types of bias (Corder & Van Sluijs, 2010).

The number of youth meeting current physical activity guidelines varies by assessment method and the intensity thresholds used when physical activity is measured by accelerometry. Objective measurements of physical activity complemented by existing self-report instruments should be internationally standardized (Ekelund, Tomkinson, & Armstrong, 2011), but this is not always the case. Self-reported measures of sedentary behavior and physical activity, might lead to misclassification or measurement error. The use of more direct measures for these behaviors (i.e. accelerometer) has the potential to avoid some of the inherent limitations of self-report instruments, such as recall bias. However their use creates prohibitive logistical issues and a cost burden for many researchers as they are expensive. They also require considerable technical expertise and extensive data processing (James et al., 2016), made more complex by the increasing diversity of methods used to process and score accelerometer data (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013). There are also concerns that using accelerometers, limits the measurement of lifting weights, upper body movements, bicycling and activities in water such as swimming (Slootmaker, Schuit, Chinapaw, Seidell, & Van Mechelen, 2009). There are also issues relating to non-compliance with wearing the device (Van et al., 2005), likely to especially be an issue among children
and youth, and non-wear time (when the participants do not wear the accelerometer during a measurement period) should be standardized across studies to reduce confusion and improve comparability of youths’ physical activity levels (Aadland, Andersen, Anderssen, & Resaland, 2018). A study among adolescents reported that compliance was significantly higher with wrist accelerometers than hip-worn accelerometers, with participants reporting that it was more comfortable and less embarrassing to wear the wrist accelerometer (Scott et al., 2017). There is a lack of consensus about the best way to define, assess and utilize physical activity and sedentary behavior (Kelly, Fitzsimons, & Baker, 2016). Given these limitations, it is likely that self-report will remain the main tool for measuring physical activity.

Trends in adolescents’ physical activity

The way young people spend their free time has been changing in recent decades, particularly with the expansion of technology. A study from Amsterdam showed that young people spend more time in their home (Karsten, 2005) and are less likely to socialize with friends outside the home. The current generation of youth are less likely to be engaging in exploratory or health risk behaviors with peers outside the home (Brooks, Magnusson, Klemera, Spencer, & Morgan, 2011). This shift in the geographies of young people may mean that, their in-home leisure activities have become a more significant component for young people. Spending time with friends and social support from friends during leisure-time have been reported to be a protective factor for psychological distress among adolescents (Myklestad, Røysamb, & Tambs, 2012).

A study from seven European countries indicated stability or a small increase in physical activity of boys and girls aged 11–15 from the mid-1980s to the early 2000s (Samdal et al., 2007). Further, another study indicated that the level of physical activity – measured objectively using accelerometers – of Norwegian 15-years old girls was lower in 2011-2012 compared to 2005-2006 (Dalene et al., 2018). Some studies have shown a decline in physical activity in Norwegian youth (Kjønniksen,
Torsheim, & Wold, 2008), a pattern also evident in youth from other countries (Bélanger, Gray-Donald, O’Loughlin, Paradis, & Hanley, 2009; Telama et al.). Other data suggest an increase in sports participation among youth (Green, Thurston, Vaage, & Roberts, 2013). However, an important distinction here is between the concept of ‘participation’ – the frequency of taking part in sport regardless of duration (minutes) and intensity – and ‘physical activity’, as defined above. Male adolescents consistently report being more physically active than female adolescents (Gortmaker et al., 2012) in most countries. A longitudinal study reported that adolescents are experiencing a shift in activity patterns, such as decreases in physical activity and increases in sedentary behavior, attributed to computer use (Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006).

A relatively recent systematic review concluded that the finding of a decline in physical activity during adolescence is consistent (Dumith, Gigante, Domingues, & Kohl, 2011). Furthermore, a recent study reported that more than 50% of adolescents overestimate their physical activity habits (Vanhelst et al., 2018). These results indicate a need for further studies on physical activity in adolescents.

Trends in physical activity and sedentary behaviour (studied in the HBSC study) among Czech schoolchildren aged 11-15 year showed a stagnation or decline in the proportion of children meeting the recommendations (≥60 min of moderate to vigorous intensity PA daily) of physical activity alongside increased sedentary time between 2002 and 2010 (Sigmundova, Sigmund, Hamrik, & Kalman, 2013). However, physical activity increased in the US over time, with adolescents reporting significantly more physical activity in 2009-2010 than in 2001-2002 and television viewing decreased (Iannotti & Wang, 2013). There are similarities and differences between countries, which makes it important to explore patterns and trends in specific countries such as Norway.
Physical activity, sedentary behaviour and mental health

From a public health perspective there is some concern about changes in both physical activity patterns and mental health among adolescents. The relationship between physical activity and mental health has received more attention in the literature. However, compared to adults, the benefits of physical activity for young people’s future mental health have been far less well documented (Biddle & Asare, 2011).

A systematic review in adolescent girls concluded that screen-based sedentary behavior is associated with depression (Costigan, Barnett, Plotnikoff, & Lubans, 2013). Another review reported that higher levels of sedentary (sitting) behavior were associated with worse mental health (Biddle & Asare, 2011). Biddle, O’Connell, and Braithwaite (2011) concluded in a review that higher levels of sedentary behavior are associated with worse mental health. Leisure time screen-based sedentary behavior in adolescents has been associated with depressive symptoms and psychological distress (Hoare, Milton, Foster, & Allender, 2016).

Physical activity has been associated with several health outcomes, including mental health. In a Norwegian study, low levels of physical activity have been associated with symptoms of depression and anxiety among adolescents (Skrove, Romundstad, & Indredavik, 2013). However, a European cross-sectional study found no evidence of the benefit of daily physical activity for mental health (McMahon et al., 2017). A meta-analysis among adults concluded that physical activity in non-clinical populations can reduce anxiety and depression symptoms, in addition to preventing the onset of clinical anxiety and depression (Rebar et al., 2015). Thus this thesis examines the role of physical activity in the prevention of adverse mental health outcomes not in the management of existing mental health problems. Patterns of physical activity in general, and among adolescents with symptoms of depression and psychological distress in particular, may be important to understand further. However, to date, few studies have been able to corroborate these views.
Longitudinal studies have a stronger study design for exploring the association between physical activity and mental health because they allow the temporal relationship between exposure and future outcomes to be explored. A relatively small number have been located: two of these focused on depression as the outcome (Motl, Birnbaum, Kubik, & Dishman, 2004; Rothon et al., 2010), and one on mental health using the Strengths and Difficulties Questionnaire (Sagatun, Sogaard, Bjertness, Selmer, & Heyerdahl, 2007). Taken together, these studies provide some evidence of an inverse association between physical activity and some dimensions of mental health, although in the case of the Sagatun et al. study (2007) this only held for males. The extent to which these impacts are durable is however unclear. A further longitudinal study based on two cohorts born 12 years apart, observed a consistent relationship between leisure-time physical activity in youth and psychological well-being 15 years later (Sacker & Cable, 2006). Another longitudinal study reported no association between objectively measured physical activity and development of symptoms of depression (Toseeb et al., 2014).

A systematic review of prospective studies (Mammen & Faulkner, 2013) concluded that physical activity may prevent depression. Of the 30 studies, 25 found that physical activity prevented the onset of depression in the future. Another systematic review reported favorable relationship between total physical activity (measured objectively) and psychological distress in children and youth aged 5-17 years (Poitras et al., 2016). A recent study using questionnaires among Icelandic adolescents aged 10-19 years (with over 50% of the adolescents in upper-secondary school) reported that as age increased, depressive symptoms increased and physical activity decreased (Baldursdottir, Valdimarsdottir, Krettek, Gylfason, & Sigfusdottir, 2017). The results also showed that a decrease in physical activity and increase in depressive symptoms is most pronounced around the age of 15 – 16 years old.

