Sleeping Behavior and Physical Health of Icelandic Adolescents

Vaka Rögnvaldsdóttir

Dissertation submitted in partial fulfilment of a Ph.D.-degree

UNIVERSITY OF ICELAND
SCHOOL OF EDUCATION

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Abstract

Background

Sleep and physical activity are essential functions of human health. According to International recommendations, adolescents should sleep 8-10 hours each night and engage in moderate to vigorous physical activity for at least 60 minutes per day for overall wellbeing. Previous studies have shown that during adolescence, sleep patterns change and most sleep studies up to date are based on subjective data for sleep duration and quality. Technological advancement in measurement of sleep and physical activity with objective measures adds value to the literature.

Aim

The main aim of the dissertation was to measure free-living sleep and physical activity in Icelandic youth at baseline (15 years) and two years later (17 years), and explore associations between sleep (duration, quality and timing), physical activity, and body composition. In addition, to compare sensitivity and agreement between subjective and objective measurements of sleep among and between ages of 15 and 17 years old.

Methods

The study sample came from six elementary schools in Reykjavík. Data was collected during spring 2015 among 315 participants at age 15. In 2017, follow-up data was gathered from 168 repeating participants at age 17. Data from one week of free-living sleep and physical activity was collected with accelerometers. Participants filled out a sleep diary to support accelerometer data and filled out a comprehensive questionnaire on sports participation, physical activity, mental health and parental education, etc. All measurements took place at the research lab (2017) or at individual schools (2015). Body composition was assessed at The Icelandic Heart Association with dual energy X-ray absorptiometry (DXA).

Results

The majority of adolescents did not get the recommended 8-10 hours of sleep per night according to accelerometer data. This especially applied during the school week (7 hours/night in bed, 6.2 hours/night actual sleeping, about 11% met the recommendation). In comparison, subjective self-reports estimated bedtimes about 1 hour earlier and two-year changes in self-reported bedtimes did not correlate with changes measured by accelerometry. While there was no association between recommended levels of physical activity and sleep measures, higher physical activity and lower day-to-day sleep variability were associated with lower fat percentage.

Conclusions

The thesis highlights patterns of sleep and physical activity in Icelandic youth, as they transitioned from age fifteen to seventeen. These are two modifiable behaviors of great importance for health. Most adolescents did not get enough sleep during school nights. This, together with insufficient physical activity, could negatively impact their future health. This study provides the foundation for future follow-up studies and potential targets for intervention studies, while serving as a reference for public health specialists, educators, and parents to support good sleep and activity practices.

Ágrip

Svefn, hreyfing og heilsa íslenskra ungmenna

Bakgrunnur

Svefn og hreyfing eru grundvallarþættir í heilsu mannsins. Alþjóðlegar svefn ráðleggingar fyrir ungmenni gera ráð fyrir 8-10 klukkustunda nætursvefni og að minnsta kosti 60 mínútna daglegri hreyfingu af miðlungs- eða mikilli ákefð til að viðhalda góðri heilsu. Á unglingsárum verða miklar breytingar á svefnmynstri einstaklinga en fyrri rannsóknir á svefni ungmenna hafa flestar byggt á huglægu mati á svefnlengd og gæðum svefnsins. Hlutlægar mælingar á svefni og hreyfingu bæta við þekkingu en fáar rannsóknir hafa beitt hlutlægum mælingum til skoðunar á þessum þáttum samtímis.

Markmið

Aðalmarkmið rannsóknarinnar var að mæla svefn og hreyfingu íslenskra ungmenna, við 15 ára aldur og aftur tveimur árum síðar (17 ára), í sínu náttúrulega umhverfi með hreyfimælum og rannsaka tengsl svefns (lengdar, gæða og tímasetningar) og hreyfingar við holdafar og efnaskiptaþætti. Að auki var næmni huglægra og hlutlægra mælinga á breytingum á svefni milli 15 og 17 ára aldurs borin saman.

