

Riitta Pyky

PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR IN YOUNG MEN

*THE DETERMINANTS AND EFFECTIVENESS OF
A TAILORED, MOBILE, GAMIFIED INTERVENTION*

UNIVERSITY OF OULU GRADUATE SCHOOL;
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RIITTA PYKY

**PHYSICAL ACTIVITY AND
SEDENTARY BEHAVIOUR IN
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The determinants and effectiveness of a tailored,
mobile, gamified intervention

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Supervised by
Professor Raija Korpelainen
Professor Timo Jämsä

Reviewed by
Professor Tiina Laatikainen
Associate Professor Genevieve Healy

Opponent
Professor Mirja Hirvensalo

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University of Oulu, P.O. Box 8000, FI-90014 University of Oulu, Finland

Abstract

Physical inactivity and sedentary behaviour (SB) are harmful to health, but both globally and in Finland, 80% of adolescents are not physically active enough and they sit too much. Unhealthy behaviour seems to accumulate in young men. Factors underlying unhealthy behaviour should be identified, and based on these, effective interventions for health promotion should be developed. In this study we aimed to clarify the determinants of physical activity (PA) and SB in young men. In addition, we studied the effects of a gamified, tailored, mobile PA intervention on PA and subjective wellbeing.

Population-based data were collected in call-ups organized by the Finnish Defence Forces in 2010, 2012 and 2013 in the Oulu area, Finland. Altogether 2526 approximately 18-year-old men filled in a questionnaire, attended physical performance tests and went through a medical examination. In 2013, all 811 men who attended physiological measurements were invited to participate in a six-month randomized controlled trial, and 496 (61%) of them agreed to do so and were randomized into intervention (n=250) and control (n=246) groups. The intervention group got access to a mobile service developed in this study. PA and SB were continuously monitored during the trial. The PA and SB of the controls was measured without feedback on behaviour.

The profiles “exercising but sitting”, “feeling unhappy”, “symptoms of disordered eating”, “being unfit with appearance-related motivation” and “gaming” were found among the sedentary young men. The men living in both built and natural environments were equally physically active. The mother’s PA was associated with PA in men living in the built environment and the father’s PA with PA among natural environment residents. The intervention had a borderline positive effect on moderate-to-vigorous PA, but there was no change in SB or light PA. Life satisfaction improved both in the intervention group and the control group. Various functionalities related to the PA of the mobile service were considered important. However, the compliance in using the service was limited. Improvements in PA, self-rated health and life satisfaction were seen, especially among the men in the intervention group with low levels of PA and poor subjective wellbeing at baseline.

This study complements existing knowledge on the PA and SB of youth and the findings on the effects of technology-based PA promotion. The study adds to literature on individual, environmental and parental factors underlying SB and PA in young men. These findings highlight the importance of individually designed health promotion among young men.

Keywords: adolescent, environment, exercise, gamification, health, intervention, parents, physical activity, sedentary behaviour, tailoring, youth

Pyky, Riitta, Nuorten miesten fyysinen aktiivisuus ja paikallaanolo. Taustatekijät ja räätälöidyn, pelillistetyn ja mobiilin intervention vaikuttavuus

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Tiivistelmä

Fyysinen inaktiivisuus ja liiallinen istuminen ovat terveydelle haitallisia. Siitä huolimatta nuoret Suomessa ja muualla maailmalla eivät liiku riittävästi ja istuvat liian paljon. Epäterveelliset elintavat näyttäivät kasaantuvan erityisesti nuorille miehille. Liikkumattomuuden taustatekijät tulisi tunnistaa ja kehittää uusia menetelmiä nuorten aktivointiin. Tämän tutkimuksen tarkoituksena oli selvittää nuorten miesten fyysisen aktiivisuuden ja paikallaan olon taustatekijöitä sekä pelillistetyn, räätälöidyn ja mobiilin intervention vaikuttavuutta.

Väestöpohjainen aineisto kerättiin Oulun alueen kutsunnoissa vuosina 2010, 2012 ja 2013. Yhteensä 2526 keskimäärin 18-vuotiasta nuorta miestä täytti hyvinvointikyselyn, osallistui kuntotesteihin ja kävi lääkärintarkastuksessa. Satunnaistettuun, kontrolloituun, kuuden kuukauden interventioon osallistui 496 nuorta. Interventio-ryhmä sai käyttöönsä tutkimuksessa kehitetyn mobiilin palvelun, joka sisälsi pelillisiä elementtejä. Lisäksi ryhmään kuuluneiden fyysistä aktiivisuutta mitattiin jatkuvasti koko intervention ajan kiihtyvyyssanturimenetelmällä ja he saivat siitä palautetta. Kontrolliryhmän aktiivisuus mitattiin, mutta he eivät saaneet palautetta.

Viisi erilaista profiilia tunnistettiin paljon istuvien nuorten miesten vastauksista: paljon istuvat liikkujat, elämänsä tyytymättömät, syömishäiriöillä oireilevat, huonokuntoiset ulkonäöstä motivoitujat ja pelaajat. Luonnollisessa ja rakennetussa ympäristössä asuvat nuoret liikkuvat yhtä paljon. Äidin runsas liikkuminen oli yhteydessä rakennetussa asuinympäristössä asuvien poikien suurempaan fyysiseen aktiivisuuteen, kun taas isän liikkumisella oli positiivinen yhteys luonnollisessa ympäristössä asuvien poikien liikkumiseen. Interventio lisäsi jonkin verran poikien kohtuukoormitteisen tai raskaan fyysisen aktiivisuuden määrää. Paikallaan olon tai kevyen aktiivisuuden määrä ei muuttunut. Elämäntyytyväisyys koheni sekä interventio- että kontrolliryhmässä. Vaikka tutkittavien sitoutuminen tutkimukseen oli kohtuullisen heikko, he pitivät monia tutkimuksessa kehitetyn mobiilin palvelun fyysiseen aktiivisuuteen liittyviä ominaisuuksia kiinnostavina. Erityisesti niillä nuorilla, jotka olivat liikkuneet vähän tai kokeneet hyvinvointinsa huonoksi tutkimuksen alussa, havaittiin positiivisia muutoksia intervention aikana.

Tutkimuksessa saatiin lisää tietoa yksilöllisten sekä ympäristöön että vanhempiin liittyvien tekijöiden merkityksestä nuorten liikkumiselle ja paikallaan ololle. Tutkimus tuotti uutta tietoa pelillistetyn, räätälöidyn mobiiliteknologian mahdollisuuksista nuorten miesten aktivoinnissa. Tulosten perusteella yksilöllinen räätälöinti on tärkeää nuorten miesten terveyden edistämiseen tähtäävissä interventioissa.

Asiasanat: fyysinen aktiivisuus, interventio, istuminen, liikunta, mobiilisovellukset, nuoret, paikallaan olo, pelillistäminen, räätälöinti, terveys, vanhemmat, ympäristö

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29.10.2019 in Oulu

Riitta

Abbreviations

BMI	body mass index
CI	confidence interval
DSM-BIA	direct segmental multi-frequency bioelectrical impedance analysis
DXA	dual X-ray absorptiometry
EDI	Eating Disorder Inventory
GIS	geographical information system
ICD-10	the 10th revision of the International Statistical Classification of Diseases and Related Health Problems
KMO	Kaiser-Meyer-Olkin Measure of Adequacy
LS	life satisfaction
LTPA	leisure-time physical activity
MET	metabolic equivalent of a task
MVPA	moderate-to-vigorous physical activity
OR	odds ratio
PA	physical activity
PCA	principal component analysis
PSD	persuasive systems design
RBDI	Raitasalo's Beck Depression Inventory
RCT	randomized controlled trial
SB	sedentary behaviour
SD	standard deviation
SE	standard error
SES	socioeconomic status
SMS	short messaging service
TTM	transtheoretical model

List of original publications

This thesis is based on the following publications, which are referred to throughout the text by their Roman numerals:

- I Pyky R, Jauho AM, Ahola R, Ikäheimo TM, Koivumaa-Honkanen H, Mäntysaari M, Jämsä T, Korpelainen R. Profiles of sedentary and non-sedentary young men – A population-based MOPO study. *BMC Public Health* (2015) 15:1164.
- II Pyky R, Puhakka S, Ikäheimo TM, Lankila T, Kangas M, Mäntysaari M, Jämsä T, Korpelainen R. Parental factors related to physical activity among adolescent men living in built and natural environment – a population-based MOPO study. 2018. (manuscript, submitted to *BMC Public Health*)
- III Leinonen AM, Pyky R, Ahola R, Kangas M, Siirtola P, Luoto T, Enwald H, Ikäheimo TM, Röning J, Keinänen-Kiukaanniemi S, Mäntysaari M, Korpelainen R, Jämsä T: Feasibility of Gamified Mobile Service Aimed at Physical Activation in Young Men: Population-Based Randomized Controlled Study (MOPO) *JMIR mHealth uHealth* 2017;5(10):e146. DOI: 10.2196/mhealth.6675.
- IV Pyky R, Koivumaa-Honkanen H, Jauho AM, Ahola R, Hirvonen N, Enwald H, Luoto T, Ferreira E, Ikäheimo TM, Keinänen-Kiukaanniemi S, Mäntysaari M, Jämsä T, Korpelainen R. Effect of tailored, gamified, mobile physical activity intervention on life satisfaction and self-rated health in young adolescent men: A population-based, randomized controlled trial (MOPO study). *Computers in Human Behavior* 2017, 72: 13–22. DOI: 10.1016/j.chb.2017.02.032.

Description of the author's role in each substudy

In Studies I and II, the first author had the responsibility on planning the data collection and practical arrangements during the call-ups, data preparation for the analyses, as well as data analysis and drafting the first version of the manuscript. She was also responsible for finishing and submission of the articles in Studies I and II, and for the revision of the article and the publication process in Study I.

In Study III, Riitta Pyky had the responsibility on planning the data collection and practical arrangements during the call-ups, and she participated in the intervention design and implementation and writing the article. In the revision phase, she also performed additional analyses on the effect of the intervention on physical activity.

In Study IV, the first author had the responsibility on planning the data collection and practical arrangements during the call-ups, data preparation for the analyses, as well as data analysis and drafting the first version of the manuscript. She participated in the intervention design and implementation, as well as development of the mobile service. She was also responsible for finishing, submission and revision of the article and the publication process.

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1 Introduction

Physical inactivity and sedentary behaviour (SB) harm the health and wellbeing of people globally and cause an enormous amount of social and health costs. The health effects of physical activity (PA) are undeniable and the knowledge on the harms of prolonged sitting has increased over the past decade. Physical inactivity is associated with many physical and mental diseases and it causes 9% of the global premature mortality (Lee et al., 2012). Moreover, SB is positively associated with all causes of mortality despite the amount of PA (Katzmarzyk, Church, Craig, & Bouchard, 2009).

Young people should exercise or be physically active with moderate intensity for at least an hour daily (World Health Organization, 2010), limit their daily screen time and avoid over one hour of uninterrupted sitting (Ministry of Social Affairs and Health, 2015). Globally and in Finland, 80% of adolescents are not physically active enough (Hallal et al., 2012; Liukkonen et al., 2014). Adolescents spend about six to eight hours daily in SB (Froberg & Raustorp, 2014; Pate, Mitchell, Byun, & Dowda, 2011), and Finnish young men may be sedentary for approximately 10 hours daily (Niemelä et al., 2016).

Finnish young men can be described as a special group. Although Finnish boys have been suggested to meet the PA recommendation more often than girls in childhood, the decline of the PA level from childhood to adolescence is rapid in Finland (Liukkonen et al., 2014). Total PA may be lower with unemployment (Wennman et al., 2019). The youth unemployment rate is high in Finland and young men are especially at risk of marginalization (e.g. staying out of employment, education or training) (Nikunen, 2017; Statistics Finland, 2017b). Thus, young men with the identified risk factors for marginalization are especially in need of health promotion. In Finland, the whole age cohort of young men can be reached annually at call-ups (i.e. the conscription organized by the Finnish Defence Forces for all boys turning 18 on that year).

The correlates and determinants of PA have been studied for decades. Many individual, interpersonal, environmental, policy-level and global factors associate with PA. (Bauman et al., 2012.) Moreover, PA can be promoted via behavioural, social, environmental and policy approaches (Heath et al., 2012). Due to digitalization and because technological devices and mobile applications are a natural part of the everyday life of young people, mobile and Internet-based approaches have been utilized in PA and health promotion for youth. According to previous studies, mobile interventions have at least short-term effects on the health

behaviour of adolescents, but the feasibility of and adherence to the interventions should be enhanced and studied further (Hamel, Robbins, & Wilbur, 2011; Turner, Spruijt-Metz, Wen, & Hingle, 2015). Population-based studies are rare or even lacking.

This doctoral dissertation is a part of the MOPO study in which we aimed to promote PA and prevent social marginalization among young, conscription-aged men (Ahola et al., 2013). We collected the yearly, population-based data on PA, health, wellbeing and the health behaviour in call-ups in the Oulu region, northern Finland, from 2009 to 2013. Based on the previous research and the gathered qualitative and quantitative data on young men in the MOPO study, we developed a tailored, mobile and gamified service for the health promotion of young men. We studied the effectiveness of this service in a six-month randomized controlled trial (RCT) that ran between September 2013 and March 2014.

Two of the publications (Studies I and II) in this thesis aimed to study the factors associated with PA and SB in young men in a cross-sectional study design. Two other publications (Studies III and IV) studied and reported the effects of the mobile intervention on PA, life satisfaction and perceived health in young men. The feasibility of the intervention is also discussed. PA, SB and their determinants, and previous results on mobile interventions are included in the literature review. The methods and results are presented based on the five aims of the study. The implications and the reliability of this thesis and the recommendations for further studies are considered in the Discussion section.

2 Review of the literature

2.1 Physical activity and sedentary behaviour

People's way of living has changed since the industrial revolution and digitalization. It has contributed to physical inactivity – the situation where a person does not move adequately for good health. Another outcome of the development of new technologies that enable people to reduce physical action is excessive sitting, which also has negative health effects independent of other health behaviour.

2.1.1 Definition of physical activity and sedentary behaviour

The health effects of PA have been known since 1950 (Blair et al., 2010; Lee et al., 2012) and the definition of PA comes from the 1980s; it is defined as any bodily movement produced by skeletal muscles that requires energy expenditure (Caspersen, Powell, & Christenson, 1985).

The term sedentary behaviour is newer and though research on the different types of sedentary actions has become more common over a couple of decades, the definition is only a couple of years old. SB is any waking behaviour characterized by energy expenditure ≤ 1.5 metabolic equivalents of a task (METs) while in a sitting, reclining or lying posture (Tremblay et al., 2017). In general this means that any time a person is sitting or lying down, they are engaging in SB. Common SBs include TV viewing, video game playing and computer use (the three of which are collective termed “screen time”), driving an automobile and reading.

2.1.2 Epidemiology of physical activity and sedentary behaviour in youth

The positive health effects of PA are undeniable. PA reduces the rates of all-cause mortality, coronary heart disease, high blood pressure, strokes, metabolic syndrome, type 2 diabetes, falling, depression, and breast and colon cancers. In addition, PA improves bone health, cognitive function, fitness and body composition. (Lee et al., 2012.)

According to the global recommendation on PA, children and youths aged 5–17 should accumulate at least 60 minutes of moderate-to-vigorous-intensity PA daily to achieve the health benefits of PA. Adults aged 18 to 64 should do at least

150 minutes of moderate-intensity aerobic PA or at least 75 minutes of vigorous-intensity PA throughout the week. (World Health Organization, 2010.) Finnish conscription-aged men are situated at the cut-off point between being youths and adults in the guidelines. Still, according to data from 105 countries, only 20% of the adolescents worldwide are physically active enough, boys being more active than girls (Hallal et al., 2012). Older adolescents are less likely to meet the PA recommendations than the younger ones (Chen et al., 2018; Corder et al., 2015; Husu, Vaha-Ypya, & Vasankari, 2016) and PA declines from adolescence to early adulthood (Corder et al., 2019). Due to differences in defining the living environment and behaviour, the findings on a comparison of PA and SB between rural and urban youth in previous studies have been mixed (McCormack & Meendering, 2016). Some studies have suggested that the amount of PA is higher among rural youth compared to urban adolescents (Kasehagen, Busacker, Kane, & Rohan, 2012; Moore, Beets, Morris, & Kolbe, 2014) but contradictory findings exist (Moore, Brinkley, Crawford, Evenson, & Brownson, 2013).

The global concern about sitting cumulated about ten years ago when the knowledge of the health effects of excessive SB increased. Prolonged sitting was shown to be associated with increased all causes of mortality regardless of the amount of PA (Katzmarzyk et al., 2009). In addition, SB has been found to positively associate with cardiovascular disease, type 2 diabetes and metabolic syndrome in adults. In children and adolescents, the strongest association has been found between the amount of SB and obesity. In addition, SB is related to blood pressure and total cholesterol, self-esteem, social behaviour problems, physical fitness and academic achievement in young people. (de Rezende, Rodrigues Lopes, Rey-Lopez, Matsudo, & Luiz Odo, 2014; Tremblay et al., 2011.)

So far, the literature has been unable to recommend a specific daily amount of SB because the health risks related to SB may depend on the amount of PA. The more daily sitting time there is, the more at least moderate-intensity activity is needed in order to decrease the risk of all-cause mortality. However, guidelines recognize the need for reducing prolonged sitting. (Powell et al., 2018.) A maximum of two hours per day of recreational screen time among children and youth has also been suggested in Canada and in Finland (Ministry of Education, 2008; Tremblay, Carson, & Chaput, 2016).

According to data from 40 countries in Europe and North America, 66% of boys and 68% of girls aged 13–15 years spend two hours or more per day watching television, and watching TV is only one type of SB (Hallal et al., 2012). Youth spend approximately six to eight hours daily in SB (Froberg & Raustorp, 2014;

Pate et al., 2011). In Finland, seven- to 14-year-old children have been found to spend over seven hours sedentary on average (Husu et al., 2016). According to objective measurement of SB in MOPO's substudy, conducted by Niemelä et al., Finnish young men may sit even 10.5 hours daily, though the amount may also include standing still (Niemelä et al., 2016). The literature on the differences in SB among rural and urban youth is insufficient and both a difference and no difference have been found in the studies (Carson, Iannotti, Pickett, & Janssen, 2011; McCormack & Meendering, 2016; Springer, Hoelscher, Castrucci, Perez, & Kelder, 2009).

2.2 The determinants of physical activity and sedentary behaviour in youth

The determinants of PA and SB have been moderately studied, but the methodological quality of the majority of the studies has been criticized (Uijtdewilligen et al., 2011). The associations between the determinants and SB appear to be contradictory and dependent on the evaluation method (i.e. on if they are subjectively measured vs objectively measured and if they measure total SB vs screen time). A review in 2011 concluded that evidence of the determinants for SB was insufficient (Uijtdewilligen et al., 2011). Findings on the determinants are more consistent for PA.

2.2.1 Genetics

Studies on the determinants of PA often focus on behavioural and environmental factors related to PA. However, it was already suggested in the 1920s that biological factors (later recognized as hormones) could influence PA levels (Lightfoot et al., 2018). Genomic and other biological factors interact with environmental factors. They also cause changes in the inflammatory signals and metabolite levels that contribute to our PA behaviour, and exercising may be easier for some individuals due to biological factors (Kujala, 2011; Lightfoot et al., 2018). In addition, genes may influence how exercise is perceived and the ability to exercise and loose weight (Stubbe et al., 2006). The existing difference between males' and females' PA levels supports the influence of sex hormones on PA, though the mechanism of this association should be further studied (Bowen, Turner, & Lightfoot, 2011). Among young people, the genetic variation in leisure-time PA (LTPA) has been

suggested to vary from 31% to 42% (de Geus, Bartels, Kaprio, Lightfoot, & Thomis, 2014).

Genetics and SB have been less studied. The association between gender and SB is mixed. Some studies have suggested that boys engage in less SB when the SB is objectively measured, but an association has not been found with subjectively evaluated SB (Stierlin et al., 2015). The heritability of SB may be stronger among boys compared with girls during early adolescence and young adulthood. On the contrary, 9% of variation in time spent sedentary among boys and 36% among girls were accounted for by genetic factors in a study among American youth. (Haberstick, Zeiger, & Corley, 2014.) The difference in the definition of sedentary behaviour may have affected the findings.

2.2.2 Parental and psychosocial factors

Self-efficacy (confidence), perceived ability to be physically active and general social support or family support are known to be determinants of PA in children and adolescents (Bauman et al., 2012; Telama et al., 2014). Perceived competence and attitude correlate with, but do not predict, PA in adolescents according to a global review (Bauman et al., 2012). Parental activity or children's perceptions of their parents' PA have not always been found to correlate with the PA of adolescents (Bauman et al., 2012), but studies wherein this association is found do exist (Cheng, Mendonca, & Farias Junior, 2014; Dumith et al., 2012; Martin-Matillas et al., 2011). Moreover, a systematic association between parents' PA and the PA of their offspring was found from childhood to young adulthood in a recent Finnish, prospective and population-based study (Kaseva et al., 2017). Perceiving stress is suggested to reduce PA in all age groups (Cortis et al., 2017).

Parental PA is significantly associated with their children's PA (Kaseva et al., 2017). However, the findings are inconsistent or lacking regarding the association between maternal PA and children's SB. However, the absence of social support in the family can increase the sedentary time of children (Stierlin et al., 2015). Children whose parents endorse screen time limits tend to have lower levels of SB, as do households with limited access to televisions or computers (Pate et al., 2011; Pyper, Harrington, & Manson, 2016). Similarly, parents' TV viewing is positively associated with the screen time of their children (Pyper et al., 2016). The association between parents' age and the SB of their children is mixed, suggesting that either the high or low age of parents may increase the SB of children (Pate et al., 2011).

2.2.3 Socioeconomic factors

Neighborhood's higher socioeconomic status has been suggested to increase moderate to vigorous PA and participation in sports hobbies of 14-18 years old adolescents (Molina-Garcia, Queralt, Adams, Conway, & Sallis, 2017), but in a German study among few years younger adolescents, the association was contradictory (Krist et al., 2017). Lower parental social status and lower income has been found to associate with physical inactivity in youth (Kantomaa, Tammelin, Nayha, & Taanila, 2007; Wells, Nermo, & Ostberg, 2017). However, no association was found between SES or parental SES and PA of adolescents in an umbrella literature review (O'Donoghue et al., 2018). In a recent Finnish study among adolescent, a subjective social status in school was negatively associated with sedentary time in school and positively associated with total MVPA (Rajala et al., 2019).