There is limited information on changes in psychological distress and physical activity among adolescents over time in general, and the ex-
tent to which physical activity patterns differ according to psychological distress. In Norway, there are few studies on time changes in mental health and physical activity.

Approximately 2/3 of all children and young people worldwide participate in organized sport (Tremblay et al., 2014). Studies report a decrease in organized sport participation during adolescence (Eime et al., 2016; Eime et al., 2015). Adolescents who participated in sport were found to have reduced levels of depression and stress (Jewett et al., 2014). Brunet et al. (2013) reported that involvement in organized sport during adolescence was associated with lower symptoms of depression, however, this was not for moderate to vigorous physical activity outside of a sport context. Youths (aged 17–37 years) who participated in team sports (UK university sportspeople) were found to report higher levels of happiness than those who played individual sports (Zhou, Heim, & O’brien, 2015). A longitudinal study among Canadian adolescents reported that being part of a sports team was associated with lower depressive symptoms (Sabiston et al., 2016), which is in line with a cross-sectional study among German adolescents (Nixdorf, Frank, & Beckmann, 2016). A cross-sectional study among European adolescents reported the lowest levels of depression and anxiety among those participating in team sports compared with individual sport participation (McMahon et al., 2017).

The importance of adolescents in Finland, Norway and Wales (aged 13) liking physical activity and sport for social reasons, such as being with friends has increased during a 20 year period (1986-2006). In this study, health reasons for liking physical activity were considered most important (Wold et al., 2016). Furthermore, adolescence is a period when the opinions of peers tend to increase in importance in relation to how they want to spend their time and who they want to spend it with. Social support from friends and family is an important contributor to increase physical activity in adolescents (Gill et al., 2018) as well as to mental health (Rueger, Malecki, Pyun, Aycock, & Coyle, 2016). These findings suggest that the physical activity contexts may be important in understanding how physical activity might be related to mental health in adolescence. This indicates a need for further studies
on changes in the association between physical activity and psychological distress over time, the physical activity context and prospective longitudinal studies on physical activity and mental health.

Young people spend approximately half of their waking day at school, which has been identified as an important setting for promoting physical activity and reducing sedentary behaviors. However, leisure-time physical activity (meta-analysis, 76% sampled adults) is one of the most important components of total physical activity (White et al., 2017), and this is particularly the case among young people as they move towards young adulthood.

A review from 2011 concluded that most of the research evidence was of limited quality (Biddle & Asare, 2011). The majority of studies have been cross-sectional in design limiting the extent to which the temporal relationship between cause and effect can be unraveled (Lagerberg, 2005; Steptoe & Butler, 1996). To our knowledge, longitudinal studies reporting on physical activity associated with later initiation of psychotropic drug use as a marker of psychological distress in youth in Norway is lacking.

Other factors associated with mental health

A considerable number of factors may affect adolescents’ mental health. As a consequence it is essential to control for these factors when examining the association between physical activity and mental health. The following describes current evidence regarding two factors (correlates) that may influence mental health in adolescence.

Gender

Gender has been identified as an important factor in the relationship between physical activity and mental health. Physical activity at age 15-16 years may influence some aspects of mental health three years later in boys, but nor in girls (Sagatun et al., 2008).
Social inequalities

It is extensively well-documented that social inequalities pattern people's health including during adolescence (Moor et al., 2015). Social inequalities in health are defined as 'systematic, socially produced (and therefore modifiable) and unfair' (Whitehead & Dahlgren, 2006, p. 2). There are clear variations not only across countries, but also within the same nation. One study reported increasing inequalities in adolescent health across Europe (Elgar et al., 2015), while another reported that social inequalities did not decrease between 1994 and 2010 in almost all European and North American countries (Moor et al., 2015). Social class among Norwegian adolescents aged 16-19 is reported to play a major role in organized sport participation, with large differences being observed between adolescents from lower and higher social classes (Andersen & Bakken, 2018).

A further study among Norwegian adolescents reported subjective health problems to be higher among families with low socioeconomic status (Sletten, 2015). Adolescents from families with lower social position report being less physically active, compared to adolescents from families with higher social position (Samdal, Bye, Torsheim, & Fismen, 2012). The greater the inequality in social position the higher the inequality in risk for many common mental disorders, that is to say, risk factors for many common mental disorders are heavily associated with social inequalities (Allen, Balfour, Bell, & Marmot, 2014). Among youth (aged 10-15 years), the prevalence of anxiety or depressed mood has been shown to be 2.5 times higher with lower socio-economic status than youth with higher socio-economic status (Lemstra et al., 2008). Many common mental disorders and mental health are shaped by various social and physical environments operating at different stages of life. As a consequence, it is necessary to take action throughout the life course if the risk of those mental disorders that are associated with social inequalities reduced (Allen et al., 2014).
Overall conclusion

The majority of studies addressing the relationship between physical activity and mental health have been cross-sectional. Longitudinal studies in young people – including linkage studies that make use of national registers – have been more rarely used. How physical activity frequency, volume and context (sports club, gym, exercise independently and other organized physical activities) might relate to symptoms of depression is still unclear, especially among adolescents. When investigating social interactions in connection to physical activity, most previous research has focused on the team sport context. There is a pressing need for further studies that explore the aforementioned gaps in the research field.

To assess the association between physical activity and mental health and how it changes over time, there is still a need for population-based studies using self-report measures, and a validated measure of mental health (psychological distress). The common facet of three of the four papers included in this thesis, is the examination of how participation in physical activity relates to mental health outcomes, adjusted for confounding variables. In paper I, the HSCL-10 measuring psychological distress was psychometric tested by the Rasch model. Given the intercountry differences in physical activity, sedentary behavior and mental health that this thesis looks specifically at Norway, a country with a strong sporting culture and relatively small social inequalities.
OVERALL AIM

The overall aim to the research in this thesis is to examine the association between physical activity and mental health among Norwegian adolescents aged 15-16 years.

The specific aims of study I-IV are:

- Study I: to investigate the psychometric properties of the HSCL-10 among adolescents in Norway using Rasch analysis.

- Study II: to examine psychological distress among Norwegian adolescents in relation to changes over time and the associations with leisure time physical activity and screen-based sedentary behavior.

- Study III: to investigate the association between physical activity and mental health in terms of subsequent use of psychotropic drugs (antidepressant and hypnotic use) in adolescents aged 15-16 years.

- Study IV: to study the association between physical activity taking place in different contexts (sports club, gym, exercise independently and other organized physical activities) and symptoms of depression.
MATERIAL AND METHODS

Data collection, study design and participants

Norwegian Youth Health surveys (NYHS)

Studies I, II and III are based on information retrieved from the NYHS, conducted by the Norwegian Institute of Public Health. A cross-sectional survey was conducted in the period 2001-2004 among 15-16 year olds in all secondary schools from six Counties (Hedmark, Oppland, Troms, Finmark, Nordland, and Oslo) in Norway. The adolescents completed a paper-based self-administered questionnaire at school during lesson time, and all students were invited to participate. The students completed a consent form before participation and all parents received written information about the study. To provide students with clarification on any matter related to the questionnaire, a researcher was present, and adolescents not present on the day of the survey were asked to fill in the questionnaire later. Additionally, in 2009 Hedmark County cooperated with the Norwegian Institute of Public Health and conducted a new cross-sectional survey among 15-16 year old students. They completed a web-based questionnaire at school.