Aðferðir

Úrtak rannsóknarinnar kom úr sex grunnskólum í Reykjavík. Gögnum var safnað á vormánuðum 2015 meðal 315 þátttakenda sem þá voru 15 ára. Árið 2017 var framkvæmd framhaldsrannsókn og gögn fengust frá 168 þátttakendum, þá 17 ára gömlum. Gögnum um svefn og hreyfingu var safnað með hröðunarmælum í eina viku. Þátttakendur fylltu út svefndagbók til hliðsjónar svefnmælingum og svöruðu spurningalista um íþróttaiðkun, hreyfingu, líðan, félagslega stöðu o.fl. Mælingar fóru allar fram á rannsóknarstofu (2017) eða í skólum þátttakenda (2015). Líkamssamsetning, mæld með tvíorku röntgengeisla-gleypnimælingu (dual energy X-ray absorptiometry, DXA) fór fram í Hjartavernd.

Niðurstöður

Fæst ungmennanna náðu að uppfylla ráðleggingar um a.m.k. 8 klukkustunda nætursvefn þegar svefn var mældur með hröðunarmælum. Þetta átti sérstaklega við á skóladögum (7 klst/nótt liggjandi í rúmi, 6,2 klst/nótt svefn, um 11% ná ráðleggingum). Huglægar mælingar tímasetningu á háttatíma

voru um klukkustund fyrr en tímasetning metin með hröðunarmælum. Ekki fundust tengsl á milli huglægra og hlutlægra mælinga á breytingum á háttatíma frá aldrinum 15-17 ára. Þeir sem uppfylltu ráðleggingar um daglega hreyfingu sváfu ekki mælanlega lengur. Aukin hreyfing og minni breytileiki á svefnlengd tengdust lægri fituprósentu og kviðfituprósentu.

Samantekt

Samspil hreyfingar, svefns og holdafars var skoðað í úrtaki íslenskra ungmenna 15 og 17 ára. Niðurstöður rannsóknarinnar benda til þess að lífsstíll ungmennanna virðist ekki endurspegla viðmið opinberra aðila um daglega hreyfingu og svefn. Skoða þarf þá þætti sem hafa áhrif á svefnvenjur og þátttöku í daglegri hreyfingu svo bæta megi heilsu íslenskra ungmenna, en niðurstöður rannsóknarinnar nýtast sem þekkingargrunnur á stöðu svefns meðal ungmenna og grunnur fyrir íhlutunarrannsóknir sem hafa það markmið að bæta svefn og auka hreyfingu.

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List of Papers

This thesis is based on the following papers:

Paper I

Sleep deficiency on school days in Icelandic youth, as assessed by wrist accelerometry. Rognvaldsdottir V, Gudmundsdottir SL, Brychta RJ, Hrafnkelsdottir SM, Gestsdottir S, Arngrimsson SA, Chen KY, Johannsson E. Sleep Medicine. 2017 May; 33:103-108.

Paper II

Longitudinal change in adolescent bedtimes measured by self-report and actigraphy. Brychta RJ, Rognvaldsdottir V, Guðmundsdottir SL, Stefánsdottir R, Hrafnkelsdottir SM, Gestsdottir S, Arngrimsson SA, Chen KY, Johannsson E. Journal for the Measurement of Physical Behavior. 2019 Dec;2(4):282-287.

Paper III

Physical activity and sleep duration of Icelandic adolescents. Rognvaldsdottir V, Valdimarsdottir BM, Brychta RJ, Hrafnkelsdottir SM, Arngrimsson SA, Johannsson E, Chen KY, Gudmundsdottir SL. Læknabladid. 2018 Feb;104(2):79-85.

Paper IV

Less physical activity and more varied and disrupted sleep is associated with a less favorable metabolic profile in adolescents. Rognvaldsdottir V, Brychta RJ, Hrafnkelsdottir SM, Chen KY, Arngrimsson SA. Johannsson E, Gudmundsdottir SL. Plos One, under revision.

The contribution of the PhD student in writing the papers was accordingly:

Data collection in 2015 and 2017, the student was responsible for measuring, collecting and analyzing all actigraphy data. The student participated in organizing the research and collecting questionnaire data, as well as lining up the database.

Paper I – Collect and analyze the data, write the manuscript and manage reviews from co-authors.

Paper II – Collect the data, participate in reviewing the manuscript.

Paper III Collect and analyze the data, write the manuscript and manage reviews from co-authors.