A meta-analysis including 39 studies concerning 10 to 19 years old adolescents suggested that the associations between SES and sedentary behaviour vary according to the income rate of the country and the type of SB. In high-income countries, SES was inversely associated with total screen time and television viewing. In low-middle-income countries, SES was positively associated with other screen time and studying but not with television time. (Mielke, Brown, Nunes, Silva, & Hallal, 2017.) On a family level the findings vary. Higher family socioeconomic status may increase the sedentary time among adolescents (Pate et al., 2011; Young et al., 2019) or the association between SES and SB has not always been found (Stierlin et al., 2015). Children from families with higher SES may engage more in objectively measured SB but the findings are inconsistent with subjective SB. It has also been suggested that in families with lower income, children have higher levels of screen time, and children from higher SES families spent more time in academic sedentary behavior such as reading and studying. (Pate et al., 2011.) Parental education has been suggested to be inversely related to children's screen time (Bounova, Michalopoulou, Agelousis, Kourtessis, & Gourgoulis, 2016; Gebremariam et al., 2015).

2.2.4 Built and natural environments

Environmental determinants of PA vary depending on the type of PA studied. A dense population, high intersection and public transport density, and a high number of parks have been shown to be connected to higher PA among adults (Sallis et al.,

2016). Moreover, the presence of safe crossroads seems to decrease the amount of SB in youth (Stierlin et al., 2015). Concerning natural environments, green areas have been suggested to promote PA (especially MVPA) and self-rated health among adults and young people (Dadvand et al., 2016; James, Banay, Hart, & Laden, 2015; McCrorie, Fenton, & Ellaway, 2014). The type of PA may vary according to the type of green area; greenness in a built environment encouraged more walking while in an agricultural environment young and middle-aged adults favoured gardening and other habitual chores (Picavet et al., 2016).

Only a few studies on the relationship between the environment and PA among youth exist and the findings are inconsistent. Adolescents spend little time in green space, boys spending a little bit more time than girls. (McCrorie et al., 2014.) To urban adolescents, streets and school grounds provide more important PA facilities than city parks (McCrorie et al., 2014; McGrath, Hopkins, & Hinckson, 2015). But there are also contradictory findings (Coombes, van Sluijs, & Jones, 2013; Jones, Coombes, Griffin, & van Sluijs, 2009) about the use of city green space. Rural young people are more likely to use farmland and grassland. Domestic gardens are potential places for both light and vigorous activity. (Bauman et al., 2012; McCrorie et al., 2014.)

Comparisons of the amount of PA according to the living environment have usually been based on urban and rural environments and not on natural and built environments. Objectively measured MVPA has previously been shown to be lower in rural youth compared with urban youth (Moore et al., 2013). However, differences in PA according to the residential environment have not always been detected among boys (Moore et al., 2014).

2.2.5 Weight, BMI, health and wellbeing

The association between weight and PA or SB has previously mainly been studied using weight as the outcome instead of behaviour. Earlier, BMI and other anthropometric measures have not been found to increase or decrease PA (Bauman et al., 2012). However, dissatisfaction with body weight may decrease the amount of physical activity in overweight adolescents (Sampasa-Kanyinga, Hamilton, Willmore, & Chaput, 2017). Body weight is positively associated with screen time in youth but no evidence was found when total SB was considered. According to a systematic review of systematic reviews and meta-analyses, associations between sedentary behaviour and adiposity in adolescents are small and there is little to no

evidence that this association is causal (Biddle, Garcia Bengoechea, & Wiesner, 2017).

Depressive symptoms seem to increase screen time in youth (Stierlin et al., 2015). Considering subjective wellbeing, more studied research question is how physical activity affects subjective wellbeing and not whether subjective wellbeing is a determinant of physical activity. Subjective wellbeing can be evaluated for instance by self-rated health and life satisfaction (Diener & Diener, 1995; Keyes & C.L.M., 2006). Physical activity level and willingness to be physically active are closely linked with self-rated health and life satisfaction (Herman, Hopman, & Sabiston, 2015; Kantomaa, Tammelin, Ebeling, Stamatakis, & Taanila, 2015; Proctor, Linley, & Maltby, 2009) and they have been shown to predict longevity (Koivumaa-Honkanen et al., 2000; Koivumaa-Honkanen et al., 2001; Kumar, Robinson, & Till, 2015; Larsson, Hemmingsson, Allebeck, & Lundberg, 2002). Among adolescents, lesser time spent on sedentary activities has been related to good self-rated health (Herman et al., 2015). In several previous studies, a change in physical activity has been shown to be bidirectionally related to change in subjective wellbeing (Biddle & Asare, 2011; Boehm & Kubzansky, 2012; Gillison, Skevington, Sato, Standage, & Evangelidou, 2009; Rejeski et al., 2001).

2.2.6 Physical activity and other health behaviours

Behavioural correlates of PA in children and adolescents vary (Bauman et al., 2012). Due to differences in study samples, determinants and outcomes and the lack of objective measures have challenged summary making (Craggs, Corder, van Sluijs, & Griffin, 2011). Of the behavioural factors, smoking has not earlier been associated with PA (Bauman et al., 2012), but limited evidence for smoking as a determinant of PA was found in a more recent review (Condello et al., 2017). A population-based study among 177 091 adolescents found poor dietary habits to be associated with PA (Tambalis, Panagiotakos, Psarra, & Sidossis, 2019). Previous physical activity and independent mobility may increase physical activity among adolescent (Bauman et al., 2012; Condello et al., 2017). Vigorous physical activity has been found to be negatively associated with overall PA (Condello et al., 2017).

No association has been found between PA and screen-based sedentary behavior in the previous studies. However, sedentary behavior related to mobile phone use may be negatively associated with physical activity. It has also been suggested that children who walk or cycle to school spent less time in sedentary

behaviors. (Pate et al., 2011.) Eating while watching TV may increase the amount of sedentary time (Pate et al., 2011; Stierlin et al., 2015).

Previously, higher amount of PA and lower SB have been found to associate with sufficient sleep duration (Y. Kim, Umeda, Lochbaum, & Stegemeier, 2016). In addition, longer sleep may increase physical activity and healthy diet among adolescents (Gong et al., 2017).

2.3 Mobile interventions to promote physical activity in youth

All Finnish adults under 55 aged use the Internet and 78% of the 16- to 24-year-olds used the Internet via mobile phones in 2017 (Statistics Finland, 2017a). Utilizing mobile phones in health promotion is common even for youth. According to Statistics Finland, 30% of Finns aged between 16 and 24 years had used mobile phone fitness apps and 9% had used some activity monitor in 2016 (Statistics Finland, 2016). Instead of traditional health promotion strategies, such as individual and group face-to-face counselling, Internet-based approaches, social aspects and having fun may be important in promoting health and PA among young people (Rees et al., 2006). In particular, adolescents presenting unhealthy behaviour have been interested in Internet-based health promotion (Tercyak, Abraham, Graham, Wilson, & Walker, 2009). Various studies have also shown that web-based tailored interventions may be a promising method to promote the health behaviour of adolescents (Bewick et al., 2013; Broekhuizen, Kroeze, van Poppel, Oenema, & Brug, 2012; Ezendam, Noordegraaf, Kroeze, Brug, & Oenema, 2013; Hustad, Barnett, Borsari, & Jackson, 2010; C. M. Lee, Neighbors, Kilmer, & Larimer, 2010).

2.3.1 The theoretical background in mobile interventions

Usually, the mobile approach is combined with more traditional health promotion methods in a mobile intervention, and therefore the exact effect of wireless promotion is difficult to verify (Turner et al., 2015). Moreover, mobile interventions should be designed based on a theoretical framework to help researchers understand which components were most effective in trials (Fanning, Mullen, & McAuley, 2012). If the reporting is only based on the theories applied, effective interventions are challenging to repeat. Thus, more practical and consistent methods for specifying and reporting interventions have been developed. (Michie et al., 2013.)

The features of PA interventions can be studied according to the theory-based framework, Persuasive Systems Design (PSD). In PSD, features can be categorized as 1) primary task support, 2) dialogue support, 3) system credibility support and 4) social support. (Matthews, Win, Oinas-Kukkonen, & Freeman, 2016.) PSD is a more compact summary compared to a review in which 93 behavioural change techniques were hierarchically clustered into 16 groups which did not depend on a theoretical structure. Those groups were: 1) scheduled consequences, 2) rewards and threats, 3) repetition and substitution, 4) antecedents (i.e. restructuring the physical and social environment), 5) association, 6) covert learning, 7) natural consequences (i.e. health and emotional consequences), 8) feedback and monitoring, 9) goals and planning, 10) social support, 11) a comparison of behaviour, 12) self-belief, 13) a comparison of outcomes, 14) identity, 15) shaping knowledge and 16) regulation (i.e. regulating negative emotions, pharmacological support). (Michie et al., 2013.)

With the increasing use of smartphones, mobile health applications have become more common in health promotion. The behaviour change techniques utilized in mobile applications are not usually highlighted in the service, but they do exist. Yang et al. (2015) studied which behaviour change techniques were applied in 100 mobile health applications. The most common techniques utilized in the applications were providing social support, information on others' approval, instructions for and demonstrations of behaviour change, and feedback on the behaviour (Yang, Maher, & Conroy, 2015). The features self-monitoring, praise, rewards, reminders, social comparison, competition and social learning (which are included in the PSD categories primary task, dialogue and social support) have also commonly been used in mobile applications. Features related to system credibility, such as real-world feel (real people exist behind the system surface) and trustworthiness, have been insufficiently included. (Matthews et al., 2016.)

According to Ritterband et al. (2009) effective Internet interventions change the behaviour of a user via a nonlinear path: the user, influenced by environmental factors, affects website use and adherence. The adherence is also influenced by support and website features. The use of a website leads to behaviour change through various behaviour change mechanisms. (Ritterband, Thorndike, Cox, Kovatchev, & Gonder-Frederick, 2009.) The extensive use of theory has been found to increase the effect size of an Internet intervention. The more behaviour change techniques were used, the larger effects were discovered. The largest effects were detected if stress management was provided to participants. (Webb, Joseph, Yardley, & Michie, 2010.) More recently, social and personal smartphone feedback were

suggested to be more effective than no feedback in an RCT among 165 men (Harries et al., 2016). In addition, a smartphone application was perceived more acceptable in social settings and found to be more effective in health behaviour change compared to a paper diary in an RCT among 34 young people (Jimoh et al., 2018). In a 12-month study on the prevention of metabolic syndrome, participants perceived self-monitoring, reminders and tunnelling (guiding information to the user) as useful (Karppinen et al., 2016). The PSD features surface credibility, dialogue support, aesthetics and content appeal, tunnelling and self-monitoring may be important, especially in interventions among adolescents with depression (Wozney et al., 2017).

2.3.2 Tailoring

Traditionally, health promotion has been general information delivered to a whole population. General information has its weaknesses; individually relevant information may be difficult to find and the information may not meet the needs of a person. (Enwald, 2013.) Tailoring health information means that the information content, the context and the way in which information is transmitted or given are determined based on a data about an individual. Tailoring consists of message construction methods, and psychological and social processes which may enhance health communication. Messages can be modified to be more acceptable so that they are easier to process, or messages may focus on the behavioural determinants of the desired change. (Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008.)

The purpose of tailoring is to enhance the perceived relevance of the information and thus to generate more desired change, for example, change in health behaviour in response to the information. Hawkins et al. 2008 suggest three strategies for tailoring. Attention and motivation to process messages may be enhanced by open examples and personalization. In addition, descriptive, comparative or evaluative feedback on a person's present health situation or behaviour may be given. By content matching, the messages can focus on the knowledge of the individual, outcome expectations, normative beliefs, efficacy or skills. (Hawkins et al., 2008.) In an intervention aiming to increase PA, one's confidence in starting to exercise, the expected outcomes of starting to be physically active and beliefs about what others think about one's exercising or not exercising could be asked about and the responses could be content matched.

In mobile interventions, individually tailored content may include feedback, health information and exercise guidance based on a participant's level of readiness,

amount of PA or stage of change (Larsen et al., 2018). Individual barriers and the motives for PA may also be taken into account in tailored messaging in mobile interventions among adolescents (Lau, Pitkethly, Leung, Lau, & Wang, 2019). Feedback, reminders and exercise tips can also be timed by machine learning algorithms and user activity analysis so that the participant receives the message at an appropriate, non-busy time (Ghanvatkar, Kankanhalli, & Rajan, 2019; Lim, Kim, & Choi, 2017).

2.3.3 Gamification

Gamification can be used in health promotion services to improve user experience and engagement (King, Greaves, Exeter, & Darzi, 2013). Gamification has been described as using game design techniques, game principles and mechanics (such as badges, points, levels and leaderboards) to improve user engagement, learning, behaviour change and reaching goals (Burke, 2014). There are number of health and fitness apps existing in the app stores that contain at least some components of gamification. A recent review analyzed the games with characteristics aimed at promoting PA. A large variety of characteristics were used in the games, but their theoretical foundation was limited. Though the acceptability and feasibility were found to be high, the clinical effectiveness and the added value of gamification in promoting PA could not be proven. (Tabak, Dekker-van Weering, van Dijk, & Vollenbroek-Hutten, 2015.)

Persuasive features in games could be effective in the promotion of health behaviour, but they are not adequately utilized in health applications (Matthews et al., 2016). A recent pilot study compared gamified and non-gamified web-based health interventions among young people and concluded that gamification may affect how positively participants perceive the intervention (Kelders, Sommers-Spijkerman, & Goldberg, 2018). A review including 30 studies suggested that games for health may increase short-term light and moderate physical activity and healthy behavior, and relax the gamers of all ages (Haaranen, Rissanen, Laatikainen, & Kauhanen, 2014). Gamification and social incentives can also be added to existing social networking services (Mo et al., 2019) and, in addition to the individual level, gamification can be conducted among a community or a neighbourhood (Harris, 2018).

2.3.4 The feasibility of mobile interventions

Though mobile interventions without face-to-face counselling may be cost-effective, their feasibility is of high importance. A recent review concluded that mobile health promotion is a feasible and acceptable method among youth (Turner et al., 2015). An Internet-based intervention was shown to be feasible in a smaller Chinese RCT among subjects aged 12 to 18 (Abraham et al., 2015). A review of mobile mental health interventions concluded that mobile mental health promotion is a flexible, interactive and spontaneous approach that encourages continual care among youth (Seko, Kidd, Wiljer, & McKenzie, 2014). Despite the high feasibility and acceptance, the compliance of a mobile intervention may be limited. A variety of technical reasons and a lack of interest may lower the engagement with smartphone health promotion applications among youth (Lubans, Smith, Skinner, & Morgan, 2014).

2.3.5 Effects on physical activity and sedentary behaviour

A previous review (Turner et al., 2015) summarized experiences related to using mobile and wireless technologies in the prevention of children's obesity and healthy behaviour promotion. According to the review, the quality and the design of the studies is heterogeneous. The mobile methods of the RCTs considered in the review mainly utilized short messaging services (SMSs) and did not have an additional effect on PA in youth (de Niet et al., 2012; Nguyen et al., 2012; Turner et al., 2015). Still, several applications and games which used SMSs related to positive short-term effects or encouraging feedback on one's PA, increased PA or the attitude towards PA (Turner et al., 2015). Another previous review concluded that the mobile interventions such as educational web-based lessons or computer-tailored feedback with parental support may increase PA in adolescents, but the effect is short-lived (Hamel et al., 2011). Another review (Bort-Roig, Gilson, Puig-Ribera, Contreras, & Trost, 2014) highlighted the need for RCTs and larger sample sizes. According to the review of Bort-Roig et al. (2014), smartphone technologies may have no more than moderate positive effects on PA in adults and the interventions should be more theory based.

Promising findings of gamification in PA enhancement exist. Health promotion via mobile exergame increased PA among 11-year-old students in a school setting (Garde et al., 2016). A pilot study comparing gamified and non-gamified web-based wellbeing interventions among youth suggested that gamification may increase

cognitive engagement, though there were no differences in the wellbeing effectiveness between the gamified and non-gamified interventions (Kelders et al., 2018). Integrating gamification and social incentives into existing social networking services in a controlled trial of 52 participants increased self-rated PA and related social cognition among youth (Mo et al., 2019).

2.3.6 Effects on subjective health and wellbeing

The information on the effects of mobile health interventions on subjective wellbeing is scanty or the studies have been made among special groups. A 10-week Internet-delivered intervention among college students with mental disorders did not have an impact on mental health outcomes (Mailey et al., 2010a). In a study among adolescents at risk of type 2 diabetes, a technology-based 12-month intervention affected the quality of life of girls, but had no effect on boys (Patrick et al., 2013). A 12-week web-based intervention succeeded in increasing the health-related quality of life in overweight young people (Riiser et al., 2014). A large meta-analysis (Fedele, Cushing, Fritz, Amaro, & Ortega, 2017) of 37 studies with 30 000 participants aged 18 years old or younger suggested that mobile health interventions are effective among youth. The effects of mobile interventions on health were significant and increased if the caregiver was involved in the intervention. (Fedele et al., 2017.) Mobile interventions have been found to be useful in engaging youth for therapeutic purposes (Seko et al., 2014).

3 Aims of the study

The overall purpose of the study was to explore the determinants of PA and SB, and the effectiveness of a mobile, tailored gamified intervention on PA and perceived health among young men.

The more specific aims were:

1. to reveal the different profiles of sedentary young men (Study I)
2. to compare the level and factors related to PA among young men living in built and natural environments (Study II)
3. to examine the effects of a gamified, mobile, tailored intervention on the PA and SB of young men (Study III)
4. to examine the effects of a gamified, mobile, tailored intervention on the life satisfaction and self-rated health of young men (Study IV)
5. to evaluate the feasibility of the gamified, mobile and tailored intervention for the physical activation of young men (Studies III and IV)

4 Subjects and methods

The present thesis is a part of a population-based study (the MOPO study) that aims to promote PA and to prevent social marginalization among young, conscription-aged men (Ahola et al., 2013). We used population-based, cross-sectional data and population-based data from a randomized controlled intervention in this thesis.

Military service or civic duty is compulsory for all male citizens in Finland, and the Finnish Defence Forces organize conscription every year for men who turn 18 that year. The entire age cohort attends the conscription except for those whose health or psychological capacities do not allow independent living. Thus, the call-ups provide a large, population-based representative target population of adolescent men.

4.1 Study design

For the study purpose both cross-sectional study design (Studies I and II) and longitudinal randomized controlled trial (Studies III and IV) were used. All the men who attended the conscription for military service in the Oulu area of northern Finland in September 2010, 2011, 2012 and 2013 ($N = 4804$) were asked to fill out a multidisciplinary questionnaire and to participate in anthropometry and fitness tests. In addition, they all went through a medical examination before the conscription. In 2013, we invited all the men who filled out the questionnaire to participate in a six-month RCT in which we aimed to explore the effectiveness of the gamified, mobile and tailored service developed in the MOPO study.

The study was conducted according to the Declaration of Helsinki and was approved by the Ethical Committee of Northern Ostrobothnia Hospital District (ETTM123/2009). The subjects had the right to refuse to participate or withdraw from the study without any effects on their future health care or military service. Written informed consent was obtained from all the participants.

4.2 Subjects

The amount of participants per year is presented in Table 1. To study the profiles of sedentary young men (Study I), all conscription-aged men who attended the conscription for military service in 2010 in Oulu area ($n = 997$) were invited to the study. In total, 616 (61.8%) of those 997 answered the questions (mean age 17.9,

SD 0.6), 610 (61.2%) underwent the physiological measurements, and 595 (59.7%) the medical examination.

In Study II, cross-sectional data from 2012 and 2013 was used to study the physical activity according to the natural and built living environment. From those 2,547 young men, a total of 1,904 (74.8%) men (17.9, SD 0.7 years) completed the questionnaire enquiring about physical activity, health and factors related to parents. Objectively measured physical activity data gathered at the baseline of the RCT in 2013 was used in this study from 202 trial participants, representing the typical daily physical activity of the subjects.

We used the data from the RCT in Studies III and IV. The number of subjects at each phase of the Studies as well as the reasons for exclusion and withdrawal are presented in Figure 1. All men who attended the conscription for military service in September 2013 (N = 1,265) were invited to fill out a questionnaire including health, wellbeing and lifestyle questions and to participate in physiological measurements. A total of 1,035 (81.8%) men completed the questionnaire, and 811 (64.1%) men participated in the measurements. All men attending the measurements were invited to participate in the 6-month RCT, and 496 (61 %) of them agreed to. The mean age of the participants was 17.8 (SD 0.6) years.

Table 1. Amount of the men attended in call-ups and participated in data collection in 2010 – 2013. Values are N (% of the call-ups attendees).

Data collection	2010	2011	2012	2013	Total
Attended Call-ups	997	1260	1262	1265/September 20/December	4804
Questionnaire	616 (61.8%)	825 (65.5%)	869 (68,9%)	1035 (80.5%)	3351
Physiological measurements	610 (61.2%)	887 (70.4%)	778 (61.6%)	811 (63.1%)	3086
RCT				496 (38.6%) (Studies III + IV)	
Number in Studies	616 (Study I)		1904 (Study II, years 2012-2013)		

Numbers in the analyses may vary due to missing values in outcome or explanatory variables.