Studies I and II are based on the data conducted in 2001 and 2009 in Hedmark County, Norway. All schools were invited in both years of the investigation. In 2009, 26 of 43 (60.5%) schools participated. In 2001, 40 of 42 (95.2%) schools participated. Among the participating schools, the average response rates were 78% (2009) and 88% (2001). Across schools, the response rates varied between 61 and 90% (2009) and 67 and 100% (2001). In total, the study population included 1975 adolescents in 2001 and 1336 adolescents in 2009. Eighty adolescents in 2001 and eight adolescents in 2009 were removed from the dataset due to non-response on the main outcome measure for psychological distress – a HSCL-10 score.

Study III includes data conducted between 2000 and 2003 from five counties (Hedmark, Oppland, Troms, Finmark and Oslo). In total, 125 individuals were removed from the dataset due to non-response on the measure for psychological distress - a HSCL-10 score.
Norwegian prescription database (NorPD)

NorPD was used in study III. Prescription data on psychotropic drug use in 2004–2013 were drawn from the NorPD, which covers the entire Norwegian population (approximately 5.2 million inhabitants). Furu (2008) reported NorPD to be a valid and reliable data source for studying use of prescription drugs. All pharmacies in Norway have from January 2004, been legally obliged to submit all electronic data on prescriptions to the Norwegian Institute of Public Health. Whether or not reimbursed, the NorPD contains information on dispensed prescriptions to individual patients living outside institutions. Drugs administered to patients while in hospital are not reported to the NorPD. The drugs are classified according to the Anatomical Therapeutic Chemical (ATC) classification system (WHO Collaborating Centre for Drug Statistics Methodology, 2017). The data in this study were patients’ unique personal identity number (encrypted), drug information (ATC code), the amount dispensed in defined daily doses [DDDs]), age and gender. This system divides active substances into different groups according to the organ or system on which they act and their therapeutic, pharmacological and chemical properties. The drugs are classified in groups at five different levels. The drugs are divided into fourteen main groups (first level), with pharmacological/therapeutic subgroup (second level). The third and fourth levels are chemical/pharmacological/therapeutic subgroups and the fifth level is the chemical substance. The second, third and fourth levels are often used to identify pharmacological subgroups (WHO Collaborating Centre for Drug Statistics Methodology, 2017).

The psychotropic drugs investigated in this thesis are antidepressants (N05A), hypnotics (N05C) and the systemic antihistamine alimemazine (R06AD01). The participants who were psychotropic drug users at baseline (n=1085), were excluded in order to examine the incident use of antidepressants and hypnotics. In total, the study population included 10737 adolescents with a participation rate of 87 %.

Antidepressants (N05A) are used for depression, but not only improvement of symptoms of depression (sadness, depressed mood), but also improvement of sleeplessness, reduced appetites, psychomotor impairment, anxiety and difficulty concentrating. Later it has been shown
that they have an effect on panic disorder and compulsive disorder, and probably a less specific effect on social phobia, generalized anxiety disorder, posttraumatic stress disorder and bulimia (Lingjærde & Aarre, 2015).

Hypnotics (N05C) are used to treat sleep disturbance. Benzodiazepines has been used, but lately benzodiazepine-like zopiklon and zolpidem has become the pure preferred hypnotics in adults (Lingjærde & Aarre, 2015). The systemic antihistamine R06AD01 (alimemazine) was included as a hypnotic drug because it has long been used for childhood insomnia in Norway (Slørdal & Bramness, 2008).

Ungdata

Study IV is based on information retrieved from Ungdata conducted by the Norwegian Social Research (NOVA) institute in cooperation with regional centers for drug rehabilitation (KoRus). Ungdata is an annual cross-national data collection scheme, designed to conduct youth surveys at the municipal level in Norway. The study is financed by the Norwegian Directorate of Health, the Ministry of Children, Equality and Social Inclusion and the Ministry of Justice and Public Security. Participation was voluntary and both parents and the adolescents were informed in advance through a written information letter. Since Ungdata started in 2010, 439200 respondents have participated. In this study, we included all adolescents from secondary schools, grade 10 aged 15-16 years from 19 municipalities from four countries (Hedmark, Oppland, Østfold and Akershus) conducting the Ungdata survey in 2017. The adolescents completed an anonymous web-based questionnaire with a teacher or an administrator present at school.
<table>
<thead>
<tr>
<th>Study</th>
<th>Aim</th>
<th>Study design</th>
<th>Study population</th>
<th>Analysis</th>
</tr>
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<tbody>
<tr>
<td>III</td>
<td>To investigate the association between physical activity and mental health in terms of subsequent use of psychotropic drugs (antidepressant and hypnotic use) in adolescents aged 15-16 years.</td>
<td>Prospective register linkage study Norwegian Youth Health Surveys NorPD (2004-2016) 2000 – 2003 10737 adolescents (ages 15-16)</td>
<td>Multinominal logistic regression</td>
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<td>IV</td>
<td>To study the association between physical activity taking place in different contexts (sports club, gym, exercise independently and other organized physical activities) and symptoms of depression.</td>
<td>Cross-sectional Ung data 2017 5531 adolescents (ages 15-16)</td>
<td>Binominal logistic regression analysis</td>
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</table>
Data analysis

Study 1

Instrument

Hopkins Symptoms Checklist-10 (HSCL-10)
The Hopkins Checklist was originally intended to study the efficacy of psychotropic drugs and had questions referring to symptomatic behavior of outpatients in adult populations (Derogatis et al., 1974). Currently, it is available in different versions and used in the versions of the Hopkins Symptom Checklist (HSCL) instrument, of different lengths (5–90 items). Among adolescents, primarily, the short versions have been used (5, 10 and 25 items). The HSCL-25 is considered to tap information about general psychological distress. The HSCL-10 is commonly used in many western studies and has a history dating back to 1950s (Derogatis et al., 1974). The HSCL version with 25 items, HSCL-25, was first described in Philadelphia in 1980. It was designed to measure the symptoms of anxiety and depression (Hesbacher, Rickels, Morris, Newman, & Rosenfeld, 1980). HSCL-25 has been used in some Norwegian counties since the late 1980s and 1990s (Tambs & Røysamb, 2014). HSCL-10 were developed using stepwise regression analysis of data on items from the HSCL-25 from another data material—regression of each item on the total score (Tambs, 2004). The instrument includes 10 items, four of them are about anxiety and six about depression (Tambs, 2004). The HSCL-10 is presented in the following way:

‘Listed below are some symptoms or problems that people sometimes have. Please read each one carefully and decide how much the symptoms bothered or distressed you during the last week, including today:
The Rasch model

The psychometric properties of the HSCL-10 were examined using Rasch Measurement Theory (Rasch, 1980). The Rasch model was used to examine whether the HSCL-10 meets the requirements of undimensionality, invariance and proper item categorization. To examine the reliability, person separation index (PSI) was used. Invariance along the latent trait was examined, e.g. whether the items worked in the same way for adolescents with high levels of psychological distress as for those with low levels. Lack of invariance across sample groups such as genders is called Different Item Functioning (DIF), which can be examined by analysis of variance (ANOVA) of standardized residuals (Hagquist & Andrich, 2004). An item shows evidence of DIF if different members of a sample group, e.g. boys and girls, respond differently to an item given in the same location on the latent trait.

With respect to DIF across genders and years of investigations. In addition to analysis using graphical displays, two-way ANOVA of standardized residuals was used to detect the DIF. To resolve the DIF, items showing DIF were split, e.g. an item showing evidence of gender DIF was split into two gender specific items by treating the opposite gender as a non-response. To distinguish real DIF from artificial DIF (David Andrich & Hagquist, 2015), the items were resolved sequentially, starting with the item with the largest DIF.