Paper IV – Collect and analyze the data, write the manuscript and manage reviews from co-authors.

List of Abbreviations

ADHD	Attention-deficit hyperactivity disorder
BMI	Body mass index
DXA	Dual energy X-ray absorptiometry
DSP	Delayed sleep phase
EYHS	Lifestyles of 9 and 15 year old Icelandic Children
GMT	Greenwich Mean Time
HHUI	Health behavior of Icelandic adolescents
MVPA	Moderate to vigorous-intensity physical activity
NREM	Non-REM
NSchD	Non-school days
NSF	National Sleep Foundation
PA	Physical activity
PSG	Polysomnography
REM	Rapid eye movement
SchD	School days
SD	Standard deviation
SAD	Seasonal affective disorder
WASO	Wakening after sleep onset
WC	Waist circumference
WHO	World Health Organization

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1 Introduction

Sleep is a fundamental behavior for most species and an important factor in health and daily functioning for humans of all ages (Mignot, 2008). The quality and quantity of sleep interact with nutrition consumption (Beebe et al., 2013; Chapman et al., 2012; Chaput, 2014; Chaput & St-Onge, 2014; Spaeth et al., 2013; A. Weiss et al., 2010), physical (Megdal, 2007), mental, and social environment wellbeing (Eaton et al., 2010; National Sleep Foundation, 2006). Insufficient sleep and/or poor sleep has been linked to a variety of serious health issues, such as mortality, metabolic disorders including obesity and diabetes, and cardiovascular diseases (Matthews et al., 2012).

Sleep is a complex state of being and new dimensions of sleep are constantly being discovered (Kryger et al., 2011). The understanding of sleep has progressed in the past century as a result of active brain research and advances in measurement technology. Technological advances have paved the way for both non-invasive and free-living sleep measurements, in addition to laboratory-based studies for assessing sleep staging and architecture. The general parameters used to describe human sleep patterns are duration, quality, and timing (National Sleep Foundation, 2017; Ohayon et al., 2017).

Sleep and physical activity are important behavioral factors in the human circadian rhythm over 24 hours, and it is believed that these behavior patterns can stimulate one another bidirectionally (Kline, 2014). However, the value of both parts yields the most health benefit (Dolezal et al., 2017). Physical activity has been associated with both physical (Myers et al., 2019) and mental health (Bell et al., 2019). Ancient physicians, such as Hippocrates (460-370 BC), prescribed exercise to promote health and cure disease. In the modern society, physical activity (PA) is believed to play a large role in promoting health and preventing disease through its metabolic effects on the human body.

Adolescence is an important development stage for physical maturation and brain development (Tarokh et al., 2016). For overall health benefits, recommendations suggest adolescents should have an 8-10 hour nightly sleep opportunity (Max Hirshkowitz et al., 2015) and a regular sleep timing routine (Gruber et al., 2014). Since previous studies on sleep in Icelandic adolescents were based on self-reported data, further studies with objective measurements will add value to earlier literature.

Previous knowledge about Icelandic adolescents' sleep patterns has mainly been based on a 2002 publication reporting later bedtimes and a shorter sleep duration compared with European peers (Thorleifsdottir et al., 2002); the study is rather dated, however and was performed before smartphone usage became common among adolescents. Yet, lack of research on sleep in adolescents in the most recent years, makes Thorleifsdottir, et al. a reference point in this current study, despite differences in sampling of this previous study compared with the current one.

During the past decade, research has focused on investigating exercise and nutrition as potential factors influencing the health of Icelandic children and adolescents, but scant attention has been paid to sleep and sleep behavior. In this study, wrist-worn actigraphy monitoring devices were used to measure free-living 24-hour movement patterns and sleep in adolescents. The interactions between sleep, PA, body composition, and metabolic factors were explored as these adolescents transitioned from the final year of compulsory school to high school, which can lead to important changes in their health.