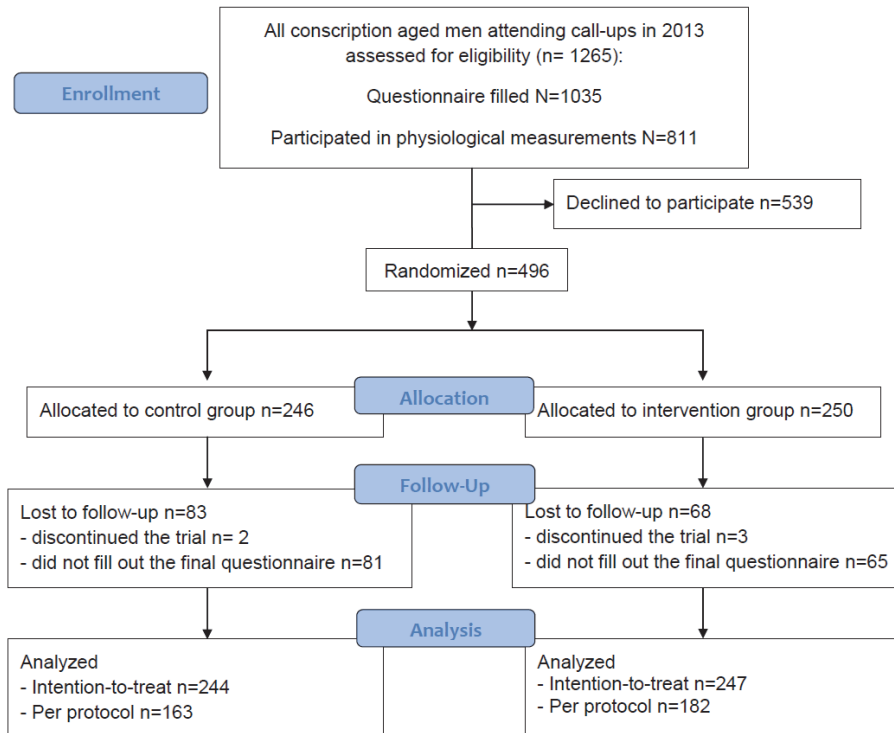


Fig. 1. A CONSORT flow diagram of the participants in the population-based six-month RCT. Numbers in the final analyses in Studies III and IV vary due to different outcome variables.

4.3 Methods

4.3.1 Socioeconomic status, health, wellbeing and health behaviour

Socioeconomic status, health and health behaviour were inquired about with a questionnaire. Participants reported whether they were full-time or part-time employees, students or if they were unemployed. Participants also filled in their highest educational level from the following options: only basic education, vocational upper secondary school, general upper secondary school or higher education. The participants reported their parents' occupation with an open-ended question. Occupations were categorized according to the Classification 89 of Occupations 2010 by Statistics Finland (2013). The categories were further pooled

into six as follows: 1) managers and entrepreneurs, 2) professionals, 3) associate professionals, 4) service and sales workers 5) manual labourers and 6) other categories (unemployed, pensioner, student or unknown). Categories 1 to 3 and 4 to 6 were pooled together and used as a dichotomous variable in the analyses for research question 2.

The participants rated their health as good, pretty good, average, pretty poor or poor. In addition, ICD-10 diagnoses from the medical examination were recorded. Depressive symptoms were evaluated with Raitasalo's modification of the widely used Beck Depression Inventory (BDI), which has shown to have high validity compared to the unmodified BDI (Raitasalo, 2007). The four-item life satisfaction (LS) scale measured overall wellbeing (i.e. happiness, interest in life, feelings of loneliness and ease of living). The LS scale has been shown to be closely related to many psychometric scales (Koivumaa-Honkanen et al., 2008) and to be able to predict several health outcomes among adults (Koivumaa-Honkanen et al., 2000; Koivumaa-Honkanen, Honkanen, Koskenvuo, Viinamaki, & Kaprio, 2002). The participants were asked whether they were able to discuss their problems with friends and family (answers ranging from 1 to 5 [from never to mostly or always]) and how often they spent time with friends (answers ranging from 1 to 5 [from almost never to almost every day]).

The participants were asked about their current smoking and snuff habits, and binge alcohol drinking was assessed by the following question: "How often do you drink alcohol of six servings or more at once?" with the answer options never, less than once a month, once a month, once a week, 2–3 times a week, daily or almost daily. The men also reported whether they usually ate breakfast and the frequency of weekly intake of vegetables, fruits, and berries, as well as their weekly intake of fast food and sweets (Helakorpi, Prättälä, & Uutela, 2008). The study participants rated their dietary habits with the Finnish school grade scale, ranging from 4 (poor) to 10 (excellent).

Disordered eating behaviour was assessed by the two subscales of the Eating Disorder Inventory (EDI) (Garner, Olmstead, & Polivy, 1983). Both the drive for thinness subscale and the bulimia subscale consist of seven questions, answered with a six-point Likert scale. The questions concerned binge eating, compensation behaviour, emotional eating and losing/gaining weight. The point distribution – with the exception of the first question (which was inversely scored) – was as follows: never, rarely or sometimes = 0 points; often = 1 point; usually = 2 points; always = 3 points.

4.3.2 Sedentary behaviour and physical activity

Daily leisure sitting time was used as a measure of SB in Study I. It was assessed with a question: “How much do you approximately sit per day outside school or work (for example, when watching TV, reading, spending time on a computer, playing video games and using the Internet)?” The respondents were categorized according to daily sitting time as sedentary (≥ 5 hours/day), moderate (2.1 - 4.9 hours/day) and non-sedentary group (≤ 2 hours/day). Time spent on the Internet and the frequency of playing Internet games were also asked about separately. In Study IV, participants reported their daily sitting time separately for leisure time and work by answering the question: “How much do you sit per day on average (e.g. when studying, working, driving, watching TV, reading or spending time on the computer)?” (Borodulin, Karki, Laatikainen, Peltonen, & Luoto, 2015).

Daily PA was assessed with various questions. Overall daily PA was assessed with the following question: “Approximately, how much are you on the move per day (i.e. biking or walking to school or work, on breaks at school, doing household chores, doing hobbies, during your leisure time etc.)?” The response alternatives were <1 h, 1–2h, and >2 h. Leisure-time PA was assessed with the question: “How much do you exercise or strain yourself physically in your leisure time?” The response alternatives were: 1) “I read, watch TV and do light housework”; 2) “I walk, cycle or exercise in some other way at least four hours per week (excluding travel to work or school)”; 3) “I exercise in order to maintain my physical condition by, for example, running, jogging, cross-country skiing, doing gymnastics, swimming, playing ball games or doing heavy gardening for at least two hours weekly”; and 4) “I take part in competitive sports or other intensive sports several times a week” (Wennman et al., 2014). The first response option was categorized as having no leisure-time PA. Categories 2 to 4 were pooled together and used as a dichotomous variable (1 vs 2–4) in the multivariable analyses.

Restrictions and motivational factors for PA were asked on a five-point scale in 2010 (ranging from 1 to 5, from not at all to very much) and on a two-point scale (yes/no) in 2012 and 2013. These scales were modified from the work of Nigg et al. (Nigg, Rossi, & Norman, G.J. & Benisovich, S.V., 1998). The restrictions included the lack of sports equipment/facilities, an appropriate group, exercise guidance, skills, money, public transport, time/interest/knowledge; laziness; tiredness due to work or school; and illness or injury. In Study I, the restrictive factors were grouped by principal component analysis (PCA) as follows: the lack of resources (i.e. sports equipment, sports facilities, an appropriate group, exercise

guidance, money or public transport); the lack of personal factors (i.e. interest, sports skills, an appropriate type of sport, knowledge of how to exercise or laziness); tiredness or the lack of time; and the lack of health (i.e. illness or injury).

The motivational factors included enhancing health, mood, energy, muscle mass, physical fitness, one's appearance; enjoying the feelings of euphoria gained by exercise; relieving stress; competing; creating or maintaining social affairs; exercising at the request of a family member or a friend; increasing one's appreciation among friends; and losing weight. In Study I, the motives were classified into four categories by PCA: health promotion (i.e. enhancing health, mood or energy; enjoying the good feeling coming from exercising; relieving stress); fitness improvement (i.e. competing; enhancing muscle mass or physical fitness); social reasons (i.e. creating or maintaining social affairs; exercising at the request of a family member or a friend; increasing one's appreciation among friends); and appearance (i.e. enhancing exterior or sexual attraction; losing weight).

Respondents were also asked whether physical education at school ignited a spark to exercise using a five-point scale (ranging from 1 to 5, from strongly disagree to strongly agree). The participants reported their PA types by answering an open question, and the answers were later categorized as ball games, ice hockey, going to the gym, running/jogging/walking/cycling, martial arts and other types of exercise by the researcher.

The participants evaluated the PA of their parents with the following question: "How regularly is your mother/father physically active?" Answer options were 1) "daily", 2) "several times a week", 3) "a few times a month", 4) "hardly ever" and 5) "I don't know". Alternatives 1 and 2 were classified as a parent being physically active. In addition, participants reported if they had exercised with their parent(s) while they were primary school-aged (7–12 years old) and secondary school-aged (13–15 years old).

In Studies II and III, PA and sedentary time were measured with a wrist-worn monitor (Polar Active, Polar Electro, Finland). The participants wore the monitor on the non-dominant wrist at least during all their waking hours and they were instructed to upload the data to the research database through Polar FlowLink® (Polar Electro). The average daily sedentary time ($1 \leq \text{MET} < 2$), light PA ($2 \leq \text{MET} < 3.5$) and MVPA (≥ 3.5 METS) time were calculated if there were at least three valid days (≥ 500 minutes of wearing time) in a week (Cain, Sallis, Conway, Van Dyck, & Calhoun, 2013). While assessing energy expenditure, a high correlation has been found between Polar Active and the doubly labelled water technique ($r = 0.86$) and between the Polar Active prototype and indirect

calorimetry ($r = 0.987$) (Brugniaux et al., 2010; Kinnunen, Tanskanen, Kyrolainen, & Westerterp, 2012).

4.3.3 Anthropometry

All physiological measurements were performed by trained personnel in standardized conditions during the call-ups in a place and room organized by the Finnish Defense Forces.

Height (in cm) was measured with 0.5 cm accuracy using a wall-mounted measuring tape. Waist circumference was measured to the nearest 1 cm with a plastic tape measure, taken midway between the lowest rib and the iliac crest at the end of a gentle expiration while the study participant was standing with his legs apart. Body composition (weight with 0.1 kg accuracy, body mass index [BMI], the percentage of body fat) was measured by direct segmental multi-frequency bioelectrical impedance analysis (DSM-BIA) (InBody720, Biospace Co., Ltd., Seoul, Korea). During the measurement the subject was standing without shoes and socks and wearing light indoor clothing. The method has been validated against whole-body dual X-ray absorptiometry (DXA) (Thomson, Brinkworth, Buckley, Noakes, & Clifton, 2007). BMI was calculated by dividing the weight (in kilograms) by the height squared (in meters).

4.3.4 Fitness

Participants were asked to rate their fitness compared to their coevals as significantly lower, somewhat lower, similar, somewhat higher or significantly higher.

Grip strength was measured with a hand dynamometer (Saehan, SAEHAN Corporation, Korea). During the test, the subject was instructed to stand with his legs apart, with one elbow at a 90° angle, and grip the instrument with his maximum strength. The best result of two attempts was documented for each hand. The mean grip strength for the right and left hands was used in the analysis.

Aerobic fitness was measured with the Polar Fitness Test™ (Polar Electro, Finland), which was conducted while the subject was resting for five minutes. The Polar Fitness Test™ predicts maximal oxygen uptake ($\text{mL}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$) from the resting heart rate, heart rate variability, gender, age, height, body weight and self-rated PA (Borodulin et al., 2004). The Polar Fitness Test™ has been compared with ergo-spirometry for measuring aerobic fitness with high correlation (0.96) and with

high accuracy (mean error: 6.5%) (Väinämö, Nissilä, Mäkikallio, Tulppo, & Röning, 1996).

4.3.5 Residential environment

Geographical information system (GIS) methods were used to define the dominant land use type of each participant's residential environment in Study II. ArcMap 10.2 software (Environmental Systems Research Institute [ESRI], 2014, ArcGIS Desktop 10.2, Redlands, California, US) and the Tabulate Overlapping Polygons tool were used to create circular one-kilometre buffer zones around each participant's home address (coordinate point, EUREFIN). The land use fell into five different categories: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands and 5) water bodies. These were calculated within the buffer with square-metre accuracy. The category which covered the biggest share of the buffer determined the land use type of the participant's residential environment. Category 1 represents the built residential environment and categories 2, 3, 4 and 5 represent the natural residential environment. The natural environment includes both rural areas and areas dominated by nature. The land use is based on CORINE Land Cover data (one grid: 20 m x 20 m), which gives spatial information of land cover obtained from satellite data (The Finnish Environment Institute, 2012).

4.4 Intervention

4.4.1 Intervention protocol

The intervention was launched in September 2013. All 496 willing participants, out of the total 1 265 conscription-aged men, were randomized into an intervention group (n = 250) and a control group (n = 246). The randomization was performed after recruitment and conducted by an assistant who was neither involved in the trial nor in the data collection and analysis. A computer-generated random list of numbers in blocks of 10 were used. Each participant received the next random assignment sequentially in the list. Both the measurements and the questionnaires were repeated at the end of the trial in March 2014. Questionnaire concerning the use of the mobile service was conducted at the end of the trial. The study included face-to-face contact twice: at the beginning and at the end of the trial, while

conducting the questionnaire and the physiological measurements. Figure 1 shows the trial flow. A total of 182 (72.8%) participants in the intervention group and 163 (66.2%) in the control group completed the study. Two participants from the control group entered the military service in January 2014 and wanted to withdraw from the study because of that. Three participants from the intervention group discontinued the study: one did not want to attend the final measurements, one moved to another location and one did not give a reason for discontinuation. From the control group, 81 participants did not fill out the final questionnaire and 65 from the intervention group did not. Altogether, 151 (30.4%) study participants were lost to follow-up (Figure 1).

In the beginning of the trial, wrist-worn PA monitors (Polar Active, Polar Electro Ltd, Finland) were given to the participants in both groups. After the blind, first-week activity data collection, the monitors displayed the accumulated daily MVPA time for the intervention group but only the time of day in the control group during the trial. The participants in both groups were asked to wear the activity monitor during all their waking hours and were advised to upload their activity data from the monitors to a database at least once every three weeks. The participants in both groups were sent a text message reminder every three weeks to upload the PA data. All the participants who uploaded the data were included in a lottery for two movie tickets once a month. After the baseline week, the intervention group was given access to a novel mobile service (MOPortal) (Luoto et al., 2015) developed in the MOPO study (see the description below). The aim of MOPortal was to motivate participants physically, mentally and socially. In addition, the participants in the intervention group received tailored feedback according to their personal PA through MOPortal. The participants in the control group did not have access to the service and were not given any feedback on their PA level. The timeline of the intervention and the content of the trial by the study groups are presented in Figure 2.

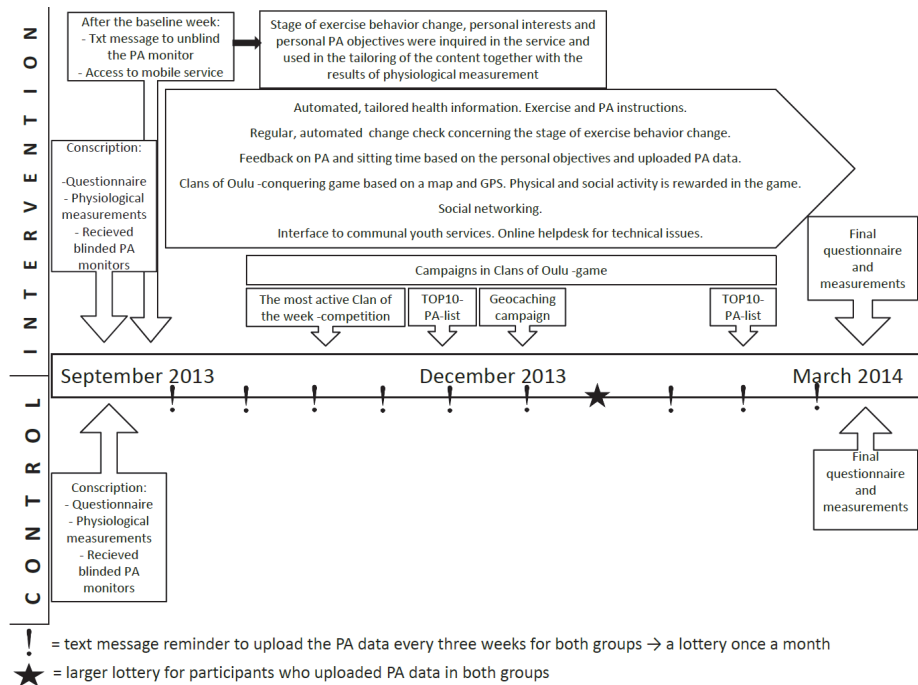


Fig. 2. The timeline of the study and the content of the trial in the intervention and control groups.

4.4.2 Mobile service

The MOPortal service (Luoto et al., 2015) was set up together with the city of Oulu and enterprises of related expertise (including the game studio Ludocraft Ltd). The requirements for the service were defined in the multidisciplinary MOPO study during 2009–2012 (http://www.tuunaamopo.fi/sivu/fi/mopo-study_in_english/) by assessing self-reported health and wellbeing, the use of media and technology, and the fitness of young adolescent men participating in the call-ups each year. In addition, 16–20-year-old men from local school classes, voluntary courses and youth workshops organized by the city were engaged in the iterative design, development and testing of the service, ensuring that youths with different life situations, even those at risk of marginalization, could participate in the co-creation of the service. Pilot interventions were carried out in 2011 and 2012 (Luoto et al., 2015). MOPortal (see Figure 3) included the following:

1. A web-based interface for communal youth services (including, e.g. tailored city news and events)
2. Personal objectives for PA and fitness improvement chosen by the participant themselves based on baseline measurements. In addition, personal tailored feedback in which their PA and amount of sitting were compared with their peers (normative feedback) or to their prior behaviour (ipsative feedback).
3. Exercise and overall PA instructions and guidelines for aerobic- and muscle-fitness improvement, as well as weight management. Men were guided with appropriate instructions with the help of tailored feedback messages.
4. Tailored, automated health information and feedback messages based on the transtheoretical model (TTM) of behaviour change (Prochaska & DiClemente, 1983); the delivered health information was based on scientific evidence reviewed before the trial
5. The Clans of Oulu game (Luoto et al., 2015), in which success was determined by the level of daily PA compared to sitting time, monitored with a wrist-worn monitor; the Clans of Oulu game is a mixed-reality conquering game based on a map and real-life events in which activity of any kind (physical, social etc.) was rewarded – the game included health messages which were written clearly in the language of young people, for example, game cards (Figure 4)
6. Social-networking possibilities: the user was able to share content in the service's social applications, such as in chat and a photo gallery



Fig. 3. Youth services, personal feedback and goals and the measurement of PA were included in the mobile service.



Fig. 4. The game cards represented both the clans and the health messages in the map-based game, Clans of Oulu, developed by Ludocraft Ltd.

4.4.3 The theoretical model as a basis for content tailoring

The tailoring of the automated health information and feedback messages was based on the Transtheoretical model of behaviour change (Cardinal, 1995; N. Hirvonen et al., 2015; Prochaska & DiClemente, 1983), which is one of the most popular behaviour change models utilized in tailored health interventions (Cugelman, Thelwall, & Dawes, 2011). This stage-based model integrates principles from different theories of behaviour change and proposes that behaviour change is a non-continuous process occurring through stages that reflect the different mind-sets of people.

In the present intervention study the participants were divided into five groups according to their stage of exercise behaviour change. The participants rated their stage of exercise-behaviour change at the beginning and every month during the trial. Participants were also able to rate the stage more often if they felt it necessary. The stage of exercise-behaviour change, according to the TTM (Prochaska & DiClemente, 1983), was assessed based on a modified scale from Cardinal (Cardinal, 1995; Hirvonen, N. Huotari, M-L. Niemelä, R. & Korpelainen, R, 2012). The respondents were instructed to choose an alternative that best described their regular exercise behaviour and intentions to exercise. Regular exercise was defined according to the Finnish national recommendations for 13–18-year-olds (Tammelin & Karvinen, 2008) as at least 1.5 hours of daily PA, of which half should be performed at a vigorous intensity. The answer options were a) “I exercise on a regular basis and have been doing so for longer than 6 months” (maintenance), b) “I exercise on a regular basis but I have only begun doing so within the past six months” (action), c) “I do not exercise, but I have been thinking about starting to exercise within the next month” (preparation), d) “I do not exercise, but I have been thinking about starting to exercise within the next six months” (contemplation), and e) “I do not exercise and do not plan to start exercising in the next six months” (pre-contemplation).

The delivered messages included a welcoming message and brief messages during the intervention sent once a week through the mobile service. The messages were tailored to match the processes of change theorized as most appropriate at each stage (Nigg et al., 2011). Some modifications were made to the design guide that was derived from the one designed by Nigg et al. (Nigg et al., 2011). Furthermore, based on research on the feedback perceptions of young men in different stages of exercise-behaviour change (Hirvonen et al., 2015), message tactics that include comparison (namely normative and ipsative strategies) were

only used in the more advanced stages (action, maintenance). The stage-tailored messages were tested in a three-month pilot intervention study in 2011 with a volunteer sample of young adolescent Finnish men (n = 129) (Jauho et al., 2015).

4.5 Statistical analysis

The main endpoints were SB (Study I), self-rated LTPA (Study II), objectively measured PA, SB and feasibility (Study III), and life satisfaction and self-rated health (Study IV). In the bivariate analyses (Studies I & II) and the baseline analyses (Studies III & IV), association between the response and explanatory factors were first analyzed using cross-tabulation and chi-squared test for the categorical variables and the Pearson product-moment correlations coefficient for continuous variables. The statistical significance of the differences between the two study groups was determined using cross-tabulation and the independent samples Student's t-test (Studies I – IV).

The power calculation of the RCT was based on a physical activity (Study III) but we tested that the sample size per group was also adequate for subjective wellbeing outcomes in Study IV. Originally at baseline in MOPO study, the power calculation was based on the estimated number of inactive boys, which was 212 (27.6%, data from the 2009 call-ups). We evaluated the proportion of inactive men being 18.5% after the trial. With study power of 80% and significance level of 5%, the calculated sample size was $((27.6 \times (100-27.6) + 18.5 \times (100-18.5)) / (27.6-18.5)^2) \times 7.9 = 335$ persons/group. This sample size was powered enough for the second main outcome, subjective wellbeing (based on the calculation, 78 needed per group.) Statistical significance was set at $p < 0.05$. The data were analyzed with PASW Statistics software (SPSS versions 18, 19 and 22.0. Armonk, NY: IBM Corp.). Multivariable analyses conducted in each study are presented below.