Targeting was examined by comparison of the items and person locations. Categorization of the items was examined by the analysis of the threshold ordering. To detect possible multidimensionality, independent t-tests of differences between person location values from two subsets of items were carried out.

The Rasch analysis was performed using the program RUMM2030 (D Andrich, Lyne, Sheridan, & Luo, 2013).
Study II

Association between physical activity (PA), screen-based sedentary behavior (SB) and psychological distress between 2001 and 2009 were analyzed with multinomial logistic regression estimated by B (exp.) interpreted as odds ratios (OR) with a 95 % confidence interval (C.I). Statistical Package for the Social Sciences (SPSS) for windows (version 20) was used for the analysis. In the current study the dependent variable (psychological distress) was divided into three categories, based on the percentile values. Individuals located at and below the 20th percentile on the scale constituted the category “lower levels”; individuals above the 20th but below the 80th percentiles represented “moderate levels”, and individuals at or above the 80th percentile constituted the category “higher levels” of psychological distress. Multinomial regression analysis was used in order to study the association between physical activity and psychological distress. Main analysis are chosen for the analysis because the inclusion of any interaction term (i.e. PA by gender, PA by SB and PA by gender by SB) did not improve the fit.

Study III

Association between physical activity and incident use of antidepressants and hypnotics have been analyzed with multinomial logistic regression estimated by B (exp.) interpreted as OR with a 95 % C.I. SPSS for windows (version 20) was used for the analysis. In the current study, in order to investigate different time intervals for incident use of antidepressants and hypnotics separately, three models were tested, stratified into different periods (2004-2007, 2008-2010, and 2011-2013).

Incident psychotropic drug use was defined to the following ATC codes: N05C (hypnotics and sedatives), N06A (antidepressants), and R06AD01 (alimemazine). Incident use was defined when an individual (nonuser of a psychotropic drug at baseline), had a psychotropic drug dispensed at least once during the period between January 1, 2004 and December 31, 2013. The unique encrypted personal identity number
was used to link the data from the Norwegian Youth Health Surveys and NorPD.

Study IV

The association between physical activity taking place in different contexts and symptoms of depression were analyzed with binominal logistic regression estimated by B (exp.) interpreted as OR with a 95% C.I. SPSS for windows (version 24) was used for the analysis.

Further adjusted for gender, parent’s education, family economy, smoking and alcohol consumption. In order to investigate the characteristics of the different physical activity groups, B values were organized (rank orders) adjusted for gender in relation to symptoms of depression. Symptoms of depression were measured with six items derived from the Depressive Mood Inventory, which were derived from the Hopkins Symptom Checklist (Derogatis et al., 1974). The adolescents were asked if during the past week, they have been affected by any of the following issues: 'Worried to much about things', 'Felt that everything is a struggle', 'had sleep problems', 'Felt unhappy, sad or depressed', 'Felt hopelessness about the future', 'Felt stiff or tense'. The six questions have four response categories: 'Not been affected at all', 'not been affected much', 'been affected quite a lot' and 'been affected a great deal'. Previous studies have referred to an internal consistency of 0.88 (Abebe, Frøyland, Bakken, & Von Soest, 2016; Granrud, Steffenak, & Theander, 2017).

The depression scale was divided into two categories based on the entire sample to examine those with depressive symptoms. A Rasch analysis was made of the six items measuring symptoms of depression. Each person was allocated a location (logit) value, which comprised nonlinearly transformed raw scores. Lower values on the scale indicated a lower degree of depressive symptoms. The cut off points, reported as logit values, were set at the 80th percentile (0.551), and the two categories were coded as depressive symptoms (≥80th percentile) and no depressive symptoms (<80th percentile).
Ethical considerations
Ethics were considered through all studies. Study I, II and IV used anonymized data. All study participation was voluntary and based on informed consent. Written information about the study and assurance of adolescent anonymity and the right to withdraw at any point was given. Study III is a record linkage study (non-identifiable) was assessed by the Regional Committee for Medical Research Ethics and approved by the Norwegian Data Protection Authority.
RESULTS

Study I
General level of analysis (10 items)

The Rasch analysis of the HSCL-10 indicated good reliability and overall, the items worked well. The PSI value for the 10 items was 0.68, indicating good separation of persons and good power of the test statistics. PSI was lower in 2001 (0.59) compared with 2009 (0.74) (incomplete data). The value for Cronbach’s α was 0.85 in 2001 and 0.91 in 2009, respectively. Targeting was examined by person-item threshold distribution, showing the locations of the items’ threshold parameter estimates relative to the distribution of the persons for the items. The person locations were negatively skewed with a mean of −2.031 logits, indicating a relatively healthy population. At the positive end of the scale (worse health), few persons were located at the item thresholds, whereas at the negative end (better health), no or only few item thresholds were at the person locations. A separate analysis of person–item threshold distribution for each year of investigation indicates worse targeting for adolescents in 2001 (mean value −2.124 logits) compared with 2009 (mean value −1.897 logits). Furthermore, figure 1, shows that the targeting is better for girls (mean value −1.633 logits) than for boys (mean value −2.434 logits).

Figure 1. Person-item threshold distribution for gender: the lower the score, the better the adolescent’s mental health.
Eight items showed a misfit according to the chi-square statistics. Item 6, ‘Difficulties falling asleep or staying asleep’, had the worst misfit and was under-discriminating. In figure 2, the expected value curve (EVC) revealed that item 6 showed lower discrimination than expected according to the Rasch model. This implies that adolescents located at the beginning of the scale tended to score higher than expected, and adolescents located in the right end of the scale tended to score lower than expected on this item. According to the residual fit values, two items showed under-discrimination (fit residual values >2.5), and seven showed over-discrimination (fit residuals <−2.5). One item, Item 1 ‘Suddenly scared for no reason’, showed reversed thresholds, which means that categories were not working empirically as intended and do not constitute the increasing levels of the trait required by the model.

![Figure 2. Expected value curves for item 6 ‘Difficulties falling asleep or staying asleep’](image)

Principal component analysis (PCA) of the item residuals showed no evidence of multidimensionality. Based on the PCA of residuals, t-test analysis and analysis of item content, the person values from the two subsets did not differ significantly. The instrument (HSCL-10) showed no response dependency, according to item residual correlations. Item 6 ‘Difficulties falling asleep or staying asleep’ was removed, because of the severe misfit. The revised item set, consisting of the 9 items, showed a slightly lower PSI value (0.66) compared with 0.68 in the original set with 10 items. The person mean value changed from −2.031 logits (girls: −1.633, boys: −2.434) with 10 items to −2.137 logits (girls:
−1.712, boys: −2.566) with 9 items. No item showed disordered thresholds in the revised item set.

Finer level of analysis

A DIF analysis based on gender and years of investigation was included. Five items (2, 5, 6, 7 and 9) showed a main effect for gender (Bonferroni’s adjusted 5%) that is to say, these items worked differently for girls and boys. With respect to class intervals, eight items (1, 2, 5, 6, 7, 8, 9 and 10) showed a misfit, indicating that they did not work invariantly along the latent trait. In figure 3, the expected values curves for item 5 'Blaming yourself for things' - divided by gender are shown. Girls scored higher than boys, given the same location of the latent trait.

No item showed reversed thresholds in the revised item set (9 item). The person mean value became -0.2137 logits in the revised set (-0.2031, 10 item).

Study II

The results showed that self-reporting of psychological distress increased significantly from 2001 to 2009, girls reporting doubled compared to boys. The proportion of adolescents fulfilling 5-7 hours of physical activity per week during leisure time decreased during the period. This was attributed to boys as the proportion of girls fulfilling 5-7
hours of physical activity increased. Physical activity ≥ 11 hours and sedentary behavior ≥ 6 hours per week during leisure time increased during the period for both boys and girls. The multinomial logistic regression analysis including physical activity and psychological distress showed that the odds for having psychological distress were lower for those who were physically active ≥ 11 hours (OR = 0.61) compared to those who were physically inactive (0 hours). For those who were sedentary ≥ 6 hours, the odds for having psychological distress were higher (OR = 1.72) compared to those who were not (0 hours).