2 Sleep, physical activity and metabolic health

2.1 Sleep regulation and biology

Theories about sleep have slowly evolved since the late nineteenth century. Earlier, sleep was thought to be a passive state of existence (Kryger et al., 2011). It was not until the late 20th century, through the work of J. Allan Hobson (1989), that sleep was understood as an active process. Hobson (1989) wrote in the opening sentence of his book, *Sleep*, that, "[m]ore has been learned about sleep in the past 60 years than in the preceding 6000." He continued by saying that, "[I]n this short period of time, researchers have discovered that sleep is a dynamic behavior. Not simply the absence of waking, sleep is a special activity of the brain, controlled by elaborate and precise mechanisms" (Hobson, 1989).

Chronobiology, the study of day-night-related rhythms of biological phenomena, is an important part of sleep research. The human circadian rhythm is based on a roughly 24-hour period, regulated by the body's internal clock and external stimuli such as the natural daily circle of brightness and darkness driven by day and night (Foster & Kreitzman, 2014). The internal clock stimulates hormonal secretions for signaling both wakefulness and sleep. As the sun rises, the body releases cortisol, a hormone that naturally wakes the body, melatonin production peaks as the evening comes, signaling the body that it is time for sleep through drowsiness or sleepiness (Klein & Moore, 1979). The two-process model, first introduces by Borbély and colleagues in 1982 (Borbely, 1982) explains the two biological mechanics that work together to regulate the sleep-wake cycle; circadian rhythm and sleep-wake homeostasis. The most important factors to the function of this balance are the input from light (through retinas/zeitgebers); the oscillation in the suprachiasmatic nucleus involving a series of clock genes interacting in a complex loop of transcription/translation (Lowrey & Takahashi, 2004) and the output of melatonin synthesis, thermoregulation, etc. (Wirz-Justice, 2007). Sleep timing, duration and quality of sleep and wakefulness are regulated by the two process model (Borbely, 1982; Borbely et al., 2016; Daan et al., 1984) with increased sleep pressure after a long period of wakefulness and diminishing sleep pressure after a restoring period of sleep (Borbely & Achermann, 1999). Echoing the cyclic environmental changes in light and dark, the circadian clock influences core body temperature and hormonal secretions along with the homeostatic balance of nutritional intake and energy expenditure. This synchronization regulates the daily rhythms in tissue functions, such as the timing of nutrient absorption, mobilization, circulation, and metabolic waste removal (Plano et al., 2017). Therefore, it is important for the homeostasis of bodily functions to be in rhythm with both daylight and darkness. The cycle of cortisol and melatonin production and secretion concurring with daylight and darkness is shown in Figure 1.

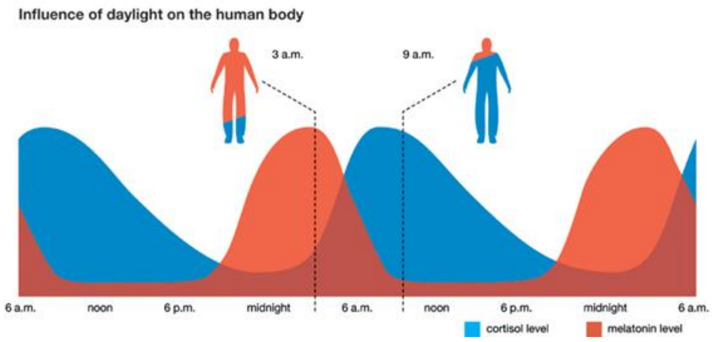


Figure 1. Influence of daylight on the human secretion of cortisol and melatonin

Figure by licht.wissen 19. (Licht.de).

Since 1968, Iceland has been in the Greenwich Mean Time (GMT) time zone all-year round, even though Iceland is farther west than London (Figure 2). Consequently, noon in Reykjavík is delayed by 1.5-hours, or at 13:30 London time. Morning light from the sunrise is vital in synchronizing information for the internal clock and bodily functions (Duffy & Czeisler, 2009).