In Study I, the restrictions and motivations for PA were grouped by PCA with Varimax rotation (Jolliffe & Morgan, 1992). Using the Varimax rotation method minimizes the number of variables that have high loadings on each component and, as such, simplifies the interpretation of the components. The components (profiles) for sedentary and non-sedentary groups were also formed by PCA with the same method. The profiles were named by the nature of the variables loaded into each component. Furthermore, two criteria were tested: the Kaiser-Meyer-Olkin (KMO) Measure of Adequacy, a measure of sampling adequacy (threshold: $KMO > 0.60$) and Bartlett's test of sphericity, which is used to test the null hypothesis that the variables in the population correlation matrix are uncorrelated (threshold: $p < 0.05$).

The variables ($n = 30$) included in the PCA were chosen from 112 variables correlated with SB. Selection was based on the maximal amount of variables that can be included in the analysis taking into account the sample size, and only one variable per phenomenon was included. Variables with factor loadings ≥ 0.4 were used to calculate factor scores for each of the factors. The number of components for the sedentary group was determined by an eigenvalue >1.5 and visual examination of the scree plots. Missing data in PCA were replaced with the means of the groups.

In Study II, to evaluate the factors associated with self-rated LTPA separately for men living in a natural environment and those living in a built environment, multivariable binary logistic regression analyses with the enter method were carried out. Variables associated with PA in univariate analyses and without multicollinearity were entered in the logistic regression analysis. The level of significance was set at $p < 0.07$ to avoid excluding any variables potentially associated with reported PA. Non-significant variables were removed from the model one by one. To establish possible dose dependency, we also carried out multinomial logistic regression analysis with the forward entry method using four-level self-reported LTPA as a dependent variable. Multivariable analyses were not carried out for objectively measured PA due to the amount of missing values in the multivariable data. The results are presented as odds ratios (OR) with 95% confidence intervals (CI). The study is reported according to the STROBE statement.

In Study III, the anthropometry, fitness, SB and PA variables were tested for normality with the Kolmogorov-Smirnov test. The statistical significance of the differences at baseline were analyzed using the independent samples *t*-test on continuous variables between the intervention and control groups, between the study participants and nonparticipants, and between those young men who, based on the log data, visited the MOPortal service at least once and those who did not visit the service at all during the trial. The within-group changes from baseline in the intervention and control groups were analyzed using the paired samples *t*-test. The difference over time in the change in light PA, MVPA and sedentary time between the intervention and control groups was analyzed using multiple linear mixed models with full maximum likelihood, compound symmetry and Bonferroni correction. All available personal weekly averages of mean daily time spent in LPA and MVPA, and sedentary time for both study groups were included in the mixed model analyses. The Pearson correlation coefficient (*R*) was used to evaluate which variables measured at baseline were significantly associated with the main outcome

measure in the intervention group. The association between the usage frequency of the service and the occurred change in MVPA time was analyzed using the Spearman's rank correlation coefficient (ρ).

In Study IV, the primary analyses were performed on an intention-to-treat approach. A linear mixed model with full maximum likelihood, compound symmetry and Bonferroni correction for the continuous variables and a McNemar test with multiple imputation for the categorical variables were used to analyze the statistical significance of the within-group change from baseline. An independent samples *t*-test for the continuous variables and the Mann-Whitney *U*-test for the categorical variables with multiple imputation (number of imputations: 5) were used to compare the difference in the change from baseline between the intervention and control group. In addition to intention-to-treat analyses, we performed per protocol analyses within the adolescent men who attended the follow-up visit. In order to estimate the predictors of the change, we defined improvement of life satisfaction as a decrease of the life satisfaction continuous score by at least one point (as a higher score indicates lower life satisfaction). Transition from a lower category to an upper one was defined as improved self-rated health. Univariate analysis (with Pearson's chi-square test and a *t*-test) was used to examine the associations of the baseline characteristics and their change during the trial in terms of the change in life satisfaction or self-rated health. To define the independent predictors of the change in self-rated health and life satisfaction, multivariable binary logistic regression analyses (the enter method) including all the variables associated with the outcomes in the univariate analysis without multi-collinearity were performed in the intervention group ($N = 250$) and in the combined group (intervention group + control group = combined; $N = 496$). Analysis within the combined group included the group (intervention/control) as one of the explanatory variables. Statistically insignificant variables were removed from the model one by one. The results are presented as odds ratios with 95% confidence intervals. Statistical significance was set at $p < 0.05$ but variables with p -values < 0.10 in the univariate analysis were entered into a logistic regression so that no potentially predictive variables were excluded prematurely. The study is reported according to the CONSORT statement.

5 Results

5.1 Profiles of sedentary young men (Study I)

The characteristics of the study participants are presented in Table 1. Information on daily sitting time was received from 595 participants. Altogether 30.1% ($n = 179$) were classified as sedentary (sitting ≥ 5 h/day) and 28.9% ($n = 172$) as non-sedentary (sitting ≤ 2 h/day) with the mean hours of daily sitting being 6.3 (SD: 1.8; 95% CI) and 1.7 (SD: 0.5; 95% CI) respectively.

The non-sedentary men had better aerobic fitness and grip strength, significantly less body fat, less depressive symptoms and better life satisfaction. They rated their health and fitness better and their eating habits were healthier. They also spent less time on the Internet. Furthermore, they reported less binge drinking but they used snuff more often compared with the sedentary men. A higher proportion of those in the non-sedentary group fulfilled the daily recommendation of 60 minutes of exercise compared with the sedentary group (88% vs 72%; $p < 0.001$). In addition, restrictions for PA in sedentary men more often included personal factors, such as a lack of sports skills or laziness, than in non-sedentary men, but improving fitness motivated the non-sedentary men more frequently (see Table 1).

PCA discovered five different profiles among the sedentary young men (see Table 2). In the profile “exercising but sitting”, the amount of sitting was substantial, but self-rated PA, fitness, health and experiences from physical education were good. Life dissatisfaction, low self-esteem, a lack of support from friends and family, and poor mental health were identified in the profile “feeling unhappy”. High body fat, and low fitness and exercise motivation related to appearance were detected in the fourth profile. Indications of disordered eating distinguished the third profile and a high amount of screen time distinguished the fifth profile (see Table 2).

Table 1. The characteristics of the study population by sedentary status. Values are means (SD) unless otherwise stated. Variables in italics were included in the PCA.

Characteristic	All (n = 616)	Sedentary, sitting time ≥5 h (n = 179)	Non-sedentary, sitting time ≤2 h (n = 172)	p ¹
Age (years)	17.9 (0.6)	17.9 (0.6)	17.9 (0.6)	0.272
<i>Socioeconomic status, n [%]</i>				0.034
Full-time student/employee	579 (94.0)	160 (89.4)	166 (96.5)	
Part-time student/employee	10 (1.6)	5 (2.8)	1 (0.6)	
Unemployed	27 (4.4)	14 (7.8)	5 (2.9)	
Daily sitting time (hours)	3.8 (2.1)	6.3 (1.8)	1.7 (0.5)	<0.001
PA, daily hours >1 h, n [%]	490 (81.2)	128 (71.5)	150 (87.7)	< 0.001
BMI (kg/m ²)	22.9 (3.9)	23.1 (4.8)	22.9 (3.6)	0.908
BMI ≥ 30, n [%]	31 (5.1)	9 (7.4)	4 (2.9)	0.152
Waist circumference (cm)	82.2 (9.8)	82.7 (11.7)	81.3 (8.8)	0.740
<i>Body fat (%)</i>	16.0 (7.7)	18.3 (9.0)	14.7 (6.7)	< 0.001
<i>Aerobic fitness</i> (Polar Fitness Test, mL·min ⁻¹ ·kg ⁻¹)	53.4 (7.4)	51.3 (6.6)	56.1 (7.6)	< 0.001
<i>Grip strength (kg)</i>	49 (9)	47 (8)	52 (9)	< 0.001
<i>Self-perceived fitness; similar/better, n [%]</i>	449 (73.6)	97 (55.1)	151 (88.8)	< 0.001
<i>Self-perceived health; moderate/good, n [%]</i>	567 (95.9)	157 (90.3)	161 (98.1)	< 0.001
<i>Depressive symptoms (RBDI)²</i>	1.8 (3.7)	3.0 (5.2)	0.7 (1.8)	< 0.001
<i>Life satisfaction³</i>	7.6 (2.8)	8.5 (3.3)	6.8 (2.3)	< 0.001
<i>Self-esteem⁴</i>	6.5 (4.1)	5.3 (3.9)	8.1 (4.0)	< 0.001
<i>Diagnosed mental disorders, n [%]</i>	19 (1.9)	11 (6.1)	2 (1.2)	0.020
<i>EDI⁵: Symptoms of bulimia (cut-off 4p), n [%]</i>	34 (6.3)	15 (9.0)	7 (4.7)	0.132
<i>EDI: Drive for thinness, n [%]</i>	46 (8.4)	17 (10.6)	7 (4.7)	0.054
<i>Postponed or exempted from military service due to medical reasons, n [%]</i>	160 (27.6)	56 (34.6)	35 (21.3)	0.008

¹ p-values (sedentary vs non-sedentary group) independent samples t-test or crosstabs chi-squared tests.

Fisher's Exact Test was used if n ≤ 5.

SD = standard deviation, PCA = principal component analysis, BMI = body mass index, RBDI = Raitasalo's Beck Depression Index, EDI = Eating Disorder Inventory

Table 2. The profiles of the sedentary men and the factor loadings of the variables based on the PCA.

Variable	1) Exercising but sitting	2) Feeling unhappy	3) Symptoms of disordered eating	4) Being unfit with appearance-related motivation	5) Gaming
Motivation: Fitness improvement	0.736				
High self-rated PA	0.676				
Not restricting: A lack of personal factors	0.633				
Physical education ignited the spark to exercise	0.601				
Good self-rated fitness	0.527				
Good self-rated health	0.480				
Dissatisfaction with life		0.803			
Low self-esteem		0.686			
Depressive symptoms		0.644			
Unable to discuss problems with friends or family		0.608			
Diagnosed mental disorders		0.493			
Signs of bulimia			0.874		
The drive to be thin			0.833		
A regular snuff habit			0.591		
A high body fat percentage				0.769	
Low measured aerobic fitness				0.657	
Motivation: Appearance				0.534	
A high amount of time is spent on the Internet daily					0.846
Playing a lot of Internet games					0.779
Variances explained (%)	14.764	8.263	6.341	6.258	4.991
Eigenvalues	4.725	2.644	2.029	2.003	1.597

Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.663

Bartlett's Test of Sphericity: Sig. 0.000

5.2 Physical activity among young men living in built and natural environment (Study II)

From those whose data on residence was available, altogether 1 144 (62%) adolescent men lived in a built environment and 714 (38%) in a natural environment. The men living in the natural environment studied more often in vocational upper secondary school compared to the men living in the built environment (49.1% vs 41.2%; $p = 0.003$). A larger proportion of men in the built environment drank alcohol at least once a week compared to natural environment residents (19.2% vs 15.4%; $p = 0.045$). There were no statistical differences in self-rated or objectively measured PA, parental PA or occupation according to the residential environment of the participants. Of the men living in built environment, 215 (19.2%) did not exercise on their leisure time compared to 115 (16.6%) men from the natural environment ($p=0.111$). In the subsample of 202 men whose PA was objectively measured, young men from the built living environment ($n = 114$) had approximately 60 minutes of MVPA daily and men from the natural environment ($n = 84$) had 62 minutes of daily MVPA ($p = 0.531$).

The motives for PA did not differ between the men living in the built or natural environment. The most common motives for exercise in both environmental types were health promotion (in the built environment, 82.5% reported this motive; in the natural environment, 83.6% reported this motive), enjoying the euphoria gained by exercising (both groups: 75.5%) and fitness enhancement (built environment: 75.1%; natural environment: 75.3%). In addition, men in both groups often reported their PA being restricted by tiredness (built environment: 49.1%; natural environment: 51.5%), laziness (both groups: 42.4%) or a lack of time (built environment: 33.4%; natural environment: 33.9%). Poor transportation ($p = 0.002$) and a lack of an appropriate exercise group ($p = 0.04$) restricted the residents of a natural environment more than those residing in built environments. The most popular types of exercise were ball games (built environment: 22.7%; natural environment: 24.0%), going to the gym (built environment: 26.4%; natural environment: 21.9%) and walking, jogging or cycling (built environment: 18.7%; natural environment: 17.5%).

The factors associated with self-rated LTPA in the residential environment in the univariate analysis are presented in Table 3. Educational level, weight, the mother's occupation and exercising with parents at primary school age were associated with PA among residents of the built environment, but not the natural

environment. The father's occupation was positively associated with PA in men living in natural environments but not in built environments.

According to the multivariable binary logistic regression (see Table 4), self-perceived health (OR: 5.9; 95% CI 4.0–8.7) and the mother's PA (OR: 1.9; 95% CI 1.3–2.8) were significantly associated with PA in men living in the built environment. Self-rated health (OR: 5.2; 95% CI 3.0–9.0) and the father's PA (OR: 2.8; 95% CI 1.7–4.8) were significantly associated with PA in men living in the natural environment. Those with symptoms of depression were more likely to be physically inactive (built environment OR: 0.5; 95% CI 0.3–0.8; natural environment OR: 0.3; 95% CI 0.1–0.6).

5.3 The effects of the intervention on physical activity and sedentary behaviour (Study III)

Altogether 187 (74.8%) men in the intervention group and 167 (67.9%) in the control group completed the study and attended the final measurements after the six-month trial. From all study participants, 142 (28.6%) did not participate in the final measurements.

Among the participants who completed the study and had valid PA data ($n = 167$), there was a marginal difference in the change in the mean daily time spent in MVPA between the intervention and control groups (11.9 min vs -9.1 min, $p = 0.055$) according to linear mixed model analysis. During the last weeks of the RCT, there was a significant difference between the groups in MVPA (p -value ranging across the weeks < 0.05 to $p < 0.001$) according to the t -test. Within the intervention group, vigorous PA at baseline was inversely associated with the change in daily MVPA time during the trial ($R = -0.382$, $p = 0.010$).

Self-rated weekly leisure-time PA did not significantly change during the intervention in either of the groups. Within the intervention group, the proportion of those doing no PA other than light housework were 14.5% at baseline and 12.1% at the end of the trial compared with the change from 14.7% to 15.2% among the controls ($p = 0.434$ for the difference between the groups) (see Table 5). There were no statistically significant changes in the self-reported daily sitting in either of the groups (see Table 5). Among those who completed the trial, there was no difference in the change in objectively measured, mean daily time spent in SB ($p = 0.220$) or light PA ($p = 0.527$) between the intervention and control groups according to linear mixed model analysis (*unpublished data*).

Table 3. The association between selected explanatory variables and LTPA by the residential environment among adolescent men (n = 1 838). The values are n (%) unless otherwise stated.

Variable	Built environment (n = 1144)			Natural environment (n = 694)		
	low LTPA (n = 215)	high LTPA (n = 902)	p ^a	low LTPA (n = 115)	high LTPA (n = 579)	p ^a
Education: basic education or vocational upper secondary school	117 (56.0)	399 (45.1)	0.005	70 (61.4)	293 (52.1)	0.080
Weight (kg), mean (SD)	76.1 (21.5)	73.2 (13.9)	0.047	73.5 (17.5)	72.0 (12.3)	0.366
At least mild depression symptoms	47 (22.7)	61 (7.1)	<0.001	34 (30.9)	36 (6.7)	<0.001
Self-rated health: good or pretty good	82 (39.6)	698 (81.1)	<0.001	45 (41.3)	453 (82.1)	<0.001
The father's occupation: an associate professional or a higher level profession	68 (44.2)	367 (51.2)	0.131	34 (36.6)	250 (51.8)	0.009
The mother's occupation: associate professional or a higher level profession	64 (38.8)	394 (52.3)	0.002	46 (46.9)	262 (53.8)	0.224
PA with parents when primary school aged	121 (62.4)	603 (72.1)	0.009	74 (67.3)	397 (75.6)	0.073
PA with parents when junior high school aged	36 (19.0)	243 (29.8)	0.003	17 (15.7)	159 (30.8)	0.002
A physically active father	74 (50.3)	495 (67.7)	<0.001	42 (49.4)	350 (71.0)	<0.001
A physically active mother	90 (55.6)	555 (71.6)	<0.001	54 (57.4)	362 (72.0)	0.005

^a Independent samples t-test for continuous variables and Pearson's chi-squared test for categorical variables for the difference between the low and high LTPA groups within the residential environment
LTPA = leisure-time physical activity; low LTPA = light housework but no other LTPA; high LTPA = PA, exercising several times weekly; SD = standard deviation

Table 4. The factors associated with high self-rated PA (OR; 95% CI) among adolescent men (n = 1 456) living in built and natural environments according to multivariable logistic regression analyses.

Environment	Adjusted OR (95% CI)	p
Natural (n = 553, Model R ² = 0.249)		
Quite good or better self-rated health (vs moderate, poor or very poor self-rated health)	5.2 (3.0–9.0)	<0.001
Mild depression symptoms or higher levels of depression (vs no symptoms or only very mild symptoms)	0.3 (0.1–0.6)	<0.001
The father exercises at least several times a week (vs a few times a month or almost never)	2.8 (1.7–4.8)	<0.001
Built (n = 903, Model R ² = 0.207)		
Quite good or better self-rated health (vs moderate, poor or very poor self-rated health)	5.9 (4.0–8.7)	<0.001
Mild depression symptoms or higher levels of depression (vs no symptoms or only very mild symptoms)	0.5 (0.3–0.8)	0.010
The mother exercises at least several times a week (vs a few times a month or almost never)	1.9 (1.3–2.8)	0.001

OR = odds ratio, CI = confidence interval

Model R² = Nagelkerke regression coefficient

5.4 The effects of the intervention on life satisfaction and self-rated health (Study IV)

In total, 182 (72.8%) men in the intervention group and 163 (66.2%) in the control group reported outcome variables of Study IV after the six-month trial. Life satisfaction improved in both the intervention group ($p < 0.001$) and the control group ($p = 0.010$). There was no significant difference in the change between the groups. Neither were there statistically significant changes from baseline in the self-rated health (see Table 5).

In the univariate analyses, baseline factors associated with improvement in life satisfaction during the trial were low family income ($p = 0.015$); at least slight life dissatisfaction ($p < 0.001$); average, pretty poor or poor self-rated health ($p = 0.039$); improving one's mood as an important motive for exercise ($p = 0.026$); and perceiving the future as hopeless ($p = 0.016$). An improvement in perceived health was associated with the following baseline factors: low self-rated fitness ($p = 0.012$); poor self-rated health ($p = 0.018$); a lack of interest ($p = 0.026$); a lack of

guidance ($p = 0.013$) restricting PA; low self-reported PA ($p = 0.006$); the preparation, contemplation or pre-contemplation stages regarding exercise behaviour change ($p < 0.001$); and the hopelessness of the future ($p = 0.042$). Changes in self-rated fitness and LTPA during the trial were also associated with improved self-rated health ($p = 0.026$ and $p = 0.042$ respectively).

The binary logistic regression model was adjusted for all variables associated with improved life satisfaction or self-rated health in the univariate analyses. According to the multivariable analysis, baseline life dissatisfaction (OR: 13.8; 95% CI 3.7–51.8) and mood enhancement as important motives for exercise (OR: 2.5; 95% CI 1.1–5.6) were associated with improved satisfaction in the intervention group. The predictors of improved self-rated health during the trial were lower self-rated health at baseline compared with pretty good health or good health (OR: 9.6; 95% CI 3.7–24.9) and improved self-rated fitness during the trial (OR: 4.2; 90% CI 1.5–11.9). When the intervention and control groups were combined, the results remained the same except that mood enhancement as important motive for exercise was not related to improved life satisfaction. The group type (intervention/control) was not associated with improved life satisfaction or improved self-rated health.

Table 5. Health-related characteristics at baseline and at six months. Values are mean values (SE) unless otherwise stated.

Variable	Intervention group (n = 250)		Control group (n = 246)		Mean difference (95% CI)	p ^c
	Baseline	6 months	Baseline	6 months		
Weight, kg	73.4 (0.9)	74.9 (0.9)	72.9 (0.9)	74.5 (0.9)	0.4 (-0.6-1.4)	0.421
BMI, kg/m ²	23.2 (0.3)	23.6 (0.3)	23.0 (0.3)	23.5 (0.3)	0.1 (-0.2-0.4)	0.497
Life satisfaction score ^d	7.9 (0.2)	7.1 (0.2)	7.5 (0.2)	7.0 (0.2)	-0.5 (-1.3-0.3)	0.215
Self-reported daily sitting, h	8.9 (0.3)	9.2 (0.3)	9.4 (0.3)	8.8 (0.3)	0.6 (-0.7-1.9)	0.323
Self-rated health: pretty good or good (vs average, pretty poor or poor health); original data, n (%)	175 (79.5)	153 (84.1)	181 (80.4)	141 (86.0)		0.654
Imputation number 1						0.830
Imputation number 2						1.000
Imputation number 3						0.115
Imputation number 4						0.267
Imputation number 5						1.000
Light household but no other LTPA ^e (vs ≥4 h LTPA weekly); original data, n (%)	33 (14.5)	22 (12.1)	34 (14.7)	25 (15.2)		0.434
Imputation number 1						0.483
Imputation number 2						0.461
Imputation number 3						0.653
Imputation number 4						0.461
Imputation number 5						0.476

^{a,b} A linear mixed model with full maximum likelihood, compound symmetry and Bonferroni correction for the continuous variables and McNemar test with multiple imputation for the categorical variables for the change within the intervention and control groups over the study period. ^c The independent samples t-test for the continuous variables and the Mann-Whitney U test for the categorical variables for the difference in the change from baseline between the intervention and control groups with multiple imputation. Pooled imputation is reported as a mean difference for the continuous variables. For the categorical variables, p-values describe the difference in the distribution of answers between the intervention and control groups at the end of trial. ^d Life satisfaction as a continuous variable; a higher score indicates lower life satisfaction. ^e LTPA: (self-reported) leisure-time physical activity. BMI = body mass index; SE = standard error.