Study III
The results showed for the time period 2004-2007, the odds of incident hypnotic drug use were lower for those who were physically active (OR 0.48-0.64), compared to those who were physically inactive < 1 hour. However, four years post-baseline, the association became non-significant (2008-2010 and 2011-2013). For the time period (crude model) 2004-2007, 2008-2010 and 2011-2013, the odds of incident antidepressant use were lower for physically active adolescents (2004-2007: OR 0.46-0.71, 2008-2010: OR 0.40-0.67 and 2011-2013: OR 0.37-0.58, compared to those who were physically inactive < 1 h. The association became non-significant after adjustment for confounders in all time periods except for the physical activity 5-7 h and 8-10 h categories in the period 2008-2010. Psychological distress was significantly associated with incident antidepressant and hypnotic use in all periods (2004-2007, 2008-2010 and 2011-2013). Overall, according to physical activity and gender, a higher proportion of girls (67.9%), compared to boys (48.7%) reported to be physically active < 5h per week. The adolescents reported to be physically active < 5h per week, overall and in gender subgroup, reported significantly poorer psychological distress, poorer general health and were more likely to smoke than the rest of the population. Overall, and in gender subgroups, incident use of antidepressants and hypnotics 1-13 years after participation in the NYHS was higher among adolescents who reported to be physically active < 5h per week at baseline.
Study IV
The odds of having symptoms of depression were lower in the crude model for those who were physically active in a sports club (OR: 0.40), in a sports club and gym (OR: 0.40), in a sports club and exercise independently (OR: 0.52) and in a sports club, gym and exercise independently (OR: 0.58). The association became significant after adjustment for confounders for those who were physically active in a sports club (OR: 0.46), other organized PA (OR: 0.53), in a sports club and gym (OR: 0.47), in a sports club and other organized PA (OR: 0.57), in a sports club and exercise independently (OR: 0.65) and other organized PA and exercise independently (OR: 0.47). Girls (OR: 3.68) had a higher odds of having depression symptoms than boys after controlling for the other variables. A smaller proportion overall, and in gender subgroups, of the adolescents fulfilling 3 times and more with physical activity per week reported depressive symptoms (≥80 percentiles), compared to those who reported no depression symptoms (<80 percentiles).
DISCUSSION

The main focus of this thesis was to study the association between physical activity and mental health among adolescents in Norway. In the following sections, the main findings are summarized and discussed, followed by a discussion of key methodological considerations relating to this research.

Study II and III showed a weak association between physical activity and mental health among adolescents. Self-reported measures of physical activity were used in both studies, however, two different outcome measures were used to measure mental health: in study II, psychological distress (HSCL-10), and in study III, incident use of antidepressants and hypnotics. The former is undiagnosed and therefore reflects the prevalence of psychological distress in the community and the latter is an indicator of diagnosed and reflects the burden of mental health problems in contact with health services. Further, study II was a cross-sectional study while study III was a longitudinal (record linkage) study. Given previous research among adolescents in relation to physical activity and mental health, the results presented in study II and III should not come as a surprise. Study III is an important contribution to previous research, given the scarcity of longitudinal studies investigating the association between physical activity and mental health as well as incident antidepressant and hypnotic drug use among adolescents. In contrast to research among adults, studies on physical activity and mental health among adolescents show very divergent results. Some studies demonstrate associations while other do not. The reasons or explanations for these ambiguous results seem to be unknown. Hypothetically, the lack of associations and the inconsistent results may at least in part be due to different methodological factors.

Measurement methods assessing psychological distress in the community are important in public health, not just because psychological distress causes suffering per se but also because it is a risk factor for developing mental illness if unattended. Good measurement instruments
and scales are, therefore, important both for clinical and research purposes. Any instrument must measure what it is intended to measure in the targeted population and psychometrically meet requirements for proper measurement.

In order to qualify the analyses of physical activity and mental health and to explore some possible explanations for the weak, if any, associations (study II and III), in study IV the association between physical activity and symptoms of depression was studied in relation to different types of physical activity contexts (sports club, gym, exercise independently or other organized physical activities). Training or competing with a sports club was associated with fewer symptoms of depression compared to no regular exercise. The results partly support previous studies, but also add to the understanding by analyzing symptoms of depression in relation to different physical activity contexts, controlling for socio-demographic variables and other health-related behaviors.

_Evaluating the HSCL-10 instrument_

The Rasch analysis of the HSCL-10 in study 1 indicated good reliability and, overall, the items work well. Earlier studies have reported HSCL-10 to be a useful instrument in epidemiological research among adolescents (Haavet et al., 2011) and in a Norwegian population ≥15 years (Strand, Dalgard, Tambs, & Rognerud, 2003).

Since the HSCL-10 has been widely used for both clinical and epidemiological purposes, but has not previously been exposed to rigorous psychometric analyses, the examination of the HSCL-10 is a contribution to previous literature. Previous psychometric examinations of the HSCL-10 have mainly used factor analysis and focusing on the Cronbach’s α measure. In study 1, the item, “sleeping difficulties” misfit, and the item under-discriminates. This item is also a part of the scale measuring symptoms of depression (study IV). Unpublished Rasch analysis on the depression symptoms scale (Ungdata), also showed problems related to under-discrimination and misfit for the
item 'sleep problems’. This may be due to reasons for sleep problems other than depression, and therefore needs to be further examined.

However, on the basis of the result from Study 1, there is no reason to delete the item 'sleeping difficulties' in the HSCL-10. When deleting an item, the PSI value slightly decreases. However, in future research using the HSCL-10, some revision to the wording of the item is suggested in order to make it more precise, and closer to the English wording. For example, having difficulties falling asleep or staying asleep is more precise than sleep problems. Furthermore, the relationship between sleep and depression is well-documented and therefore its inclusion in a measure of psychological distress is important. A systematic review of longitudinal studies reported a consistent relationship between getting an adequate amount of sleep during adolescence, and a reduced risk of depression (Cairns, Yap, Pilkington, & Jorm, 2014).

The item, 'sleeping difficulties' worked differently for boys and girls, i.e. boys scored higher values than girls on this item given the same location on the latent trait. This may be explained by boys and girls having different reasons for sleep problems. Girls have been reported to sleep more than boys (Olds, Blunden, Petkov, & Forchino, 2010), and gender differences related to sleep quality (Galland et al., 2017) and sleep disturbance have been reported (Hysing, Pallesen, Stormark, Lundervold, & Sivertsen, 2013). By resolving the DIF it is possible to find out whether the DIF item is real or artificial. When resolving the DIF by creating separate items of responses unique for boys and girls respectively, the consequences for the variable needs to be considered. It turns out to be a trade-off between item fit and validity. Information about the sources of the DIF is therefore required in order to judge whether the split of the items is appropriate or not (Hagquist & Andrich, 2017).

The unpublished Rasch analysis of the six items measuring depressive symptoms (study IV) showed that there are some weaknesses and therefore room for improvements of the scale. However, as a whole the depressive symptoms scale works reasonably well. The depression symptoms scale has not previously been assessed with rigorous psychometric testing, so this is a contribution to knowledge on this scale.
The targeting of the HSCL-10 should have been improved. In future studies, adding less severe items to the instrument should be considered in general populations of adolescents.