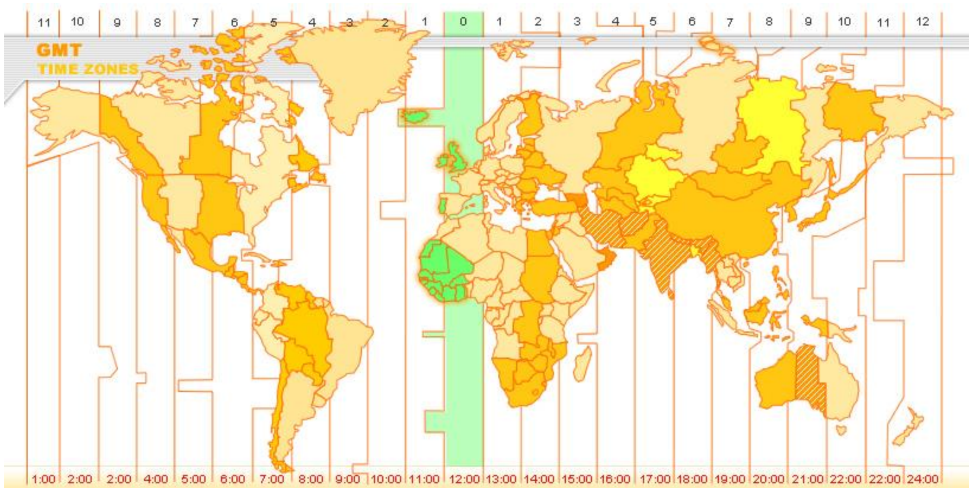


Figure 2. Map of time zone - Reykjavík Iceland
Map by Woldtravelserver (Worldtravelserver).

In Iceland, the sun rises early in spring and summer and late during the winter months of November-March. In countries geographically far from the equator, the biological clock may become desynchronized during the short days of the dark season, characterized by fatigue, sadness, depressive moods, and sleep problems (Friborg et al., 2012; Friborg et al., 2014; Kuller, 2002). Seasonal affective disorder (SAD), first recognized by Rosenthal et al. in 1984, is a recurrent depression that occurs at the same time each year. SAD symptoms have been recognized as excessive sleepiness, overeating, carbohydrate craving and seems primarily caused by lack of light in winter (Rosenthal et al., 1984).

Lack of daylight has been associated with later bedtimes and rising times, increased problems falling asleep, daytime fatigue, and depressive moods. Thus, the geographic location of Iceland, far from the equator, is believed to cause greater misalignment in sleep timing because of delayed daylight over the winter months, known as clock fatigue (Heilbrigðisráðuneyti, 2018). Furthermore, studies on geographical location have shown that people living in the western part of a time zone have both later bedtimes and shorter sleep durations than people in the eastern area of a time zone (Giuntella & Mazzonna, 2019; Roenneberg et al., 2007).

In modern society, scheduled factors like school, work, or the social calendar greatly influence and organize the sleep-wake cycle (Roenneberg et al., 2012; Wittmann et al., 2006). The term social jetlag is used when there is a misalignment between a person’s social schedule and circadian clock (Barnes & Drake, 2015; Wittmann et al., 2006), causing a shift in the timing of the midpoint of sleep between workdays and free-days (Roenneberg et al., 2012). The misalignment between sleep timing and circadian rhythm not only makes us feel unfocused and sleepy at inconvenient times, it is also associated with a wide range of interrelated pathologies, such as reduced mental and physical response time, reduced motivation, depression, insomnia, metabolic abnormalities, obesity, and mental diseases (Wulff et al., 2010). Results from a recent study on Russian children and adolescents compared a period (2011-2014) where daylight saving time was practiced to no daylight savings time (years before and after) and found the greatest disassociation between the social and biological clock in children and adolescents (10-17 years old) living in the Arctic city of Vorkuta (Borisenkov et al., 2017). This social clock manipulation had a strong impact on social jetlag, later rising times on non-school days, and SAD among children and adolescents. Previously, it was shown that the human circadian system is entrained by the solar clock but not social clock (Roenneberg et al., 2007) and children and adolescents’ circadian system is highly sensitive to light signals (Crowley et al., 2015). In a recent review, Ronneberg et al. 2019, suggest that official time zones (official social clock), should be in the region of the geographic time zones marked by the actual sun-c*lock, as studies have shown desynchronization between the biological clock and* the social clock with outcomes such as social jetlag (Roenneberg et al., 2019). A study on evening daylight (longer days) found that activity increased slightly with longer evening daylight (Goodman et al., 2014). Increased springtime activity has been found in countries near the Arctic. A seasonal effect on PA was found among Norwegian adolescents where both weather and day length in spring was associated with increased odds of meeting the PA recommendations as compared to winter months (Kolle et al., 2009). Similarly, seasons with higher rain, winds, and snow and lower temperatures result in lower PA (Rich et al., 2012).