5.5 The feasibility of the gamified, mobile and tailored intervention (Studies III and IV)

In total, 161 men (64.4%) in the intervention group visited the MOPortal service during the trial according to the log data. Of them, 118 (47.2%) logged on to the service more than once and 41 (16.4%) logged on more than five times. In total 1 044 visits were recorded (median: 3; range: 1 to 202 visits). The rate of use decreased during the trial from 400 visits during the first month of the RCT to 69 during the last month. Fifty-six participants used the Clans of Oulu game in the service. The participants who had not logged in at all reported that their service use was restricted by a lack of interest or laziness (51%), forgetting about the service (49%) or technical problems (15%). The most common reasons reported for the low logging in rate among the participants who had used MOPortal were technical problems or discomfort with the wrist-worn PA monitor.

Based on a questionnaire concerning the use of the mobile service ($n = 94$), data related to PA (collected by diary and feedback) were important for 90% of the service users. Moreover, 11% reported important elements of the service to be instructions, tests and the goals of PA and 11% regarded general information on health as an important element of the service. Personal data on PA was the most used functionality in the service according to the log data. Feedback graphs on daily and weekly PA motivated 65% of participants using the MOPortal service. Additionally, 61% found the feedback messages related to goals to be motivational for PA. Tips of the week, including PA and health messages, were perceived to be mostly clear, interesting and reliable. The participants also reported how MOPortal should be developed further. They hoped for a more visual and clearer user interface ($n = 6$ respondents), more interesting content ($n = 5$), a more simple solution ($n = 3$) or a technically more solid and mature solution ($n = 1$).

The participants who visited MOPortal at least once during the RCT had a somewhat higher BMI (mean difference: 1.2 kg/m²; 95% CI 0.1–2.2) and body fat percentage (mean difference: 2.2%; 95% CI 0.1–4.2) at baseline compared to all the other men in the intervention group. Otherwise there were no differences in anthropometry and fitness at baseline between these two groups. Among those men within the intervention group who logged on to the service at least once, the usage frequency of the MOPortal service was not associated with the change from baseline in the mean daily time spent in MVPA ($\rho = 0.045$, $p = 0.770$). Instead, within the intervention group, those with less vigorous PA at baseline were more likely to increase MVPA during the trial ($R = -0.382$, $p = 0.010$). Within the

intervention group, the change in the waist circumference differed between the men who were inactive according to their stage of exercise behaviour change and those who were active (mean change: -0.3 cm vs 1.7 cm; $p = 0.013$, t-test).

Factors associated with improvements in perceived health and life satisfaction were low income, life dissatisfaction, poor perceived health, low self-reported PA, feeling hopeless about the future, and lacking exercise guidance and interest in exercise. This reflects that the intervention might be feasible among young men with poor subjective wellbeing and a need for health promotion.

6 Discussion

6.1 Methodology (Studies I–IV)

We used cross-sectional data in Studies I–II and RCT in Studies III–IV. Due to the cross-sectional study design of Studies I and II, conclusions about the causality cannot be drawn. The strength of this thesis is its population-based design, including entire age cohorts of young men, and the high compliance due to obligatory conscription. The data collection was comprehensive, including the multidisciplinary questionnaire and objective measurements. The questionnaire response rate increased year by year, being 62% (Study I, 2010), 75% (Study II, 2012–2013) and 82% (Studies III–IV, 2013). In 2012 and 2013, the medical examination data of those young men who did not participate in the MOPO study was received from the Finnish Defence Forces in order to examine whether the participants differed from non-participants. In both years, the MOPO study participants had slightly lower BMI compared to those who refused to participate (2012: 23.2 kg/m² vs 23.9 kg/m²; $p = 0.040$; 2013: 23.3 vs 24.2; $p = 0.040$). The difference is clinically minor, but it may have affected the results.

Almost 40% of the total age cohort participated to the trial in 2013. An RCT with 496 participants is exceptionally large in this field of science. Because the final achieved number of participants per study group was lower than estimated in the power calculation, and the study slightly underpowered, the PA differences between the intervention and control groups might actually be larger than observed here if the study were repeated among a larger sample. In terms of subjective wellbeing the group size was large enough. Previously, the quality of the design and protocol in the technology-based interventions has been low (due to the lack of a control group for example), which makes it difficult to draw conclusions about the effectiveness (Lau, Lau, Wong del, & Ransdell, 2011). The RCT participants in our study did not differ according to the subjective wellbeing measures, LTPA, BMI, SES and alcohol intake from the young men who refused to participate in the six-month intervention but filled in the questionnaire and participated in the physical measurements.

The study questionnaire was extensive and it may have led to a lower response rate to the questions at the end of the survey. Using questionnaires may also cause overestimation of the amount of PA (Hagstromer, Ainsworth, Oja, & Sjostrom, 2010) and underestimation of SB (Shephard, 2003). The commonly known social

desirability bias (Althubaiti, 2016) may have affected the answers to sensitive or personal questions though the probability of such bias was decreased via anonymity. The participants may have also encountered difficulties in recalling their previous behaviour or events (Althubaiti, 2016), for example, in recalling whether they exercised with their parents in their childhood. We mostly utilized validated and widely used questions to overcome the weaknesses concerning self-reporting methods. Previous studies have, however, suggested that in addition to validity and reliability, the ease of administration is crucial in population-based studies among young people (Biddle, Gorely, Pearson, & Bull, 2011).

Feasible and acceptable methods which were easy to conduct in a large population were chosen for the objective physical measurements. The methods used were validated, the devices were calibrated and measurement personnel were trained to perform measurements in a consistent manner. Still, the factors related to participants may have affected the results. For example, the self-evaluated PA level in the measurement of aerobic fitness may have caused bias.

The technical development of the gamified, tailored and mobile service MOPOrtal was a long process and we have discussed the lessons learned from its development in the article of Tuovinen et al. (Tuovinen et al., 2016). The study aim of achieving a fully automated service was quite ambitious. Though we put a lot of time into developing MOPOrtal, utilized participatory design principles (Holtzblatt & Jones, 1993) – according to which the young men participated in the design process – and administered two pilot interventions before the actual RCT in 2013, only one-fifth of the participants became regular users of the service during the trial.

In Study I, we used PCA, which combined a high amount of variables into profiles. It enabled revealing new associations and new knowledge. Still, the interpretation of the results provided by PCA is partly subjective, which can be considered as a limitation of the method. In Study I, we lacked data on objectively measured PA and sedentary time, and the data on sedentary time in work activities. Information on daily leisure time sitting was not received from 40.3% of the participants and the proportion of missing data varied from 0% to 56% between the variables. These can be considered the limitations of the study.

In Study II we used the dominant land-use type to categorize the residential environment. To our knowledge, it was the first time that this kind of approach has been used in defining the living environment of study participants in the physical activity study among youth. This pioneering approach has unfortunately led to results that are not directly comparable to previous studies in which the residential environment have mainly been defined based on adjacency to city centres or the

number of inhabitants (Martin-Matillas et al., 2011; Moore et al., 2013). A limitation was the inability to use the objectively measured PA in multivariable analyses due to missing values. In addition, we do not know how long the participants have lived in their current residential area. As the parental PA was evaluated by the participants, and not by the parents themselves, there may be bias in our results.

In Study III, the continuous measurement of PA within both study groups allowed us to objectively evaluate the change in MVPA during the whole trial. The continuous measurement of PA also enabled us to give real-time feedback to the intervention group. We did not have any face-to-face meetings in our RCT except at baseline and at six months. Because of that, the study produced new knowledge on the automated, home-based intervention in contrast with more common school-based approaches. Unfortunately, we had a lot of missing PA data in our study and it increased towards the end of the trial. The men in the intervention group received straight feedback from the PA monitor so they may have not seen the need for providing their PA data to the service database. Automated and wireless data transfer from the monitor to the service would have improved our study methods as would have a long-term follow-up PA measurement after the end of the trial.

In Study IV, 66% of the controls and 73% the intervention group attended the final measurement so the compliance to outcome subjective wellbeing measures was quite high. However, the adherence to mobile service use was quite low consistent with some previous studies (Flores Mateo, Granado-Font, Ferré-Grau, & Montaña-Carreras, 2015; Kohl, Crutzen, & de Vries, 2013). Regular face-to-face meetings with participants or shorter trial could have increased the use of the service, which could have led to more significant differences between the intervention and control groups.

There were some limitations in this study. The follow-up measurements or upcoming military service may have activated the young adolescent men participating in both the intervention and control groups, and this may have confused the results. Moreover, 36% of the intervention group participants did not use the mobile service. The study population consisted of young adolescent men of a specific age, which may limit the generalizability of the results.

Concerning our RCT, the TTM of behaviour change has been widely used for health promotion purposes, but it has also been criticized. Originally the model was developed in the context of smoking and there are doubts about whether the model is adaptable to non-addictive behaviour (Povey, Conner, Sparks, James, & Shepherd, 1999), such as PA and exercise. In the context of PA interventions, its

limitations include the complexity of PA behaviour, the lack of validated staging algorithms and the possibility that PA behaviour is influenced by factors not yet included in the TTM (Nigg et al., 2011). Though research still supports the use of the TTM in PA interventions (Woods, Mutrie, & Scott, 2002), there is evidence that a TTM-tailored website may not be more effective than a non-tailored one (Wanner, Martin-Diener, Braun-Fahrlander, Bauer, & Martin, 2009).

6.2 Profiles of the sedentary young men (Study I)

In Study I, a variety of physical, behavioural, social, environmental and health factors were taken into account in profiling the sedentary young men. Our comprehensive approach complements previous studies in which sedentary patterns among children and adolescents have mainly been studied in respect to dietary patterns (Gorely, Marshall, Biddle, & Cameron, 2007; Wang, Biddle, Liu, & Lim, 2012) and have mostly focused on different actions (i.e. TV viewing, reading, computer usage, homework) within SB. The five profiles found were named: “exercising but sitting”, “feeling unhappy”, “symptoms of disordered eating”, “being unfit with appearance-related motivation” and “gaming”.

A high amount of sitting and PA were detected in the first profile. Formerly, a physically active sedentary group was not found among British adolescents (Gorely et al., 2007). However, Wang et al. (Wang et al., 2012) identified a group with a sedentary pattern but a high PA level. Also, in another study, adolescents participating in both skating and video gaming had the highest odds of meeting the PA recommendations (Nelson, Gordon-Larsen, Adair, & Popkin, 2005). In a recent study among Australian adolescents, a moderately active but high screen-time group was found, in accordance with our study (Parker, Salmon, Brown, Villanueva, & Timperio, 2019). Thus, SB and PA do not necessarily displace one another and may coexist.

Poor subjective wellbeing – measured by low life satisfaction, low self-esteem and depressive symptoms – was accumulated in one of our sedentary profiles. In accordance with our results, life dissatisfaction and SB were associated in an American study among college students (Maher, Doerksen, Elavsky, & Conroy, 2014). A similar association has also been found among adolescents with type 1 diabetes (da Costa, Luce Marina F. C. & Vieira, 2015). In a large review containing 91 studies, the association between depressive symptoms, self-esteem and SB stayed indeterminate, contrary to our findings (Suchert, Hanewinkel, & Isensee, 2015).

In the present study, an unhealthy diet or symptoms of disordered eating were found in the sedentary profile. A review by Suchert et al. 2015 found both similar and opposing results about the relation between disordered eating and sedentary time. An association was not found in nine studies and a positive association was detected in 12 of the studies. This indicates the complex phenomena of SB and mental health, and the lack of longitudinal studies. (Suchert et al., 2015)

It is not surprising that poor physical fitness accumulated in one of the profiles (“being unfit with appearance-related motivation”). Also, previously self-reported leisure sitting time has been inversely linked with measured physical fitness (Santos et al., 2014). Positively, men in this profile could be motivated to exercise because their motives are concrete and the outcomes (such as losing weight) are easy to measure. Previously, body shape and weight management have been inconsistent in motivating people, especially teenagers and women (Allender, Cowburn, & Foster, 2006). In men, competition, social recognition and fitness improvement have motivated them to exercise, while having fun has especially motivated young men (Kilpatrick, Hebert, & Bartholomew, 2005). Losing weight can motivate physically inactive people, social factors can motivate less educated people and the improvement of physical fitness can motivate adults who already exercise (Skov-Ettrup et al., 2014).

Time spent on the Internet and engagement in Internet games were associated with a sedentary lifestyle in Study I in accordance with the general assumption of Internet-time increasing sitting, and previous studies (Cabanas-Sánchez et al., 2019; Tremblay et al., 2011). In a recent study of Parker et al., a high amount of video gaming was associated with high screen-based sedentary time but not with a high amount of total SB (Parker et al., 2019).

Our results showed that the profiles of the sedentary young men differed according to SES, physical and mental health, health behaviour, PA, restrictions to exercising and motives to exercise. Thus, the motivation of sedentary young men to engage in PA should be more individual and it cannot be based solely on the activity level.

6.3 The motives for and factors related to physical activity among the young men (Study II)

In Study II, the parental roles related to PA in the young men varied according to the residential area. The mother’s PA was positively associated with the PA of those men who lived in the built environment, and the father’s activity was positively

associated with his son's PA in the natural living environment. The support of parents encourages adolescents to engage in PA (Courtney, Moss, Butki, & Li, 2019; K. W. Kim, Wallander, Felt, Elliott, & Schuster, 2019; Mikalsen, Lagestad, Bentzen, & Safvenbom, 2019; Sleddens et al., 2012). However, previous studies have revealed mixed results regarding the association between parents' and their children's PA or even revealed a lack of association (Bauman et al., 2012). In two large-scale studies from Brazil and urban Spain, the father's PA was associated with boys' self-rated PA (Cheng et al., 2014; Martin-Matillas et al., 2011). Still, rural and urban residents were not compared in these studies as they were in our study. An association between the mother's and the son's PA has been found in earlier studies (Dumith et al., 2012), even though the mother's PA is more commonly associated with the PA of the daughter (Schoeppe, Liersch, Robl, Krauth, & Walter, 2016). In a Korean study among 1 342 participants, only maternal PA was related to the PA of adolescents, and the association was stronger among girls and 13–15-years-olds (Yoon, Lee, Ju, Nam, & Park, 2018). In contrast with our study, a difference according to the type of residency was not detected for the association between the PA of parents and their children in an Indian study among rural and urban residents (Swaminathan, Thomas, Yusuf, & Vaz, 2013). This may be due to cultural differences in, for example, gender roles and family dynamics between India and Finland. The significant role of fathers in regard to their sons' PA has also been found among 835 urban adolescents from Lithuania (Lisinskiene & Juskeliene, 2019). The youth culture, families' role and leisure-time activities in rural areas have especially been studied in eastern Finland. The central role of fathers in leisure-time activities among rural adolescents was also found in a study by Tuuva-Hongisto et al. (Tuuva-Hongisto, Pöysä & Armila, 2016). A recent Finnish study showed that high mothers' and fathers' physical activity may increase their children's physical activity to young adulthood despite the living environment or parents' SES. Higher physical activity of fathers was associated with their sons' PA while physically active mothers may increase their daughters' exercising. After adjusting for covariates, mothers' PA was especially associated with their son's PA. (Kaseva et al., 2017.) Kaseva et al. did not find differences according to living environment as we did in our study. A qualitative study approach among our study participants would complement the knowledge on this study finding.

Good subjective health and less depressive symptoms were significantly associated with higher PA in natural and built living environments in our study. The strong association between self-rated health and PA has also been found in previous studies among youth (Kantomaa et al., 2015; Kleszczewska, Szkutnik, Siedlecka,

& Mazur, 2019). The association exists irrespective of the residential area or age. The presence of and access to green space in the suburbs has previously been found to be related to leisure-time PA and to self-rated health in a random sample of 8 000 Finns (Pietilä et al., 2015). Mental health and PA are strongly related among adolescents (Biddle & Asare, 2011; Vella, Gardner, Swann, & Allen, 2019; Velten, Bieda, Scholten, Wannemuller, & Margraf, 2018), which is in agreement with the findings here regarding the negative association of depressive symptoms and PA in both built and natural residential environments.

The motives and restrictions for PA were otherwise similar except that poor transportation and the lack of an appropriate exercise group restricted PA more among natural environment residents compared to young men living in the built environment. Because the natural residential environment category in this study included participants who lived in rural areas, the finding is not surprising. The public transportation level and guided exercise possibilities are usually poorer in rural areas and even in suburban environments compared to urban areas.

The amount of PA did not differ according to the living environment. The PA was objectively measured in the sub-sample of young men and their mean amount of PA fulfilled the daily global recommendation of at least 60 minutes of MVPA (World Health Organization, 2010). Objectively measured MVPA has previously been shown to be lower in rural youth compared with urban youth (Moore et al., 2013), which is inconsistent with our study. Higher MVPA and lower sedentary time have also been found in moderately urban areas when compared with more urban areas in adolescents in the United States (Euler et al., 2019). However, differences in PA according to the residential area have not always been detected among boys (Moore et al., 2014), which is in agreement with the present findings.

6.4 The effects of the intervention on physical activity and sedentary behaviour (Study III)

In Study III we evaluated the effects of the intervention on anthropometry, fitness and both self-rated and objectively measured PA and SB. The intervention had no effect on fitness, self-rated PA and daily sitting time or the objectively measured SB. Waist circumference decreased within the most inactive men. There was a positive trend over time (in favour to the intervention group) in objective daily MVPA.

Previously, web-based interventions have been suggested to have at least a short-term effect on PA in young people (Hamel et al., 2011; Tong et al., 2019; Zach

S., Raviv T., Meckel, Y., 2016). Besides the comparatively long trial period, our study has also other differences when compared with previous PA interventions. To our knowledge, this is one of the few web-based, fully automated PA intervention studies that was implemented in a home setting, did not include regular face-to-face contact, utilized several elements and included young male participants. In a three-month pilot RCT among young men (Ashton, Morgan, Hutchesson, Rollo, & Collins, 2017), weekly MVPA increased but, because of their weekly face-to-face counselling, this study is not completely comparable to our study. A mHealth intervention may also improve short-term confidence in performing PA when professional counselling is included (Partridge, McGeechan, Bauman, Phongsavan, & Allman-Farinelli, 2017).

A previous four-week intervention among Chinese youth utilized automated SMSs but PA was not increased during the trial (Lau et al., 2019). Another recent study evaluated the effectiveness of an automated and low-cost smartphone intervention in a smaller two-month RCT. The intervention increased walking among young to early-middle-aged men (Harries et al., 2016). Including a texting component in an automated mHealth intervention was found effective in a five-week randomized clinical trial among 50 adults (Martin et al., 2015). A recent meta-analysis with 21 studies and 1 700 participants studied the influence of mHealth technologies on SB. The results indicated that mHealth interventions may have small-to-moderate-sized positive effects on PA, but a control group without any counselling was usually lacking in the studies (Direito, Carraca, Rawstorn, Whittaker, & Maddison, 2017).

A nine-week intervention study conducted among adults that included a fully automated Internet-based behaviour change system with continuous measurement of PA (Hurling et al., 2007) consistent with our study design. The intervention increased moderate PA to over two hours weekly in the intervention group compared to the control group (Hurling et al., 2007). Engagement and the service-use rate were higher than in our study, which may be due to it having older participants or factors related to the features and attractiveness of the service. In addition, a web-based intervention without any face-to-face contact in older adults increased the MVPA within the intervention group (Wijsman et al., 2013). However, in contrast with our study, the participants were older adults, the study period was a half shorter and the objective measurement of PA was not continuous.

In our study, the multi-component intervention had no effect on the SB of the young men. In our earlier study we concluded that only feedback from a wrist-worn activity monitor had a short-term positive effect on the SB of the young men (Jauho

et al., 2015). Contrary findings also exist. Consumer-wearable activity monitors did not decrease the SB in adults in a 12-months RCT (Sloan et al., 2018). However, a 12-month intervention using a website only was more effective in decreasing sedentary time compared to usual care among 12–16-year-old adolescents at risk of type 2 diabetes (Patrick et al., 2013). According to the meta-analysis of Direito et al. 2017, sedentary time decreased slightly during mHealth RCTs, but somewhat “active” comparator groups may have biased the results (Direito et al., 2017). A recent systematic review (Schoeppe et al., 2016) included five interventions that contained mobile applications targeting decreasing sedentary time in different age groups. Two of these studies reported improvements in SB. (Schoeppe et al., 2016.) The effectiveness of a 12-week mobile health intervention was evaluated in an Australian study among young adults. The intervention included similar elements to those we had in our study (e.g. a smartphone application, Internet forums, health messages). Consistent with our study, the intervention did not affect SB but light PA increased during the trial. Low engagement with the intervention also restricted the analysis and the interpretation of the results in their study. (Hebden et al., 2014.)

6.5 The effects of the intervention on life satisfaction and self-rated health (Study IV)

Life satisfaction increased similarly both in the intervention and control groups in Study IV, but there were no changes in self-rated health. Our study approach was unusual because only a few mobile PA interventions in youth have reported the effects on subjective health and wellbeing. In particular, population-based studies are lacking and trials which reported the effects on psychological wellbeing have mainly been conducted among risk groups.

Previously, college students with mental disorders participated in a 10-week Internet-delivered intervention aiming to increase physical activity and decrease depression and anxiety, but an impact on mental health outcomes was not found, in contrast with our study (Mailey et al., 2010b). Similarly, a three-month RCT that including a website, PA monitor and face-to-face counselling did not enhance life satisfaction among young Australian men (Ashton et al., 2017). The difference may be due to smaller sample size and shorter trial period when compared with our study. In a study among adolescents at risk of type 2 diabetes, a technology-based 12-month intervention promoting weight loss enhanced the quality of life of girls, but had no effect on boys (Patrick et al., 2013). A 12-week web-based intervention (Riiser et al., 2014) succeeded in increasing the health-related quality of life of

overweight young people, but it did not have any effect on the control group, unlike the present study.

The enhancement of life satisfaction also among controls may be due to anticipation of the follow-up measurements or simply due to the Hawthorne effect: just participating and being considered in the study may have enhanced their subjective wellbeing. In our study, the participants in the control group wore blinded activity monitors and received a reminder by text message about uploading the activity data to the database, which may have partly motivated them.

6.6 The feasibility of the gamified, mobile and tailored intervention (Studies III and IV)

Over 64% of the intervention group visited the MOPortal service, but the rate of use decreased during the trial. Fifty-six participants used the Clans of Oulu game in the service. Less than fifth logged on to the service more than five times. The personal data related to PA was the most popular feature of the service. Baseline higher BMI was related to the higher use rate of the service. Men with less vigorous PA at baseline were more likely to increase their MVPA during the trial. Poor subjective wellbeing at baseline was associated with positive changes in life satisfaction and self-rated health within the intervention group.