*Changes in physical activity sedentary behavior and mental health among adolescents*

In study II, self-reported psychological distress among the students increased between 2001 and 2009, and the proportion of girls reporting psychological distress was twice as large as the proportion of boys.

Among adolescents, mental health problems have increased worldwide (Bor et al., 2014), as well as in Norway (von Soest & Wichstrom, 2014). Girls report more psychological distress, anxiety and depression than boys, which has also been reported in other Norwegian studies (Abebe et al., 2016; Moen & Hall-Lord, 2018; Moksnes, Løhre, Lillefjell, Byrne, & Haugan, 2016; Nordfjærn, Flemmen, & Dahl, 2012) and elsewhere, for example, in Canada (Arbour-Nicitopoulos KP, 2012) and in Australia (Hoare, Milton, Foster, & Allender, 2017; Mewton et al., 2016). Further, this is confirmed in a systematic review of the international literature, showing an increase in internalizing problems among girls, while the results for boys were inconsistent (Bor et al., 2014).

Earlier studies have reported gender differences in both depressive symptoms and physical activity, with girls reporting higher levels of symptoms of depression and being less physically active than boys (Baldursdottir et al., 2017; Hoare et al., 2017), which is in line with the results presented in this thesis.

In study II, the proportion of students being physically active ≥11 h per week increased between 2001 and 2009, and the proportion of boys reporting ≥ 11 hours of physical activity was twice as large as girls. A recent study among Norwegian adolescents, reported that girls in 2011-2012 had a lower physical activity level (measured objectively using accelerometers) compared to girls aged 15 in 2005-2006, however, the
overall level of physical activity did not differ for boys between the two cohorts (Dalene et al., 2018). In study II, the proportion of students fulfilling 5-7 hours per week after school decreased from 2001 to 2009 attributed to boys only, while the proportion of girls increased. This might be attributed to the different methodologies employed to measure physical activity.

In a longitudinal study among Norwegian adolescents using accelerometer data, both boys and girls reported a substantial decrease in physical activity during a 5-year period (from age 14 to 19) (Lagestad, van den Tillaar, & Mamen, 2018). However some studies have reported physical activity levels to remain relatively stable over time in American (Li, Treuth, & Wang, 2010) and European (Samdal et al., 2007) adolescents. The divergent results may be due to different physical activity measurements (self-report or accelerometer data), different ages, how long the longitudinal period was and when the examination was done. Therefore up-to-date data on physical activity and mental health are required. Study II adds knowledge to both variables, even though it is a cross-sectional study.

The proportion of students being sedentary ≥6 h per week increased between 2001 and 2009. An increase in sedentary behavior has been shown in adolescents in many parts of Europe and North America during the last decade (Bucksch et al., 2016). Norwegian adolescents (aged 15 years) reported to spend more time being sedentary in 2011-2012 compared to their peers in 2005-2006 (Dalene et al., 2018). The increase may be due to the societal changes relating to rapid developments in technology. Computers and mobile phones are more attractive and available, and the popularity of screen-based media among adolescents has increased.
The association of physical activity, sedentary behaviors and mental health

In study II, screen-based sedentary behavior (≥6h) after school were associated with psychological distress which is in line with a study among Australian adolescents (Hoare et al., 2017). They reported a significant relationship between screen-based sedentary behaviour and psychological distress only in the group reporting the highest level of screen-based sedentary behavior (internet use). Previous literature have reported associations between screen-time (≥2 hours and more per day) and psychological distress among adolescents (Trinh, Wong, & Faulkner, 2015). These findings may indicate that it is more usual and normal to use a lot of time on screen-based activities.

In study II, only high levels of physical activity were associated with fewer symptoms of psychological distress. These findings are consistent with previous studies suggesting that higher volumes of physical activity are associated with fewer anxiety and depressive symptoms (Doré, O’Loughlin, Beauchamp, Martineau, & Fournier, 2016). Further, a recent meta-analysis of prospective cohort studies (of all ages), indicated that higher levels of physical activity offer a protective effect on future development of depression (Schuch et al., 2018). However McMahon et al. (2017) reported no evidence for the benefit of daily physical activity for mental health, but underlined the importance of increasing physical activity among the least active.

In study III, incident psychotropic drug use (hypnotics and antidepressants) was used as an outcome measure for mental health. Physical activity seems to be a stronger predictor for incident use of hypnotics than incident use of antidepressants 1 – 3 years after physical activity was measured. Over the 13-year period, the findings suggest that the associations between physical activity and incident use of antidepressants and hypnotics are mainly explained by variables other than physical activity. This is in line with another longitudinal study, showing no association between physical activity and symptoms of depression (Toseeb et al., 2014).
In study IV participation in a sports club was associated with reduced depressive symptoms. A study reported that young adults with symptoms of depression during adolescence participated in less team sport and moderate physical activity compared to young adults with less symptoms of depression during adolescence (Sabiston et al., 2013). A study among Norwegian adolescents reported that being with friends during leisure time and social support from friends showed the strongest negative association with psychological distress (Myklestad et al., 2012). Eime, Young, Harvey, Charity, and Payne (2013) concluded in a review that participation in team sports rather than individual activities is associated with better health, and that this is presumed to be due to the social nature of team sport and the positive involvement of adults and peers. A Norwegian study examined the association between competitive and noncompetitive sports and mental health (measured by SDQ) in adolescents. They found that the adolescents who participated in sports reported fewer mental health problems, and number of friends, diet and weekly exercise were found to be partially mediating factors (Breistøl, Clench-Aas, Van Roy, & Raanaas, 2017). Study IV showed that adolescents who exercise independently (running, swimming, cycling etc.) had a higher prevalence of symptoms of depression compared to those who participated in a sports club. Using 'physical activity' as a single variable in mental health research might be limited. Similarly, in research that focuses on mental health outcomes the environment within which the physical activity takes place may be as, if not more, important as the volume and intensity of physical activity.

How physical activity (volume and context) relates to mental health and mental disorder remains unclear as adolescents make the transition from youth to adulthood (Doré et al., 2016). Earlier studies have shown that people move towards individual physical activities and drift away from organised sports clubs (Eime et al., 2015), and participation in sport declines rapidly during adolescents (Eime et al., 2016). However, this is not the case in Norway where participation peaks between the ages of 16-19 years of age (Green, Thurston, Vaage, & Moen, 2015). This is even though there is a drift away from organized sport towards individual lifestyle activities. This suggests that although the patterns in different countries have some similarities, there may be important country-specific differences. A study among Australian adolescent
girls, showed a shift in participating in physical activities, away from organized, towards non-organized and individual types of physical activity (Eime, Harvey, et al., 2013). There are many plausible reasons for this. During adolescents’ transition towards adulthood the structure of organized sport tends to get more formalized and competitive. However, this corresponds to a time within leisure which relates increasingly to friends and opportunities to expand an identity relating to their choices beyond school and the family. Furthermore, changing priorities in leisure time gives rise to a shift from organized sport to non-organized, relationships, study and work (Eime & Harvey, 2018). This study showed relatively similar patterns and associations between participation in a sports club and symptoms of depression across grades 8, 9 and 10.

In relation to outcome measures of mental health, the substantial majority of measures used in practice and research are focused on mental illness, assessing reduction in risk factors such as attainment of an adequate level of functioning symptoms, or stress, or cognitive problems (Thornicroft & Slade, 2014). Shifting the focus to also include measures of protective factors and positive wellbeing may nuance and change the associations between physical activity and mental health.

In this thesis, adolescents aged 15-16 years were examined (adding grade 8 and 9 in some analysis in study IV). Age is a dynamic period and in particular the period of adolescence during which profound changes occur and in which the pace and trajectory varies from person to person and between genders, which make it challenging to study. Within an age group there may be individual variations both socially and psychologically. There are many new pressures and challenges for adolescents. They need to deal with considerable change at this time, i.e. changing social relationships with family and peers and emotional changes associated with maturation.