It has been suggested that social jetlag is a key factor in increasing body mass index (BMI) and obesity, independent of sleep duration (Roenneberg et al., 2012). Furthermore, misalignment of sleep timing is associated with metabolic risk factors that can lead to diabetes and heart disease (Wong et al., 2015). Ronneberg et al. (2012) have stressed the importance of studying the implementation of daylight saving time and work or school times, which all contribute to the cumulative severity of individuals' social jetlag.

During sleep, the individual will usually pass through regular cycles of distinct phases. Two separate sleep phases have been defined, based on physiological records, rapid eye movement (REM) and non-REM (NREM) sleep. NREM sleep can be described as "[r] elatively inactive yet actively regulating brain in a movable body" (Kryger et al., 2011). The American Academy of Sleep Medicine (2007) further classifies four stages of sleep as stages N1, N2, N3 (NREM), and Stage R (REM) (Iber, 2007).

R sleep is defined by periodic bursts of rapid eye movement, muscle twitches, and cardiorespiratory irregularities, this sleep stage is not divided into further sleep stages (Kryger et al., 2011). The mental activity of R sleep is associated with dreaming (Dement & Kleitman, 1957b). During the overnight sleep, cycles of 90-100 minutes of travelling between sleep stages R to N3 are marked as sleep lightens and deepens in a recurring cycle throughout the night. The first stage of sleep after sleep onset is light sleep N1, followed by a period of N2 sleep and thereafter deep sleep (N3). After a period of deep sleep (N3), sleep lightens again (N2-N1) until one enters R sleep and completes the sleep cycle (Dement & Kleitman, 1957a). N3 deep sleep is predominant in the first half of the night and R sleep increases during the second half of the night (Kryger et al., 2011).

2.2 Sleep recommendations

Adequate sleep is important for optimal health and for daily functioning throughout life (Bin et al., 2012). NSF has issued recommendations that adults should sleep seven to nine hours per night. The recommendations are based on 575 studies on sleep published from 2004 to 2014. Data summarized for recommendations often does not distinguish between time in bed and actual sleep time. However, actual sleep time is typically less than time in bed, which biases data from objective and subjective findings (M. Hirshkowitz et al., 2015). Sleep recommendations for overall health benefits for various age groups are shown in Figure 3. Although sleep duration outside the recommended range may be appropriate, deviations far from the normal range are rare (Max Hirshkowitz et al.). Medical conditions linked to various kinds of sleep disorders in adults include depression, attention-deficit hyperactivity disorder (ADHD), obesity, diabetes, high blood pressure, heart disease, stroke and transient ischemic attacks (mini-stroke) (National Heart Lung and Blood Institute, 2012b). Keeping a regular sleep schedule maintains the timing of the body's internal clock and can help with falling asleep and waking up more easily (National Sleep Foundation).