Previously, low engagement in the interventions has complicated the evaluation of their effectiveness among young people (Epton et al., 2014; Hebden et al., 2014; Kohl et al., 2013). Furthermore, the quality of the design and protocol of the previous information and communication-technology-based interventions has been low (due to, for example, the lack of a control group or a population-based study design), which makes it difficult to draw conclusions about the effectiveness (Lau et al., 2011).

In several studies, the use of an app or a service has dropped after the first month of the study (Flores Mateo et al., 2015). In a study where a smartphone app was used together with a face-to-face school-based programme in adolescent boys, 20% of the participants did not use the app at all (Lubans et al., 2014). A study using PA monitoring and a tailored PA coaching website for increasing PA reported that only 24% (n = 10) of participants had uploaded PA data regularly to the service during the three-month trial (Slootmaker, Chinapaw, Seidell, van Mechelen, & Schuit, 2010). Contradictorily, 94% of the 50 young male participants in an Australian HEYMAN study participated in the follow-up measurements, but the study design was not population-based as our study was, so the participants may

have, in principle, been more interested in participation. In addition, maybe due to the different study sample and the weekly face-to-face contacts, all the Australian participants visited their intervention website during the trial, contrary to our study. (Ashton et al., 2017.)

We observed a minor increase in daily MVPA, especially among those with a low amount of vigorous PA at baseline. However, these data may be biased due to the limited sample size. In addition, we cannot distinguish whether the positive effect is the result of the gamified service and/or the feedback given by the wrist-worn PA monitor. However, a recent quasi-experimental study with one arm found a higher increase in daily steps among young people with a lower PA level (Tong et al., 2019), supporting our study results.

Our findings suggest that a gamified, tailored and mobile intervention could be especially suitable for young men with higher BMI, lower vigorous PA, and poorer subjective health and wellbeing. It has also been previously assumed that adolescents with unhealthy behaviour could be interested in Internet-based health promotion (Tercyak 2009), which is in agreement with our results. We implemented different game mechanics in the MOPortal service to make it more engaging and attractive. MOPortal was a multicomponent service, and the impact of the game, which was accessed through the portal site, cannot be distinguished from the results. However, additional improvements are needed in order to engage the user and maintain the interest to use the service for a longer time, especially in population-based studies in which the motivation level of the participants may vary. The effect of the intervention might have been different if only inactive young men had been recruited because the used behaviour change model (the TTM) was originally developed for changing unhealthy behaviour (Prochaska & DiClemente, 1983).

7 Conclusion

The purpose of this study was to clarify the determinants of PA and SB in young men and to study the effectiveness of a gamified, tailored and mobile PA intervention. The main findings according to the study aims are presented below:

1. Five profiles were found among sedentary young men: “exercising but sitting”, “feeling unhappy”, “symptoms of disordered eating”, “being unfit with appearance-related motivation” and “gaming”.
2. Young men living in built and natural environments were equally physically active. The mother’s PA was positively associated with the PA of men living in the built environment and father’s PA was positively associated with the PA of natural environment residents. Self-rated health and depressive symptoms were related to PA despite the living environment.
3. The gamified, mobile tailored intervention had a borderline positive effect on MVPA, especially among those who did less vigorous PA at baseline. The intervention had no effect on the SB or light PA of the participants.
4. Life satisfaction improved during the trial regardless of the group allocation. Self-rated health did not change. Within the intervention group, improvements in subjective health and life satisfaction were associated with low life satisfaction and poor self-rated health at baseline.
5. The compliance for the mobile service was limited although the personal PA data was perceived as interesting. Baseline higher BMI was related to the use rate of the service. Men with less vigorous PA at baseline were more likely to increase their MVPA during the trial. Poor subjective wellbeing at baseline was associated with positive changes in life satisfaction and self-rated health within the intervention group.

This study complements existing knowledge on the PA and SB of youth and on the findings on the effects of technology-based PA promotion. The study adds to literature on individual, environmental and parental factors underlying SB and PA in young men. Sedentary time is time spent on a set of multiple behaviours, and recognizing the individual patterns and underlying factors of a lifestyle are essential for effective interventions. These findings highlight the importance of individually designed health promotion among young men.

Our intervention was one of the few population-based RCTs which utilize a mobile service without face-to-face contact. The results of this RCT can be used to target health promotion for young men at risk of low life satisfaction, poor self-

rated health and low levels of PA. Further development is still needed in order to improve the feasibility and adherence of an integrated multifunctional service.

Prospective studies are still needed in order to investigate the lifelong trajectories and determinants of SB and PA in young men. Randomized controlled, population-based trials with higher engagement would ease the study of their effectiveness. Adding face-to-face counselling or a reminder about the intervention could increase compliance. The effectiveness of a certain element would be easier to clarify if the service were to include fewer functionalities. Mobile services need to be further examined among populations of various ages. In the future studies, a mobile, gamified intervention should be implemented among young people with an inactive lifestyle and other forms of unhealthy behaviour in order to reveal the effectiveness of the selected features among those at most risk. Parental roles could be further studied taking into account the possibly different patterns and types of physical activity and sedentary behaviors of both parents and children in varying residential environments.

References

- Abraham, A. A., Chow, W. C., So, H. K., Yip, B. H., Li, A. M., Kumta, S. M., . . . Nelson, E. A. (2015). Lifestyle intervention using an internet-based curriculum with cell phone reminders for obese Chinese teens: A randomized controlled study. *PloS One*, *10*(5), e0125673. doi:10.1371/journal.pone.0125673 [doi]
- Ahola, R., Pyky, R., Jamsa, T., Mantysaari, M., Koskimaki, H., Ikaheimo, T. M., . . . Korpelainen, R. (2013). Gamified physical activation of young men--a multidisciplinary population-based randomized controlled trial (MOPO study). *BMC Public Health*, *13*, 3-32. doi:10.1186/1471-2458-13-32 [doi]
- Allender, S., Cowburn, G., & Foster, C. (2006). Understanding participation in sport and physical activity among children and adults: A review of qualitative studies. *Health Education Research*, *21*(6), 826-835. doi:cyl063 [pii]
- Althubaiti, A. (2016). Information bias in health research: Definition, pitfalls, and adjustment methods. *Journal of Multidisciplinary Healthcare*, *9*, 211-217. doi:10.2147/JMDH.S104807 [doi]
- Ashton, L. M., Morgan, P. J., Hutchesson, M. J., Rollo, M. E., & Collins, C. E. (2017). Feasibility and preliminary efficacy of the 'HEYMAN' healthy lifestyle program for young men: A pilot randomised controlled trial. *Nutrition Journal*, *16*(1), 8. doi:10.1186/s12937-017-0227-8 [doi]
- Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., Martin, B. W., & Lancet Physical Activity Series Working Group. (2012). Correlates of physical activity: Why are some people physically active and others not? *Lancet*, *380*(9838), 258-271. doi:10.1016/S0140-6736(12)60735-1 [doi]
- Bewick, B. M., West, R. M., Barkham, M., Mulhern, B., Marlow, R., Traviss, G., & Hill, A. J. (2013). The effectiveness of a web-based personalized feedback and social norms alcohol intervention on United Kingdom university students: Randomized controlled trial. *Journal of Medical Internet Research*, *15*(7), e137. doi:10.2196/jmir.2581 [doi]
- Biddle, S. J., Garcia Bengoechea, E., & Wiesner, G. (2017). Sedentary behaviour and adiposity in youth: A systematic review of reviews and analysis of causality. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 4-8. doi:10.1186/s12966-017-0497-8 [doi]
- Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine*, *45*(11), 886-895. doi:10.1136/bjsports-2011-090185 [doi]
- Biddle, S. J., Gorely, T., Pearson, N., & Bull, F. C. (2011). An assessment of self-reported physical activity instruments in young people for population surveillance: Project ALPHA. *The International Journal of Behavioral Nutrition and Physical Activity*, *8*, 1. doi:10.1186/1479-5868-8-1 [doi]
- Blair, S. N., Davey Smith, G., Lee, I. M., Fox, K., Hillsdon, M., McKeown, R. E., . . . Marmot, M. (2010). A tribute to professor Jeremiah Morris: The man who invented the field of physical activity epidemiology. *Annals of Epidemiology*, *20*(9), 651-660. doi:10.1016/j.annepidem.2010.06.001 [doi]

- Boehm, J. K., & Kubzansky, L. D. (2012). The heart's content: The association between positive psychological well-being and cardiovascular health. *Psychological Bulletin*, *138*(4), 655-691. doi:10.1037/a0027448 [doi]
- Borodulin, K., Karki, A., Laatikainen, T., Peltonen, M., & Luoto, R. (2015). Daily sedentary time and risk of cardiovascular disease: The national FINRISK 2002 study. *Journal of Physical Activity & Health*, *12*(7), 904-908. doi:10.1123/jpah.2013-0364 [doi]
- Borodulin, K., Lakka, T., Laatikainen, T., Laukkanen, R., Kinnunen, H., & Jousilahti, P. (2004). Associations of self-rated fitness and different types of leisure time physical activity with predicted aerobic fitness in 5346 Finnish adults. *Journal of Physical Activity and Health*, *1*(2), 142-153.
- Bort-Roig, J., Gilson, N. D., Puig-Ribera, A., Contreras, R. S., & Trost, S. G. (2014). Measuring and influencing physical activity with smartphone technology: A systematic review. *Sports Medicine (Auckland, N.Z.)*, *44*(5), 671-686. doi:10.1007/s40279-014-0142-5 [doi]
- Bounova, A., Michalopoulou, M., Agelousis, N., Kourtessis, T., & Gourgoulis, V. (2016). The parental role in adolescent screen related sedentary behavior. *International Journal of Adolescent Medicine and Health*, *30*(2), 10.1515/ijam-2016-0031. doi:10.1515/ijamh-2016-0031 [doi]
- Bowen, R. S., Turner, M. J., & Lightfoot, J. T. (2011). Sex hormone effects on physical activity levels: Why doesn't Jane run as much as Dick? *Sports Medicine (Auckland, N.Z.)*, *41*(1), 73-86. doi:10.2165/11536860-000000000-00000 [doi]
- Broekhuizen, K., Kroeze, W., van Poppel, M. N., Oenema, A., & Brug, J. (2012). A systematic review of randomized controlled trials on the effectiveness of computer-tailored physical activity and dietary behavior promotion programs: An update. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *44*(2), 259-286. doi:10.1007/s12160-012-9384-3 [doi]
- Brugniaux, J. V., Niva, A., Pulkkinen, I., Laukkanen, R. M., Richalet, J. P., & Pichon, A. P. (2010). Polar activity watch 200: A new device to accurately assess energy expenditure. *British Journal of Sports Medicine*, *44*(4), 245-249. doi:10.1136/bjism.2007.045575 [doi]
- Burke, B. (2014). *Gamify: How gamification motivates people to do extraordinary things* Gartner, Inc.
- Cabanas-Sánchez, V., García-Cervantes, L., Esteban-Gonzalo, L., Girela-Rejón, M. J., Castro-Piñero, J., & Veiga, Ó L. (2019). Social correlates of sedentary behavior in young people: The UP&DOWN study doi://doi.org/10.1016/j.jshs.2019.03.005
- Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoun, L. (2013). Using accelerometers in youth physical activity studies: A review of methods. *Journal of Physical Activity & Health*, *10*(3), 437-450.
- Cardinal, B. J. (1995). The stages of exercise scale and stages of exercise behavior in female adults. *The Journal of Sports Medicine and Physical Fitness*, *35*(2), 87-92.
- Carson, V., Iannotti, R. J., Pickett, W., & Janssen, I. (2011). Urban and rural differences in sedentary behavior among American and Canadian youth. *Health & Place*, *17*(4), 920-928. doi:10.1016/j.healthplace.2011.04.007 [doi]

- Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports (Washington, D.C.: 1974)*, *100*(2), 126-131.
- Chen, S. T., Liu, Y., Hong, J. T., Tang, Y., Cao, Z. B., Zhuang, J., . . . Chen, P. J. (2018). Co-existence of physical activity and sedentary behavior among children and adolescents in shanghai, china: Do gender and age matter? *BMC Public Health*, *18*(1), 128-1. doi:10.1186/s12889-018-6167-1 [doi]
- Cheng, L. A., Mendonca, G., & Farias Junior, J. C. (2014). Physical activity in adolescents: Analysis of the social influence of parents and friends. *Jornal De Pediatria*, *90*(1), 35-41. doi:10.1016/j.jped.2013.05.006 [doi]
- Condello, G., Puggina, A., Aleksovska, K., Buck, C., Burns, C., Cardon, G., . . . DEDIPAC consortium. (2017). Behavioral determinants of physical activity across the life course: A "DEterminants of DIet and physical ACTivity" (DEDIPAC) umbrella systematic literature review. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 5-2. doi:10.1186/s12966-017-0510-2 [doi]
- Coombes, E., van Sluijs, E., & Jones, A. (2013). Is environmental setting associated with the intensity and duration of children's physical activity? Findings from the SPEEDY GPS study. *Health & Place*, *20*, 62-65. doi:10.1016/j.healthplace.2012.11.008 [doi]
- Corder, K., Sharp, S. J., Atkin, A. J., Griffin, S. J., Jones, A. P., Ekelund, U., & van Sluijs, E. M. (2015). Change in objectively measured physical activity during the transition to adolescence. *British Journal of Sports Medicine*, *49*(11), 730-736. doi:10.1136/bjsports-2013-093190 [doi]
- Corder, K., Winpenny, E., Love, R., Brown, H. E., White, M., & Sluijs, E. V. (2019). Change in physical activity from adolescence to early adulthood: A systematic review and meta-analysis of longitudinal cohort studies. *British Journal of Sports Medicine*, *53*(8), 496-503. doi:10.1136/bjsports-2016-097330 [doi]
- Cortis, C., Puggina, A., Pesce, C., Aleksovska, K., Buck, C., Burns, C., . . . Boccia, S. (2017). Psychological determinants of physical activity across the life course: A "DEterminants of DIet and physical ACTivity" (DEDIPAC) umbrella systematic literature review. *PloS One*, *12*(8), e0182709. doi:10.1371/journal.pone.0182709 [doi]
- Courtney, J. B., Moss, H. E., Butki, B. D., & Li, K. (2019). Parent support, perceptions, and child attributes affect child activity. *American Journal of Health Behavior*, *43*(2), 311-325. doi:10.5993/AJHB.43.2.8 [doi]
- Craggs, C., Corder, K., van Sluijs, E. M., & Griffin, S. J. (2011). Determinants of change in physical activity in children and adolescents: A systematic review. *American Journal of Preventive Medicine*, *40*(6), 645-658. doi:10.1016/j.amepre.2011.02.025 [doi]
- Cugelman, B., Thelwall, M., & Dawes, P. (2011). Online interventions for social marketing health behavior change campaigns: A meta-analysis of psychological architectures and adherence factors. *Journal of Medical Internet Research*, *13*(1), e17. doi:10.2196/jmir.1367 [doi]
- da Costa, Luce Marina F. C., & Vieira, S. E. (2015). Quality of life of adolescents with type 1 diabetes. *Clinics*, *70*(3), 173-179. doi:10.6061/clinics/2015(03)04

- Dadvand, P., Bartoll, X., Basagana, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., . . . Nieuwenhuijsen, M. J. (2016). Green spaces and general health: Roles of mental health status, social support, and physical activity. *Environment International*, *91*, 161-167. doi:10.1016/j.envint.2016.02.029 [doi]
- de Geus, E. J., Bartels, M., Kaprio, J., Lightfoot, J. T., & Thomis, M. (2014). Genetics of regular exercise and sedentary behaviors. *Twin Research and Human Genetics: The Official Journal of the International Society for Twin Studies*, *17*(4), 262-271. doi:10.1017/thg.2014.42 [doi]
- de Niet, J., Timman, R., Bauer, S., van den Akker, E., Buijks, H., de Klerk, C., . . . Passchier, J. (2012). The effect of a short message service maintenance treatment on body mass index and psychological well-being in overweight and obese children: A randomized controlled trial. *Pediatric Obesity*, *7*(3), 205-219. doi:10.1111/j.2047-6310.2012.00048.x [doi]
- de Rezende, L. F., Rodrigues Lopes, M., Rey-Lopez, J. P., Matsudo, V. K., & Luiz Odo, C. (2014). Sedentary behavior and health outcomes: An overview of systematic reviews. *PLoS One*, *9*(8), e105620. doi:10.1371/journal.pone.0105620 [doi]
- Diener, E., & Diener, M. (1995). Cross-cultural correlates of life satisfaction and self-esteem. *Journal of Personality and Social Psychology*, *68*(4), 653-663.
- Direito, A., Carraca, E., Rawstorn, J., Whittaker, R., & Maddison, R. (2017). mHealth technologies to influence physical activity and sedentary behaviors: Behavior change techniques, systematic review and meta-analysis of randomized controlled trials. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *51*(2), 226-239. doi:10.1007/s12160-016-9846-0 [doi]
- Dumith, S. C., Gigante, D. P., Domingues, M. R., Hallal, P. C., Menezes, A. M., & Kohl, H. W., 3rd. (2012). Predictors of physical activity change during adolescence: A 3.5-year follow-up. *Public Health Nutrition*, *15*(12), 2237-2245. doi:10.1017/S1368980012000948 [doi]
- Enwald, H. (2013). Tailoring health communication: The perspective of information users' health information behaviour in relation to their physical health status.(Article dissertation).
- Epton, T., Norman, P., Dadzie, A. S., Harris, P. R., Webb, T. L., Sheeran, P., . . . Shah, I. (2014). A theory-based online health behaviour intervention for new university students (U@Uni): Results from a randomised controlled trial. *BMC Public Health*, *14*, 56-563. doi:10.1186/1471-2458-14-563 [doi]
- Euler, R., Jimenez, E. Y., Sanders, S., Kuhlemeier, A., Van Horn, M. L., Cohen, D., . . . Kong, A. S. (2019). Rural-urban differences in baseline dietary intake and physical activity levels of adolescents. *Preventing Chronic Disease*, *16*, E01. doi:10.5888/pcd16.180200 [doi]
- Ezendam, N. P., Noordegraaf, V. S., Kroeze, W., Brug, J., & Oenema, A. (2013). Process evaluation of FATaintPHAT, a computer-tailored intervention to prevent excessive weight gain among Dutch adolescents. *Health Promotion International*, *28*(1), 26-35. doi:10.1093/heapro/das021 [doi]

- Fanning, J., Mullen, S. P., & McAuley, E. (2012). Increasing physical activity with mobile devices: A meta-analysis. *Journal of Medical Internet Research*, *14*(6), e161. doi:10.2196/jmir.2171 [doi]
- Fedele, D. A., Cushing, C. C., Fritz, A., Amaro, C. M., & Ortega, A. (2017). Mobile health interventions for improving health outcomes in youth: A meta-analysis. *JAMA Pediatrics*, *171*(5), 461-469. doi:10.1001/jamapediatrics.2017.0042 [doi]
- Flores Mateo, G., Granado-Font, E., Ferré-Grau, C., & Montaña-Carreras, X. (2015). Mobile phone apps to promote weight loss and increase physical activity: A systematic review and meta-analysis. *Journal of Medical Internet Research*, *17*(11), e253. doi:10.2196/jmir.4836
- Froberg, A., & Raustorp, A. (2014). Objectively measured sedentary behaviour and cardio-metabolic risk in youth: A review of evidence. *European Journal of Pediatrics*, *173*(7), 845-860. doi:10.1007/s00431-014-2333-3 [doi]
- Garde, A., Umedaly, A., Abulnaga, S. M., Junker, A., Chanoine, J. P., Johnson, M., . . . Dumont, G. A. (2016). Evaluation of a novel mobile exergame in a school-based environment. *Cyberpsychology, Behavior and Social Networking*, *19*(3), 186-192. doi:10.1089/cyber.2015.0281 [doi]
- Garner, D. M., Olmstead, M. P., & Polivy, J. (1983). Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. *International Journal of Eating Disorders*, *2*(2), 15-34.
- Gebremariam, M. K., Altenburg, T. M., Lakerveld, J., Andersen, L. F., Stronks, K., Chinapaw, M. J., & Lien, N. (2015). Associations between socioeconomic position and correlates of sedentary behaviour among youth: A systematic review. *Obesity Reviews*, *16*(11), 988-1000. doi:10.1111/obr.12314
- Ghanvatkar, S., Kankanhalli, A., & Rajan, V. (2019). User models for personalized physical activity interventions: Scoping review. *JMIR mHealth and uHealth*, *7*(1), e11098. doi:10.2196/11098 [doi]
- Gillison, F. B., Skevington, S. M., Sato, A., Standage, M., & Evangelidou, S. (2009). The effects of exercise interventions on quality of life in clinical and healthy populations; a meta-analysis. *Social Science & Medicine (1982)*, *68*(9), 1700-1710. doi:10.1016/j.socscimed.2009.02.028 [doi]
- Gong, Q. H., Li, H., Zhang, X. H., Zhang, T., Cui, J., & Xu, G. Z. (2017). Associations between sleep duration and physical activity and dietary behaviors in Chinese adolescents: Results from the youth behavioral risk factor surveys of 2015. *Sleep Medicine*, *37*, 168-173. doi:S1389-9457(17)30291-5 [pii]
- Gorely, T., Marshall, S. J., Biddle, S. J., & Cameron, N. (2007). Patterns of sedentary behaviour and physical activity among adolescents in the United Kingdom: Project STIL. *Journal of Behavioral Medicine*, *30*(6), 521-531. doi:10.1007/s10865-007-9126-3 [doi]
- Haaranen, A., Rissanen, T., Laatikainen, T., & Kauhanen, J. (2014). Digital and video games in health promotion: Systematic review of games and health behavior. *Finnish Journal of eHealth and eWelfare*, *6*(4) Retrieved from <https://journal.fi/finjehew/article/view/48209>