This thesis has examined leisure time physical activity in studies I-III. Leisure time physical activity is one domain (Eime, Young, et al., 2013) and often one in which a chosen physical activity can be followed (enjoyment, motivation). When young people feel they belong they are more likely to make friends and interact with peers (Sheffield,
Fiorenza, & Sofronoff, 2004). A sense of belonging may also influence their ability to develop and make use of social networks. The outdoor physical activity context was not examined in this thesis, but has been in other studies. A study among Canadian adolescents (aged 11-15 years) showed that an appreciation of the importance of 'feeling connected to' nature for both males and females was associated with decreased prevalence of psychosomatic symptoms (Piccininni, Michaelson, Janssen, & Pickett, 2018). This might be a particularly important point to pursue in future research involving Norwegian adolescents, given the deeply embedded culture of friluftsliv (outdoor life) in Norway.

In paper IV, the questions about adolescents’ physical activity context, were related to leisure time activities. However some of the activities could be carried out during school time, i.e., exercise independently. Schools have been identified as having an important role to play in shaping young people's activity behaviours and are considered important settings for physical activity promotion, as no other institution has more contact with youth during the first two decades of life (Hills, Dengel, & Lubans, 2015). However, as noted above, adolescence is a period of transition during which leisure time becomes increasingly important as a context for physical activity.

When examining the association between physical activity and mental health in this thesis, gender was considered. In study II, III and IV, female gender was associated with a higher risk of psychological distress and incident psychotropic drug use compared to males. In study II, the strength of the association between physical activity and psychological distress or incident use of psychotropic drugs in study III, was unaffected by gender which is in line with a Dutch study (Stavrakakis et al., 2013). Study IV showed that 70 % of the adolescents who reported participating in other kinds of organized physical activities (dance, martial arts, etc.) were girls. After adjustment for gender, other kinds of organized physical activity were associated with lower symptoms of depression among adolescents. This may be because 70% were girls and dance was used as an example.
The research presented in this thesis indicates differences between adolescents who have lower socioeconomic status compared to those with higher socioeconomic status. Adolescents who have good family economy and parents with higher education had lower odds of having depressive symptoms compared to the rest of the adolescent population. Additionally, adolescents who reported poor family economy and vocational education had higher odds of incident use of antidepressants and hypnotics compared with the rest of the population. This is in line with a review that showed that high socioeconomic status is associated with fewer mental health problems among adolescents (Reiss, 2013).

Large differences were observed in a recent study between Norwegian adolescents participating in organized sport from lower and higher social classes, and the results showed that economic resources were particularly important (Andersen & Bakken, 2018). A similar pattern has been observed in Australian adolescents: participating in organized sports was positively associated with higher socioeconomic status (Dollman & Lewis, 2010). Adolescents in Norway have been reported to be less physically active in families with lower social status, than adolescents from families with higher social status (Samdal et al., 2012). Socioeconomic status seems to affect mental health, physical activity and participation in sports club. Therefore, it should be emphasized that an association between physical activity and depressive symptoms remained significant also after controlling for socio-demographic variables and health-related behaviors.

Physical activity is a complex measure, it is a behaviour that is influenced by a variety of biological, behavioural, social and environmental factors and interactions (Lopes, Gabbard, & Rodrigues, 2013). A recent review concluded the importance of elucidating the mechanisms (effect moderators as frequency, intensity, time, type of physical activity) underpinning the effect of physical activity on mental health. However, little is known regarding the mechanisms by which these effects work (Lubans et al., 2016).
Methodological discussion – strengths and weaknesses

The study populations in the youth health surveys and Ungdata used in this thesis were large and data from the NorPD covers prescriptions from the total population, so problems with random error were considered to be small. The main source of selection bias in survey data is non-attendance, non-response or a missing response to a single item (Rothman, Greenland, & Lash, 2012).

The overall survey participation rate could be considered acceptable in the three datasets used in this thesis. The response rate was 83% in study II, 87% in study III and 84.6% in study IV, which increases the representativeness of the sample.

In paper I and II, the response rate in 2009 (78%) was lower compared to the response rate in 2001 (88%). The main difference between the sample in 2001 and 2009 was that in 2001 the adolescents used a paper based questionnaire, and in 2009 they used a web-based questionnaire. The moderator analysis of the association between physical activity and psychological distress over years (2001 – 2009), could be due to the differences in paper and web-based questionnaires. An earlier study reported few differences in data quality between computer-based, web-based and paper-based questionnaire (Hardre, Crowson, Xie, & Ly, 2007). However, a Swedish study among adults reported the willingness to answer the questions to be higher for the web-based compared to the paper-based questionnaire (Bälter, Bälter, Fondell, & Lagerros, 2005). The survey procedure in papers I and II was similar for both years in all other aspects, so it is unlikely that the difference in the administration of the questionnaire affected the results.

Missing responses to a single item in HSCL-10 was in study III n = 125, out of 10862, in study II n = 8 out of 1328 in 2009 and in 2001, n = 80 of 1895. Missing values could also have ensured the quality of the data, the more severe psychologically distressed adolescents may have been excluded from the study, due to not being present at school, or because they did not want to answer the questions in the survey. Missing value to a single item in the symptoms of depression scale was n = 166 out of 5531 in study IV.
The samples of 15-16 years olds were invited through nationally representative samples of schools. In Study III, NorPD was used and connected to the youth health study. The regression analysis can be a powerful tool to statistically model the relationship between a dependent variable (outcome, in this thesis psychological distress, incident use of psychotropic drugs and symptoms of depression) and a set of independent (predictor, in this thesis physical activity, screen-based sedentary behaviour, gender and socioeconomic status) variables (Constantine, 2012).

The samples used in studies I, II, and IV were cross-sectional, i.e., all the variables were measured at the same time. These studies centred on the associations between different individual factors and mental health. The study designs of the current studies do not enable conclusions regarding causality between physical activity and different outcomes measures of mental health.

Study III is a prospective longitudinal study. Prospective studies with assessments before the onset may help to better understand the mechanisms that lead to the development of mental health problems (Stavrakakis et al., 2013). The present study had a follow-up period of 13 years, which made it possible to investigate prospectively the association between physical activity and the incident use of hypnotics and antidepressants in adulthood in a more robust way than is possible in cross-sectional studies. NorPD has been reported to be a complete resource for assessing use of prescription drugs with the potential for long-term follow-up and in large populations (Wettermark et al., 2013). However, there was no information about drugs used in hospital, and importantly, it was not known whether the dispensed drugs registered in study III reflected actual drug use. Furthermore, there is no way of knowing if the incident prescribing of hypnotics and antidepressants over the follow-up period changed in any way. Another limitation in the longitudinal study is that data on physical activity were collected only at one point in time. However, to some degree, this weakness is addressed by analysing the associations for different time periods.
Most of the variables used in the analyses presented in this thesis were based on self-report measures. Self-reported physical activity was measured differently in paper II, III and IV. In paper II and III physical activity was measured with hours per week after school, (volume) and in paper IV with times per week (frequency). Additionally, the physical activity context was measured in paper IV. In paper II, self-reported measures of physical activity (after school and at weekends) and screen-based sedentary behavior (after school from Monday to Friday) were used, which might lead to misclassification or measurement error with regard to the exposure variable. The focus on leisure time may have led to an under-estimation of physical activity and sedentary behavior because it does not take account of school-based activity nor, in the case of sedentary behavior, of time spent at the weekend. The limitations of the self-report measures are that participants tend to over-report physical activity in self-report measures (PA recommendations) when compared to objectively measured activity (Steene-Johannessen et al., 2015), and they have shortcomings in evaluating light to moderate physical activity (James et al., 2016). As far as we know, no evaluation has been performed in the youth health surveys or Ungdata with regard to self-report of physical activity or screen-based sedentary behaviour. This limitation should be examined in future studies.