- Haberstick, B. C., Zeiger, J. S., & Corley, R. P. (2014). Genetic and environmental influences on the allocation of adolescent leisure time activities. *BioMed Research International*, 2014, 805476. doi:10.1155/2014/805476 [doi]
- Hagstromer, M., Ainsworth, B. E., Oja, P., & Sjostrom, M. (2010). Comparison of a subjective and an objective measure of physical activity in a population sample. *Journal of Physical Activity & Health*, 7(4), 541-550.
- Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., & Lancet Physical Activity Series Working Group. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet*, 380(9838), 247-257. doi:10.1016/S0140-6736(12)60646-1 [doi]
- Hamel, L. M., Robbins, L. B., & Wilbur, J. (2011). Computer- and web-based interventions to increase preadolescent and adolescent physical activity: A systematic review. *Journal of Advanced Nursing*, 67(2), 251-268. doi:10.1111/j.1365-2648.2010.05493.x [doi]
- Harries, T., Eslamolchilar, P., Rettie, R., Stride, C., Walton, S., & van Woerden, H. C. (2016). Effectiveness of a smartphone app in increasing physical activity amongst male adults: A randomised controlled trial. *BMC Public Health*, 16, 92-9. doi:10.1186/s12889-016-3593-9 [doi]
- Harris, M. A. (2018). Maintenance of behaviour change following a community-wide gamification based physical activity intervention. *Preventive Medicine Reports*, 13, 37-40. doi:10.1016/j.pmedr.2018.11.009 [doi]
- Hawkins, R. P., Kreuter, M., Resnicow, K., Fishbein, M., & Dijkstra, A. (2008). Understanding tailoring in communicating about health. *Health Education Research*, 23(3), 454-466. doi:10.1093/her/cyn004 [doi]
- Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., . . . Lancet Physical Activity Series Working Group. (2012). Evidence-based intervention in physical activity: Lessons from around the world. *Lancet (London, England)*, 380(9838), 272-281. doi:10.1016/S0140-6736(12)60816-2 [doi]
- Hebden, L., Cook, A., van der Ploeg, H. P., King, L., Bauman, A., & Allman-Farinelli, M. (2014). A mobile health intervention for weight management among young adults: A pilot randomised controlled trial. *Journal of Human Nutrition and Dietetics: The Official Journal of the British Dietetic Association*, 27(4), 322-332. doi:10.1111/jhn.12155 [doi]
- Helakorpi, S., Prättälä, R., & Uutela, A. (2008). *Suomalaisen aikuisväestön terveyskäyttäytyminen ja terveys, kevät 2007. Health behaviour and health among the Finnish Adult population, spring 2007.* (). Retrieved from <http://www.julkari.fi/bitstream/handle/10024/78308/2008b06.pdf?sequence>
- Herman, K. M., Hopman, W. M., & Sabiston, C. M. (2015). Physical activity, screen time and self-rated health and mental health in Canadian adolescents. *Preventive Medicine*, 73, 112-116. doi:10.1016/j.ypmed.2015.01.030 [doi]

- Hirvonen, N., Huotari, M.-L., Niemelä, R., & Korpelainen, R. (2012). Information behavior in stages of exercise behavior change. *Journal of the American Society for Information Science and Technology*, 63(9), 1804.
- Hirvonen, N., Enwald, H., Bath, P. A., Pyky, R., Korpelainen, R., & Huotari, M. L. (2015). Individual factors affecting preferences for feedback message tactics in the contexts of physical activity. *Journal of Health Communication*, 20(2), 220-229. doi:10.1080/10810730.2014.925015 [doi]
- Holtzblatt, K., & Jones, S. (1993). In Schuler D., Namioka A. (Eds.), *Participatory design - principles and practices*. Hillsdale, New Jersey: Lawrence Erlbaum Associates Inc., Publishers.
- Hurling, R., Catt, M., Boni, M. D., Fairley, B. W., Hurst, T., Murray, P., . . . Sodhi, J. S. (2007). Using internet and mobile phone technology to deliver an automated physical activity program: Randomized controlled trial. *Journal of Medical Internet Research*, 9(2), e7. doi:v9i2e7 [pii]
- Hustad, J. T., Barnett, N. P., Borsari, B., & Jackson, K. M. (2010). Web-based alcohol prevention for incoming college students: A randomized controlled trial. *Addictive Behaviors*, 35(3), 183-189. doi:10.1016/j.addbeh.2009.10.012 [doi]
- Husu, P., Vaha-Ypyä, H., & Vasankari, T. (2016). Objectively measured sedentary behavior and physical activity of Finnish 7- to 14-year-old children- associations with perceived health status: A cross-sectional study. *BMC Public Health*, 16, 33-0. doi:10.1186/s12889-016-3006-0 [doi]
- James, P., Banay, R. F., Hart, J. E., & Laden, F. (2015). A review of the health benefits of greenness. *Current Epidemiology Reports*, 2(2), 131-142. doi:10.1007/s40471-015-0043-7 [doi]
- Jauho, A. M., Pyky, R., Ahola, R., Kangas, M., Virtanen, P., Korpelainen, R., & Jamsa, T. (2015). Effect of wrist-worn activity monitor feedback on physical activity behavior: A randomized controlled trial in Finnish young men. *Preventive Medicine Reports*, 2, 628-634. doi:10.1016/j.pmedr.2015.07.005 [doi]
- Jimoh, F., Lund, E. K., Harvey, L. J., Frost, C., Lay, W. J., Roe, M. A., . . . Finglas, P. M. (2018). Comparing diet and exercise monitoring using smartphone app and paper diary: A two-phase intervention study. *JMIR mHealth and uHealth*, 6(1), e17. doi:10.2196/mhealth.7702 [doi]
- Joliffe, I. T., & Morgan, B. J. (1992). Principal component analysis and exploratory factor analysis. *Statistical Methods in Medical Research*, 1(1), 69-95.
- Jones, A. P., Coombes, E. G., Griffin, S. J., & van Sluijs, E. M. (2009). Environmental supportiveness for physical activity in English schoolchildren: A study using global positioning systems. *The International Journal of Behavioral Nutrition and Physical Activity*, 6, 4-42. doi:10.1186/1479-5868-6-42 [doi]
- Kantomaa, M. T., Tammelin, T. H., Nayha, S., & Taanila, A. M. (2007). Adolescents' physical activity in relation to family income and parents' education. *Preventive Medicine*, 44(5), 410-415. doi:S0091-7435(07)00034-5 [pii]

- Kantomaa, M. T., Tammelin, T., Ebeling, H., Stamatakis, E., & Taanila, A. (2015). High levels of physical activity and cardiorespiratory fitness are associated with good self-rated health in adolescents. *Journal of Physical Activity & Health, 12*(2), 266-272. doi:10.1123/jpah.2013-0062 [doi]
- Karppinen, P., Oinas-Kukkonen, H., Alahaivala, T., Jokelainen, T., Keranen, A. M., Salonurmi, T., & Savolainen, M. (2016). Persuasive user experiences of a health behavior change support system: A 12-month study for prevention of metabolic syndrome. *International Journal of Medical Informatics, 96*, 51-61. doi:S1386-5056(16)30025-9 [pii]
- Kasehagen, L., Busacker, A., Kane, D., & Rohan, A. (2012). Associations between neighborhood characteristics and physical activity among youth within rural-urban commuting areas in the US. *Maternal and Child Health Journal, 16 Suppl 2*, 258-267. doi:10.1007/s10995-012-1188-3 [doi]
- Kaseva, K., Hintsala, T., Lipsanen, J., Pulkki-Raback, L., Hintsanen, M., Yang, X., . . . Tammelin, T. (2017). Parental physical activity associates with offspring's physical activity until middle age: A 30-year study. *Journal of Physical Activity & Health, 14*(7), 520-531. doi:10.1123/jpah.2016-0466 [doi]
- Katzmarzyk, P. T., Church, T. S., Craig, C. L., & Bouchard, C. (2009). Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Medicine and Science in Sports and Exercise, 41*(5), 998-1005. doi:10.1249/MSS.0b013e3181930355 [doi]
- Kelders, S. M., Sommers-Spijkerman, M., & Goldberg, J. (2018). Investigating the direct impact of a gamified versus nongamified well-being intervention: An exploratory experiment. *Journal of Medical Internet Research, 20*(7), e247. doi:10.2196/jmir.9923 [doi]
- Keyes, & C.L.M. (2006). The subjective well-being of America's youth: Toward a comprehensive assessment. *Adolescent & Family Health, 4*(1), 3-11.
- Kilpatrick, M., Hebert, E., & Bartholomew, J. (2005). College students' motivation for physical activity: Differentiating men's and women's motives for sport participation and exercise. *Journal of American College Health: J of ACH, 54*(2), 87-94. doi:10.3200/JACH.54.2.87-94 [doi]
- Kim, K. W., Wallander, J. L., Felt, J. M., Elliott, M. N., & Schuster, M. A. (2019). Associations of parental general monitoring with adolescent weight-related behaviors and weight status. *Obesity (Silver Spring, Md.), 27*(2), 280-287. doi:10.1002/oby.22372 [doi]
- Kim, Y., Umeda, M., Lochbaum, M., & Stegemeier, S. (2016). Physical activity, screen-based sedentary behavior, and sleep duration in adolescents: Youth risk behavior survey, 2011-2013. *Preventing Chronic Disease, 13*, E131. doi:10.5888/pcd13.160245 [doi]
- King, D., Greaves, F., Exeter, C., & Darzi, A. (2013). 'Gamification': Influencing health behaviours with games. *Journal of the Royal Society of Medicine, 106*(3), 76-78. doi:10.1177/0141076813480996 [doi]

- Kinnunen, H., Tanskanen, M., Kyrolainen, H., & Westerterp, K. R. (2012). Wrist-worn accelerometers in assessment of energy expenditure during intensive training. *Physiological Measurement*, *33*(11), 1841-1854. doi:10.1088/0967-3334/33/11/1841 [doi]
- Kleszczewska, D., Szkutnik, A. M., Siedlecka, J., & Mazur, J. (2019). Physical activity, sedentary behaviours and duration of sleep as factors affecting the well-being of young people against the background of environmental moderators. *International Journal of Environmental Research and Public Health*, *16*(6), 10.3390/ijerph16060915. doi:E915 [pii]
- Kohl, L. F., Crutzen, R., & de Vries, N. K. (2013). Online prevention aimed at lifestyle behaviors: A systematic review of reviews. *Journal of Medical Internet Research*, *15*(7), e146. doi:10.2196/jmir.2665 [doi]
- Koivumaa-Honkanen, H., Honkanen, R., Koskenvuo, M., Viinamaki, H., & Kaprio, J. (2002). Life dissatisfaction as a predictor of fatal injury in a 20-year follow-up. *Acta Psychiatrica Scandinavica*, *105*(6), 444-450. doi:10.1080/08038560210000287 [pii]
- Koivumaa-Honkanen, H., Honkanen, R., Viinamaki, H., Heikkila, K., Kaprio, J., & Koskenvuo, M. (2000). Self-reported life satisfaction and 20-year mortality in healthy finnish adults. *American Journal of Epidemiology*, *152*(10), 983-991.
- Koivumaa-Honkanen, H., Honkanen, R., Viinamaki, H., Heikkila, K., Kaprio, J., & Koskenvuo, M. (2001). Life satisfaction and suicide: A 20-year follow-up study. *The American Journal of Psychiatry*, *158*(3), 433-439.
- Koivumaa-Honkanen, H., Tuovinen, T. K., Honkalampi, K., Antikainen, R., Hintikka, J., Haatainen, K., & Viinamaki, H. (2008). Mental health and well-being in a 6-year follow-up of patients with depression: Assessments of patients and clinicians. *Social Psychiatry and Psychiatric Epidemiology*, *43*(9), 688-696. doi:10.1007/s00127-008-0353-x [doi]
- Krist, L., Burger, C., Strobele-Benschop, N., Roll, S., Lotz, F., Rieckmann, N., . . . Muller-Riemenschneider, F. (2017). Association of individual and neighbourhood socioeconomic status with physical activity and screen time in seventh-grade boys and girls in Berlin, Germany: A cross-sectional study. *BMJ Open*, *7*(12), e01797-017974. doi:10.1136/bmjopen-2017-017974 [doi]
- Kujala, U. M. (2011). Physical activity, genes, and lifetime predisposition to chronic disease. *European Review of Aging and Physical Activity*, *8*(1), 31-36. doi:https://doi.org/10.1007/s11556-010-0077-2
- Kumar, B., Robinson, R., & Till, S. (2015). Physical activity and health in adolescence. *Clinical Medicine (London, England)*, *15*(3), 267-272. doi:10.7861/clinmedicine.15-3-267 [doi]
- Larsen, B., Benitez, T., Cano, M., Dunsiger, S. S., Marcus, B. H., Mendoza-Vasconez, A., . . . Zive, M. (2018). Web-based physical activity intervention for Latina adolescents: Feasibility, acceptability, and potential efficacy of the ninas saludables study. *Journal of Medical Internet Research*, *20*(5), e170. doi:10.2196/jmir.9206 [doi]

- Larsson, D., Hemmingsson, T., Allebeck, P., & Lundberg, I. (2002). Self-rated health and mortality among young men: What is the relation and how may it be explained? *Scandinavian Journal of Public Health*, 30(4), 259-266. doi:10.1080/14034940210133997 [doi]
- Lau, P. W. C., Pitkethly, A. J., Leung, B. W. C., Lau, E. Y., & Wang, J. J. (2019). The intervention effect of SMS delivery on Chinese adolescent's physical activity. *International Journal of Environmental Research and Public Health*, 16(5), 10.3390/ijerph16050787. doi:E787 [pii]
- Lau, P. W., Lau, E. Y., Wong del, P., & Ransdell, L. (2011). A systematic review of information and communication technology-based interventions for promoting physical activity behavior change in children and adolescents. *Journal of Medical Internet Research*, 13(3), e48. doi:10.2196/jmir.1533 [doi]
- Lee, C. M., Neighbors, C., Kilmer, J. R., & Larimer, M. E. (2010). A brief, web-based personalized feedback selective intervention for college student marijuana use: A randomized clinical trial. *Psychology of Addictive Behaviors : Journal of the Society of Psychologists in Addictive Behaviors*, 24(2), 265-273. doi:10.1037/a0018859 [doi]
- Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working Group. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet*, 380(9838), 219-229. doi:10.1016/S0140-6736(12)61031-9 [doi]
- Lightfoot, J. T., DE Geus, E J C, Booth, F. W., Bray, M. S., DEN Hoed, M., Kaprio, J., . . . Bouchard, C. (2018). Biological/genetic regulation of physical activity level: Consensus from GenBioPAC. *Medicine and Science in Sports and Exercise*, 50(4), 863-873. doi:10.1249/MSS.0000000000001499 [doi]
- Lim, C. G., Kim, Z. M., & Choi, H. J. (2017). Developing a mobile wellness management system for healthy lifestyle by analyzing daily living activities. *Studies in Health Technology and Informatics*, 245, 146-150.
- Lisinskiene, A., & Juskeliene, V. (2019). Links between adolescents' engagement in physical activity and their attachment to mothers, fathers, and peers. *International Journal of Environmental Research and Public Health*, 16(5), 10.3390/ijerph16050866. doi:E866 [pii]
- Liukkonen, J., Jaakkola, T., Kokko, S., Grasten, A., Yli-Piipari, S., Koski, P., . . . Tammelin, T. (2014). Results from Finland's 2014 report card on physical activity for children and youth. *Journal of Physical Activity & Health*, 11 Suppl 1, 51. doi:10.1123/jpah.2014-0168 [doi]
- Lubans, D. R., Smith, J. J., Skinner, G., & Morgan, P. J. (2014). Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. *Frontiers in Public Health*, 2, 42. doi:10.3389/fpubh.2014.00042 [doi]
- Luoto, T., Korpelainen, R., Röning, J., Ahola, R., Enwald, H., Hirvonen, N., . . . Heikkinen, H. I. (2015). Gamified persuasion: User experiences of online activation service. *International Journal of Sociotechnology and Knowledge Development*, 6(4), 1-17.

- Maher, J. P., Doerksen, S. E., Elavsky, S., & Conroy, D. E. (2014). Daily satisfaction with life is regulated by both physical activity and sedentary behavior. *Journal of Sport & Exercise Psychology, 36*(2), 166-178. doi:10.1123/jsep.2013-0185 [doi]
- Mailey, E. L., Wojcicki, T. R., Motl, R. W., Hu, L., Strauser, D. R., Collins, K. D., & McAuley, E. (2010a). Internet-delivered physical activity intervention for college students with mental health disorders: A randomized pilot trial. *Psychology, Health & Medicine, 15*(6), 646-659. doi:10.1080/13548506.2010.498894 [doi]
- Mailey, E. L., Wojcicki, T. R., Motl, R. W., Hu, L., Strauser, D. R., Collins, K. D., & McAuley, E. (2010b). Internet-delivered physical activity intervention for college students with mental health disorders: A randomized pilot trial. *Psychology, Health & Medicine, 15*(6), 646-659. doi:10.1080/13548506.2010.498894 [doi]
- Martin, S. S., Feldman, D. I., Blumenthal, R. S., Jones, S. R., Post, W. S., McKibben, R. A., . . . Blaha, M. J. (2015). mActive: A randomized clinical trial of an automated mHealth intervention for physical activity promotion. *Journal of the American Heart Association, 4*(11), 10.1161/JAHA.115.002239. doi:10.1161/JAHA.115.002239 [doi]
- Martin-Matillas, M., Ortega, F. B., Chillón, P., Perez, I. J., Ruiz, J. R., Castillo, R., . . . AVENA Study. (2011). Physical activity among Spanish adolescents: Relationship with their relatives' physical activity - the AVENA study. *Journal of Sports Sciences, 29*(4), 329-336. doi:10.1080/02640414.2010.523091 [doi]
- Matthews, J., Win, K. T., Oinas-Kukkonen, H., & Freeman, M. (2016). Persuasive technology in mobile applications promoting physical activity: A systematic review. *Journal of Medical Systems, 40*(3), 7-x. Epub 2016 Jan 9. doi:10.1007/s10916-015-0425-x [doi]
- McCormack, L. A., & Meendering, J. (2016). Diet and physical activity in rural vs urban children and adolescents in the United States: A narrative review. *Journal of the Academy of Nutrition and Dietetics, 116*(3), 467-480. doi:S2212-2672(15)01629-9 [pii]
- McCrorie, P. R., Fenton, C., & Ellaway, A. (2014). Combining GPS, GIS, and accelerometry to explore the physical activity and environment relationship in children and young people - a review. *The International Journal of Behavioral Nutrition and Physical Activity, 11*, 9-0. doi:10.1186/s12966-014-0093-0 [doi]
- McGrath, L. J., Hopkins, W. G., & Hinckson, E. A. (2015). Associations of objectively measured built-environment attributes with youth moderate-vigorous physical activity: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 45*(6), 841-865. doi:10.1007/s40279-015-0301-3 [doi]
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine : A Publication of the Society of Behavioral Medicine, 46*(1), 81-95. doi:10.1007/s12160-013-9486-6 [doi]
- Mielke, G. I., Brown, W. J., Nunes, B. P., Silva, I. C. M., & Hallal, P. C. (2017). Socioeconomic correlates of sedentary behavior in adolescents: Systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.), 47*(1), 61-75. doi:10.1007/s40279-016-0555-4 [doi]

- Mikalsen, H. K., Lagestad, P., Bentzen, M., & Safvenbom, R. (2019). Does eagerness for physical activity matter? The association between eagerness and physical activity among adolescents. *Frontiers in Public Health*, 7, 88. doi:10.3389/fpubh.2019.00088 [doi]
- Ministry of Education. (2008). *Fyysisen aktiivisuuden suositus kouluikäisille. Recommendation for the physical activity of school-aged children*. Helsinki: Retrieved from http://www.ukkinstituutti.fi/filebank/1477-Fyysisen_aktiivisuuden_suositus_kouluikäisille.pdf
- Ministry of Social Affairs and Health. (2015). *Sit less - feel better! National recommendations for reducing sitting*. Ministry of Social Affairs and Health.
- Mo, D., Xiang, M., Luo, M., Dong, Y., Fang, Y., Zhang, S., . . . Liang, H. (2019). Using gamification and social incentives to increase physical activity and related social cognition among undergraduate students in shanghai, china. *International Journal of Environmental Research and Public Health*, 16(5), 10.3390/ijerph16050858. doi:E858 [pii]
- Molina-Garcia, J., Queralt, A., Adams, M. A., Conway, T. L., & Sallis, J. F. (2017). Neighborhood built environment and socio-economic status in relation to multiple health outcomes in adolescents. *Preventive Medicine*, 105, 88-94. doi:S0091-7435(17)30312-2 [pii]
- Moore, J. B., Beets, M. W., Morris, S. F., & Kolbe, M. B. (2014). Comparison of objectively measured physical activity levels of rural, suburban, and urban youth. *American Journal of Preventive Medicine*, 46(3), 289-292. doi:10.1016/j.amepre.2013.11.001 [doi]
- Moore, J. B., Brinkley, J., Crawford, T. W., Evenson, K. R., & Brownson, R. C. (2013). Association of the built environment with physical activity and adiposity in rural and urban youth. *Preventive Medicine*, 56(2), 145-148. doi:10.1016/j.ypmed.2012.11.019 [doi]
- Nelson, M. C., Gordon-Larsen, P., Adair, L. S., & Popkin, B. M. (2005). Adolescent physical activity and sedentary behavior: Patterning and long-term maintenance. *American Journal of Preventive Medicine*, 28(3), 259-266. doi:S0749-3797(04)00342-3 [pii]
- Nguyen, B., Shrewsbury, V. A., O'Connor, J., Steinbeck, K. S., Lee, A., Hill, A. J., . . . Baur, L. A. (2012). Twelve-month outcomes of the loozit randomized controlled trial: A community-based healthy lifestyle program for overweight and obese adolescents. *Archives of Pediatrics & Adolescent Medicine*, 166(2), 170-177. doi:10.1001/archpediatrics.2011.841 [doi]
- Niemelä, M., Ahola, R., Pyky, R., Jauho, A., Tuovinen, L., Siirtola, P., . . . Korpelainen, R. (2016). Self-reported versus measured physical activity and sedentary behavior in young men. *Liikunta & Tiede*, 53(2-3), 73-79.
- Nigg, C. R., Geller, K. S., Motl, R. W., Horwath, C. C., Wertin, K. K., & Dishman, R. K. (2011). A research agenda to examine the efficacy and relevance of the transtheoretical model for physical activity behavior. *Psychology of Sport and Exercise*, 12(1), 7-12. doi:10.1016/j.psychsport.2010.04.004 [doi]
- Nigg, C. R., Rossi, J. S., & Norman, G.J. & Benisovich, S.V. (1998). Structure of decisional balance for exercise adoption. *Annals of behavioral medicine* (pp. 20-211)

- Nikunen, M. (2017). Young people, future hopes and concerns in Finland and the European Union: Classed and gendered expectations in policy documents. *Journal of Youth Studies, 20*(6), 661-676.
- O'Donoghue, G., Kennedy, A., Puggina, A., Aleksovska, K., Buck, C., Burns, C., . . . Boccia, S. (2018). Socio-economic determinants of physical activity across the life course: A "DEterminants of DIet and physical ACTivity" (DEDIPAC) umbrella literature review. *PloS One, 13*(1), e0190737. doi:10.1371/journal.pone.0190737 [doi]
- Parker, K. E., Salmon, J., Brown, H. L., Villanueva, K., & Timperio, A. (2019). Typologies of adolescent activity related health behaviours. *Journal of Science and Medicine in Sport, 22*(3), 319-323. doi:S1440-2440(18)30583-8 [pii]
- Partridge, S. R., McGeechan, K., Bauman, A., Phongsavan, P., & Allman-Farinelli, M. (2017). Improved confidence in performing nutrition and physical activity behaviours mediates behavioural change in young adults: Mediation results of a randomised controlled mHealth intervention. *Appetite, 108*, 425-433. doi:S0195-6663(16)30696-1 [pii]
- Pate, R. R., Mitchell, J. A., Byun, W., & Dowda, M. (2011). Sedentary behaviour in youth. *British Journal of Sports Medicine, 45*(11), 906-913. doi:10.1136/bjsports-2011-090192 [doi]
- Patrick, K., Norman, G. J., Davila, E. P., Calfas, K. J., Raab, F., Gottschalk, M., . . . Covin, J. R. (2013). Outcomes of a 12-month technology-based intervention to promote weight loss in adolescents at risk for type 2 diabetes. *Journal of Diabetes Science and Technology, 7*(3), 759-770.
- Picavet, H. S., Milder, I., Kruize, H., de Vries, S., Hermans, T., & Wendel-Vos, W. (2016). Greener living environment healthier people? Exploring green space, physical activity and health in the doetinchem cohort study. *Preventive Medicine, 89*, 7-14. doi:10.1016/j.ypmed.2016.04.021 [doi]
- Pietilä, M., Neuvonen, M., Borodulin, K., Korpela, K., Sievänen, T., & Tyrväinen, L. (2015). Relationships between exposure to urban green spaces, physical activity and self-rated health. *Journal of Outdoor Recreation and Tourism, 10*, 44-54.
- Povey, R., Conner, M., Sparks, P., James, R., & Shepherd, R. (1999). A critical examination of the application of the transtheoretical model's stages of change to dietary behaviours. *Health Education Research, 14*(5), 641-651.
- Powell, K. E., King, A. C., Buchner, D. M., Campbell, W. W., DiPietro, L., Erickson, K. I., . . . Whitt-Glover, M. C. (2018). The scientific foundation for the physical activity guidelines for Americans, 2nd edition. *Journal of Physical Activity & Health, , 1*-11. doi:10.1123/jpah.2018-0618 [doi]
- Prochaska, J. O., & DiClemente, C. C. (1983). Stages and processes of self-change of smoking: Toward an integrative model of change. *Journal of Consulting and Clinical Psychology, 51*(3), 390-395.
- Proctor, C. L., Linley, A. P., & Maltby, J. (2009). Youth life satisfaction: A review of the literature. *Journal of Happiness Studies, (10)*, 583-630. doi:10.1007/s10902-008-9110-9

- Pyper, E., Harrington, D., & Manson, H. (2016). The impact of different types of parental support behaviours on child physical activity, healthy eating, and screen time: A cross-sectional study. *BMC Public Health*, *16*(1), 56-0. doi:10.1186/s12889-016-3245-0 [doi]
- Raitasalo, R. (2007). *Mood questionnaire. Finnish modification of the short form of the beck depression inventory measuring depression symptoms and self-esteem.* (No. 86). Helsinki, Finland: The Social Insurance Institution. Studies in social security and health.
- Rajala, K., Kankaanpaa, A., Laine, K., Itkonen, H., Goodman, E., & Tammelin, T. (2019). Associations of subjective social status with accelerometer-based physical activity and sedentary time among adolescents. *Journal of Sports Sciences*, *37*(2), 123-130. doi:10.1080/02640414.2018.1485227 [doi]
- Rees, R., Kavanagh, J., Harden, A., Shepherd, J., Brunton, G., Oliver, S., & Oakley, A. (2006). Young people and physical activity: A systematic review matching their views to effective interventions. *Health Education Research*, *21*(6), 806-825. doi:cyl120 [pii]
- Rejeski, W. J., Shelton, B., Miller, M., Dunn, A. L., King, A. C., Sallis, J. F., & Activity Counseling Trial Research Group. (2001). Mediators of increased physical activity and change in subjective well-being: Results from the activity counseling trial (ACT). *Journal of Health Psychology*, *6*(2), 159-168. doi:10.1177/135910530100600206 [doi]
- Riiser, K., Londal, K., Ommundsen, Y., Smastuen, M. C., Misvaer, N., & Helseth, S. (2014). The outcomes of a 12-week internet intervention aimed at improving fitness and health-related quality of life in overweight adolescents: The young & active controlled trial. *PloS One*, *9*(12), e114732. doi:10.1371/journal.pone.0114732 [doi]
- Ritterband, L. M., Thorndike, F. P., Cox, D. J., Kovatchev, B. P., & Gonder-Frederick, L. A. (2009). A behavior change model for internet interventions. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *38*(1), 18-27. doi:10.1007/s12160-009-9133-4 [doi]
- Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., . . . Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: A cross-sectional study. *Lancet (London, England)*, *387*(10034), 2207-2217. doi:10.1016/S0140-6736(15)01284-2 [doi]
- Sampasa-Kanyinga, H., Hamilton, H. A., Willmore, J., & Chaput, J. P. (2017). Perceptions and attitudes about body weight and adherence to the physical activity recommendation among adolescents: The moderating role of body mass index. *Public Health*, *146*, 75-83. doi:S0033-3506(17)30002-1 [pii]
- Santos, R., Mota, J., Okely, A. D., Pratt, M., Moreira, C., Coelho-e-Silva, M. J., . . . Sardinha, L. B. (2014). The independent associations of sedentary behaviour and physical activity on cardiorespiratory fitness. *British Journal of Sports Medicine*, *48*(20), 1508-1512. doi:10.1136/bjsports-2012-091610 [doi]
- Schoeppe, S., Liersch, S., Robl, M., Krauth, C., & Walter, U. (2016). Mothers and fathers both matter: The positive influence of parental physical activity modelling on children's leisure-time physical activity. *Pediatric Exercise Science*, *28*(3), 466-472. doi:10.1123/pes.2015-0236 [doi]

- Schoeppe, S., Alley, S., Van Lippevelde, W., Bray, N. A., Williams, S. L., Duncan, M. J., & Vandelandotte, C. (2016). Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: A systematic review. *The International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 12-y. doi:10.1186/s12966-016-0454-y [doi]
- Seko, Y., Kidd, S., Wiljer, D., & McKenzie, K. (2014). Youth mental health interventions via mobile phones: A scoping review. *Cyberpsychology, Behavior and Social Networking*, *17*(9), 591-602. doi:10.1089/cyber.2014.0078 [doi]
- Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine*, *37*(3), 19-206; discussion 206.
- Skov-Ettrup, L. S., Petersen, C. B., Curtis, T., Lykke, M., Christensen, A. I., & Tolstrup, J. S. (2014). Why do people exercise? A cross-sectional study of motives to exercise among Danish adults. *Public Health*, *128*(5), 482-484. doi:10.1016/j.puhe.2014.02.005 [doi]
- Sleddens, E. F., Kremers, S. P., Hughes, S. O., Cross, M. B., Thijs, C., De Vries, N. K., & O'Connor, T. M. (2012). Physical activity parenting: A systematic review of questionnaires and their associations with child activity levels. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *13*(11), 1015-1033. doi:10.1111/j.1467-789X.2012.01018.x [doi]
- Sloan, R. A., Kim, Y., Sahasranaman, A., Muller-Riemenschneider, F., Biddle, S. J. H., & Finkelstein, E. A. (2018). The influence of a consumer-wearable activity tracker on sedentary time and prolonged sedentary bouts: Secondary analysis of a randomized controlled trial. *BMC Research Notes*, *11*(1), 18-9. doi:10.1186/s13104-018-3306-9 [doi]
- Slootmaker, S. M., Chinapaw, M. J., Seidell, J. C., van Mechelen, W., & Schuit, A. J. (2010). Accelerometers and internet for physical activity promotion in youth? Feasibility and effectiveness of a minimal intervention [ISRCTN93896459]. *Preventive Medicine*, *51*(1), 31-36. doi:10.1016/j.ypmed.2010.03.015 [doi]
- Springer, A. E., Hoelscher, D. M., Castrucci, B., Perez, A., & Kelder, S. H. (2009). Prevalence of physical activity and sedentary behaviors by metropolitan status in 4th-, 8th-, and 11th-grade students in Texas, 2004-2005. *Preventing Chronic Disease*, *6*(1), A21. doi:A21 [pii]
- Statistics Finland. (2016). Official statistics of Finland. The use of information and communication technologies among population. Retrieved from http://www.stat.fi/til/sutivi/2016/sutivi_2016_2016-12-09_tau_015_fi.html
- Statistics Finland. (2017a). Finnish official statistics. Use of information and communication technologies in the population. Use of internet with mobile devices. Retrieved from http://www.stat.fi/til/sutivi/2017/13/sutivi_2017_13_2017-11-22_kat_002_fi.html
- Statistics Finland. (2017b). Finnish official statistics. Work force survey. Employment and unemployment. Retrieved from http://www.stat.fi/til/tyti/2017/13/tyti_2017_13_2018-04-12_kat_004_fi.html

- Stierlin, A. S., De Lepeleere, S., Cardon, G., Dargent-Molina, P., Hoffmann, B., Murphy, M. H., . . . DEDIPAC consortium. (2015). A systematic review of determinants of sedentary behaviour in youth: A DEDIPAC-study. *The International Journal of Behavioral Nutrition and Physical Activity*, *12*, 13-4. doi:10.1186/s12966-015-0291-4 [doi]
- Stubbe, J. H., Boomsma, D. I., Vink, J. M., Cornes, B. K., Martin, N. G., Skytthe, A., . . . de Geus, E. J. (2006). Genetic influences on exercise participation in 37,051 twin pairs from seven countries. *PloS One*, *1*, e22. doi:10.1371/journal.pone.0000022 [doi]
- Suchert, V., Hanewinkel, R., & Isensee, B. (2015). Sedentary behavior and indicators of mental health in school-aged children and adolescents: A systematic review. *Preventive Medicine*, *76*, 48-57. doi:10.1016/j.ypmed.2015.03.026 [doi]
- Swaminathan, S., Thomas, T., Yusuf, S., & Vaz, M. (2013). Clustering of diet, physical activity and overweight in parents and offspring in south India. *European Journal of Clinical Nutrition*, *67*(2), 128-134. doi:10.1038/ejcn.2012.192 [doi]
- Tabak, M., Dekker-van Weering, M., van Dijk, H., & Vollenbroek-Hutten, M. (2015). Promoting daily physical activity by means of mobile gaming: A review of the state of the art. *Games for Health Journal*, *4*(6), 460-469. doi:10.1089/g4h.2015.0010 [doi]
- Tambalis, K. D., Panagiotakos, D. B., Psarra, G., & Sidossis, L. S. (2019). Concomitant associations between lifestyle characteristics and physical activity status in children and adolescents. *Journal of Research in Health Sciences*, *19*(1), e00439.
- Tammelin, T., & Karvinen, J. (Eds.). (2008). *Recommendation for the physical activity of school-aged children*. Helsinki: Ministry of Education and Culture & Nuori Suomi ry.
- Telama, R., Yang, X., Leskinen, E., Kankaanpaa, A., Hirvensalo, M., Tammelin, T., . . . Raitakari, O. T. (2014). Tracking of physical activity from early childhood through youth into adulthood. *Medicine and Science in Sports and Exercise*, *46*(5), 955-962. doi:10.1249/MSS.0000000000000181 [doi]
- Tercyak, K. P., Abraham, A. A., Graham, A. L., Wilson, L. D., & Walker, L. R. (2009). Association of multiple behavioral risk factors with adolescents' willingness to engage in eHealth promotion. *Journal of Pediatric Psychology*, *34*(5), 457-469. doi:10.1093/jpepsy/jsn085 [doi]
- The Finnish Environment Institute. (2012). Maanpeitteen seuranta. Retrieved from http://www.syke.fi/fi-FI/Avoim_tieto/Seurantatiedot/Maanpeitteen_seuranta
- Thomson, R., Brinkworth, G. D., Buckley, J. D., Noakes, M., & Clifton, P. M. (2007). Good agreement between bioelectrical impedance and dual-energy X-ray absorptiometry for estimating changes in body composition during weight loss in overweight young women. *Clinical Nutrition (Edinburgh, Scotland)*, *26*(6), 771-777. doi:S0261-5614(07)00132-X [pii]
- Tong, H. L., Coiera, E., Tong, W., Wang, Y., Quiroz, J. C., Martin, P., & Laranjo, L. (2019). Efficacy of a mobile social networking intervention in promoting physical activity: Quasi-experimental study. *JMIR mHealth and uHealth*, *7*(3), e12181. doi:10.2196/12181 [doi]

- Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., . . . SBRN Terminology Consensus Project Participants. (2017). Sedentary behavior research network (SBRN) - terminology consensus project process and outcome. *The International Journal of Behavioral Nutrition and Physical Activity*, 14(1), 7-8. doi:10.1186/s12966-017-0525-8 [doi]
- Tremblay, M. S., Carson, V., & Chaput, J. P. (2016). Introduction to the Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition Et Metabolisme*, 41(6 Suppl 3), iii-iv. doi:10.1139/apnm-2016-0203 [doi]
- Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., . . . Connor Gorber, S. (2011). Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *The International Journal of Behavioral Nutrition and Physical Activity*, 8, 9-98. doi:10.1186/1479-5868-8-98 [doi]
- Tuovinen, L., Ahola, R., Kangas, M., Korpelainen, R., Siirtola, P., Luoto, T., . . . Jämsä, T. Software design principles for digital behavior change interventions - lessons learned from the MOPO study. In Proceedings of the 9th International Joint Conference on Biomedical Engineering Systems and Technologies – Volume 5: HEALTHINF, pp. 175-182. doi:10.5220/0005656101750182
- Turner, T., Spruijt-Metz, D., Wen, C. K., & Hingle, M. D. (2015). Prevention and treatment of pediatric obesity using mobile and wireless technologies: A systematic review. *Pediatric Obesity*, 10(6), 403-409. doi:10.1111/ijpo.12002 [doi]
- Tuuva-Hongisto S, Pöysä V, Armila P. (2016). *Young people in remote villages - forgotten residents?* (No. 99). Keuruu, Finland: The Foundation for Municipal Development. Retrieved from [http://kaks.fi/wp-content/uploads/2016/10/Syrj%C3%A4kylien-
nuoret-unohdetut-kuntalaiset.pdf](http://kaks.fi/wp-content/uploads/2016/10/Syrj%C3%A4kylien-nuoret-unohdetut-kuntalaiset.pdf)
- Uijtendewilligen, L., Nauta, J., Singh, A. S., van Mechelen, W., Twisk, J. W., van der Horst, K., & Chinapaw, M. J. (2011). Determinants of physical activity and sedentary behaviour in young people: A review and quality synthesis of prospective studies. *British Journal of Sports Medicine*, 45(11), 896-905. doi:10.1136/bjsports-2011-090197 [doi]
- Väinämö, K., Nissilä, S., Mäkikallio, T., Tulppo, M., & Röning, J. Artificial neural networks for aerobic fitness approximation. Paper presented at the *Proceedings of International Conference on Neural Networks (ICNN)*, Washington DC. 1939-1949.
- Vella, S. A., Gardner, L. A., Swann, C., & Allen, M. S. (2019). Trajectories and predictors of risk for mental health problems throughout childhood. *Child and Adolescent Mental Health*, 24(2), 142-148. doi:10.1111/camh.12279
- Velten, J., Bieda, A., Scholten, S., Wannemuller, A., & Margraf, J. (2018). Lifestyle choices and mental health: A longitudinal survey with German and Chinese students. *BMC Public Health*, 18(1), 63-2. doi:10.1186/s12889-018-5526-2 [doi]
- Wang, C. K. J., Biddle, S. J. H., Liu, W. C., & Lim, B. S. C. (2012). A latent profile analysis of sedentary and physical activity patterns. *Journal of Public Health (Germany)*, 20(4), 367-373. doi:10.1007/s10389-011-0464-9

- Wanner, M., Martin-Diener, E., Braun-Fahrlander, C., Bauer, G., & Martin, B. W. (2009). Effectiveness of active-online, an individually tailored physical activity intervention, in a real-life setting: Randomized controlled trial. *Journal of Medical Internet Research*, *11*(3), e23. doi:10.2196/jmir.1179 [doi]
- Webb, T. L., Joseph, J., Yardley, L., & Michie, S. (2010). Using the internet to promote health behavior change: A systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *Journal of Medical Internet Research*, *12*(1), e4. doi:10.2196/jmir.1376 [doi]
- Wells, L., Nermo, M., & Ostberg, V. (2017). Physical inactivity from adolescence to young adulthood: The relevance of various dimensions of inequality in a swedish longitudinal sample. *Health Education & Behavior: The Official Publication of the Society for Public Health Education*, *44*(3), 376-384. doi:10.1177/1090198116672040 [doi]
- Wennman, H., Kronholm, E., Partonen, T., Tolvanen, A., Peltonen, M., Vasankari, T., & Borodulin, K. (2014). Physical activity and sleep profiles in Finnish men and women. *BMC Public Health*, *14*, 8-82. doi:10.1186/1471-2458-14-82 [doi]
- Wennman, H., Pietilä, A., Rissanen, H., Valkeinen, H., Partonen, T., Mäki-Opas, T., & Borodulin, K. (2019). Gender, age and socioeconomic variation in 24-hour physical activity by wrist-worn accelerometers: The FinHealth 2017 survey. *Scientific Reports*, *9*(1), 6534. doi:10.1038/s41598-019-43007-x
- Wijmsman, C. A., Westendorp, R. G., Verhagen, E. A., Catt, M., Slagboom, P. E., de Craen, A. J., . . . Mooijaart, S. P. (2013). Effects of a web-based intervention on physical activity and metabolism in older adults: Randomized controlled trial. *Journal of Medical Internet Research*, *15*(11), e233. doi:10.2196/jmir.2843 [doi]
- Woods, C., Mutrie, N., & Scott, M. (2002). Physical activity intervention: A transtheoretical model-based intervention designed to help sedentary young adults become active. *Health Education Research*, *17*(4), 451-460.
- World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland: WHO Press. Retrieved from http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf?ua=1.
- Wozney, L., Huguet, A., Bennett, K., Radomski, A. D., Hartling, L., Dyson, M., . . . Newton, A. S. (2017). How do eHealth programs for adolescents with depression work? A realist review of persuasive system design components in internet-based psychological therapies. *Journal of Medical Internet Research*, *19*(8), e266. doi:10.2196/jmir.7573 [doi]
- Yang, C. H., Maher, J. P., & Conroy, D. E. (2015). Implementation of behavior change techniques in mobile applications for physical activity. *American Journal of Preventive Medicine*, *48*(4), 452-455. doi:10.1016/j.amepre.2014.10.010 [doi]
- Yoon, H. J., Lee, S. A., Ju, Y. J., Nam, J. Y., & Park, E. C. (2018). The relationship between physical activity level of parents and that of their adolescent children. *Journal of Physical Activity & Health*, *15*(8), 613-619. doi:10.1123/jpah.2017-0123 [doi]

- Young, D. R., Sidell, M. A., Koebnick, C., Saksvig, B. I., Mohan, Y., Cohen, D. A., & Wu, T. T. (2019). Longitudinal sedentary time among females aged 17 to 23 years. *American Journal of Preventive Medicine*, *56*(4), 540-547. doi://doi.org/10.1016/j.amepre.2018.11.021
- Zach S., Raviv T., Meckel, Y. (2016). Using information communication technologies (ICTs) for motivating female adolescents to exercise/run in their leisure time. *Computers in Human Behavior*, *60*, 593-601.

Original publications

- I Pyky R, Jauho AM, Ahola R, Ikäheimo TM, Koivumaa-Honkanen H, Mäntysaari M, Jämsä T, Korpelainen R. Profiles of sedentary and non-sedentary young men – A population-based MOPO study. *BMC Public Health* (2015) 15:1164.
- II Pyky R, Puhakka S, Ikäheimo TM, Lankila T, Kangas M, Mäntysaari M, Jämsä T, Korpelainen R. Parental factors related to PA among adolescent men living in built and natural environment – a population-based MOPO study. 2018. (manuscript submitted to *BMC Public Health*)
- III Leinonen AM, Pyky R, Ahola R, Kangas M, Siirtola P, Luoto T, Enwald H, Ikäheimo TM, Röning J, Keinänen-Kiukaanniemi S, Mäntysaari M, Korpelainen R, Jämsä T: Feasibility of Gamified Mobile Service Aimed at Physical Activation in Young Men: Population-Based Randomized Controlled Study (MOPO) *JMIR Mhealth Uhealth* 2017;5(10):e146. DOI: 10.2196/mhealth.6675.
- IV Pyky R, Koivumaa-Honkanen H, Jauho AM, Ahola R, Hirvonen N, Enwald H, Luoto T, Ferreira E, Ikäheimo TM, Keinänen-Kiukaanniemi S, Mäntysaari M, Jämsä T, Korpelainen R. Effect of tailored, gamified, mobile PA intervention on life satisfaction and self-rated health in young adolescent men: A population-based, randomized controlled trial (MOPO study). *Computers in Human Behavior* 2017, 72: 13–22. DOI: 10.1016/j.chb.2017.02.032.

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