In the present thesis different outcome measures of mental health have been used: in paper II, psychological distress (HSCL-10), in paper III incident use of hypnotics and antidepressant, and in paper IV symptoms of depression. The outcome measures of psychological distress and depressive symptoms were examined using Rasch Measurement Theory.

In study II the HSCL-10 variable was used as a trichotomised variable based on percentiles. The intention was to capture the adolescents with higher levels of psychological distress, and compare them with those with lower psychological distress. Due to the cut-off point, the 20th percentile was compared to the 80th percentile in paper II. In study IV, the depression scale was dichotomized and the cut-off point was set at the 80th percentiles, ≥80th percentiles coded as depressive symptoms and <80th percentiles coded as no depressive symptoms. Using incident use of antidepressant and hypnotics has been reported to be a valid and
reliable data source for studying use of prescription drugs (Furu, 2008).

The incident use of hypnotics and antidepressant (paper III), psychological distress (paper II) and depressive symptoms (paper IV) may not only be an outcome but may also act as an exposure. Physical activity might lead to better mental health or, conversely, poorer mental health might lead to physical inactivity. At any one time, in a population both of these may be occurring. Furthermore, both physical activity and mental health might be influenced by other variables than those controlled for, either as covariates, moderators, mediators or outcomes. A recent longitudinal study among Australian adolescence found a bidirectional relationship between time involved in sports participation and internalizing problems (Vella, Swann, Allen, Schweickle, & Magee, 2017).
CONCLUSIONS AND IMPLICATIONS

Adolescents’ mental health and physical activity have become a main focus of attention in public health in Norway, and they both are important issues on the political agenda.

The results reported in this thesis indicate only a weak association between physical activity and mental health among adolescents when frequency and volume are used to measure physical activity. A more distinct pattern appears when not just the frequency and volume, but also the context of the physical activity is taken into account. Participating in a sports club was associated with significantly fewer symptoms of depression compared to no regular exercise, and after controlling for socio-economic conditions, specific health-related behaviours as well as other background variables. Hence, the results underline the need for broader approaches in studies of the association between physical activity and mental health in general and specifically in relation to adolescents. Both physical activity and mental health are complex phenomena and need to be operationalised as such in research exploring the relationship between the two. How mental health is operationalised and measured may have an impact on its relationship with physical activity, for example, when different sample groups are compared. The Rasch analysis of the psychometric properties of the HSCL-10 also adds to the research field. Because of the designs of the studies included in the thesis, no firm conclusions about causality can be made. However, some tentative pathways for the relationship have been discussed in the above.

The findings in this thesis, together and separately, provide evidence to inform public health workers and professionals who target physical activity as a way of enhancing mental health in young people.
FUTURE STUDIES

This thesis generated several important results which may lead to further studies in the public health science field. Leisure-time physical activity is an important domain to examine further, especially in terms of different physical activity contexts.

The depression symptom scale used in Ungdata should be further examined, and additional measures of mental health and physical activity should in future studies be used and psychometrically examined using Rasch Measurement Theory. These measurement issues are also of great importance in monitoring trends and for cross-country comparisons.

Longitudinal design should be used to better elucidate the association between physical activity/sedentary behavior and mental health. Young people’s screen-based sedentary behavior has changed markedly in recent years, and this should be investigated further, especially with regard to gender-based differences. Ethnicity is also a variable which should be considered given the changing composition of the Norwegian population.

There is limited research on the mechanism for the increase in gender differences in mental health. There is also a need for more knowledge about objectively measured physical activity in adolescents.

The results from these studies could be followed up with interviews of adolescents to gain a deeper insight in why they are physically active or not, and why or why not they have attended different physical activities (contexts).
ACKNOWLEDGEMENTS

It would not have been possible to write this doctoral thesis without the help and support of the kind people around me. I would like to express my sincere gratitude to all who have supported me and given me valuable help during this journey. In particular, I would like to show appreciation to:

The Norwegian Institute of Public Health (and Hedmark County Council for data collection in 2009) for providing the data. Paper III is a part of the project 'The epidemiology of prescription drug use – A record-linkage study in Norway', coordinated by the Norwegian Institute of Public Health. The Ungdata surveys were conducted by the Norwegian Social Research (NOVA) institute in cooperation with regional centres for drug rehabilitation (KoRus). I want to thank them for their cooperation and for conducting the data collection.

My main supervisor Curt Hagquist for the continuous support of my work, motivation and immense knowledge. You are always enthusiastic and positive. Thank you for sharing this with me.

My supervisors Ingeborg Hartz and Miranda Thurston. Thank you very much for sharing your knowledge, encouragement, support, insightful comments and critical questions, and Miranda, thank you very much for helping me with the language revision.

The Karlstad University and Professor Carl-Gustav Bornehag for accepting me as a doctoral student, and the research group at CFBUPH for given me valuable comments on articles in seminars and creating an environment where I always feel welcome. I would also like to thank Bodil Wilde-Larson and Maria Larsson at the Department of Nursing for allow me to participate in the doctoral seminars.

Innland Norway University of Applied Sciences former Dean Sven Inge Sunde, Vice Dean of research Ingeborg Hartz and Head of the Department of Sports and Active Lifestyle Dag Andre Nilsen for employing me as a PhD student. I also want to thank current Dean Ingrid Guldvik,
and former and current Heads of Department of Public Health Eivind Skille, Linda Lundsbakken and Svein Barene for facilitating my work during the period.

Librarians Annelie Ekberg Andersson at Karlstad University and Elin Oppheim at Innland Norway University of Applied Science for helping me with references and Endnote. Thanks to Bente Giset for all your administrative help.

My colleagues and fellow PhD students at Innland Norway University of Applied Sciences; especially Tuva Sandsdalen, Anne Kjersti Myhrene, Anne Mari Steigen, Hanne Søberg Finnbråten and Marie Dalen Granerud for keeping me company during all the car trips to Karlstad while discussion PhD course, writing, statistics, sharing encouragement, frustrations and laughter; Arild Vaktskjold for his support in discussing about statistics.

I have wonderful family and friends. Thank you for your love and support.

My dearest Kamilla, Katrine and Kristian for sharing your life with me. Thank you for reminding me about what is important in life, and for filling my life with joy and love. I am so proud of you!

Georg, my dear husband, thank you for being there, encouraging, supporting and believing in me.


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Mental health and physical activity in adolescence

Mental health is considered to be an important public health issue, particularly during adolescence. The World Health Organization has reported that half of all mental health disorders in adults start by age 14, but most of them are undetected and untreated. Furthermore, there are concerns about how to measure mental health, and a need for valid instruments has been identified.

This thesis considers the relationship between physical activity and mental health in Norwegian adolescents. It consists of four studies, all based on data collected from surveys among adolescents aged 15-16 years old. The results indicate a weak association between physical activity and mental health, and that participating in a sports club is associated with fewer symptoms of depression. Furthermore, the psychometric analysis of the Hopkins Symptoms Checklist-10 instrument using Rasch Measurement Theory is a step towards more valid assessment of psychological distress among adolescents.

This thesis contributes to the field of public health sciences by underlining the need for broader approaches in studies of the association between physical activity and mental health using proper measures.

ISBN 978-91-7063-865-7 (print)
ISSN 1403-8099
DOCTORAL THESIS  |  Karlstad University Studies  |  2018:32