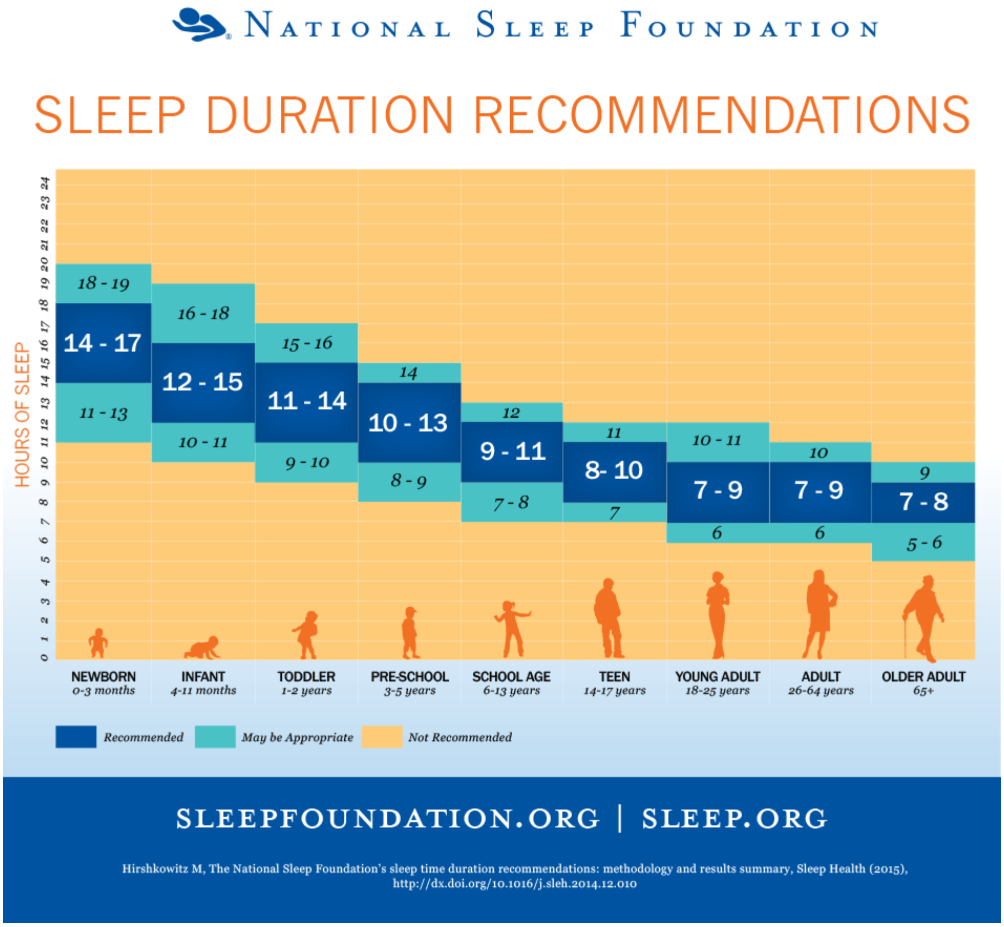


Figure 3. Sleep duration recommendations across the life span.

Copyright © 2015 National Sleep Foundation. (Max Hirshkowitz et al.).

2.3 Parameters to measure sleep

The terms insufficient sleep, inadequate sleep, short sleep duration, sleep loss and sleep restriction are used interchangeably in the literature. They refer to getting less sleep than needed (Owens, 2014). Sleep duration has been the primary measurement in sleep research, but sleep duration alone is not an appropriate indicator of insufficient sleep (Brand et al., 2009). In addition to the duration of sleep, schedule, timing and variability are also important sleep parameters to study (Max Hirshkowitz et al., 2015).

Sleep duration has been the most widely used sleep parameter. Over the decades, self-reported measures of sleep duration have been used in population-based studies. Sleep duration has been based on the time spent in bed and actual hours slept, since subjective questionnaire data cannot differentiate between the two unless participants are specifically asked. In this thesis, two terms will be used for the quantity of sleep; sleep duration for hours or minutes spent asleep and rest duration for hours or minutes spent in bed. Although adequate sleep duration is necessary, the quality of sleep has also been found to be important. In 2017, NSF assembled a panel of experts to answer the question of what good sleep quality entails in order to form recommendations regarding indicators of good sleep quality. The resulting key markers and their determinants for otherwise healthy individuals are described in Table 1. It should be kept in mind that the absolute measurement and interpretation of each sleep quality marker is dependent on age, sex and season (Ohayon et al., 2017).

Table 1. Sleep quality markers and determinants

Sleep quality markers	Determinants of good sleep
Sleep latency	Falling asleep in 30 minutes or less
Sleep awakenings	Waking up no more than once per night >5 minutes
Wake after sleep onset (WASO)	Being awake for 20 minutes or less after initially falling asleep
Sleep efficiency	Sleeping while in bed (at least 85% of the total time)
R Sleep/N sleep (%)	Normal cycles between R, N1, N2, N3 sleep
Naps	Nap duration, nap frequency

Abbreviations: %, percentage; R, REM sleep, N1-N3, Non-REM sleep. The table is adopted from National Sleep Foundation’s sleep quality recommendations (Ohayon et al., 2017).

Sleep schedule refers to an individual's routine of sleep timings, or the time points of the sleep period (bedtime, midpoint of sleep or rise time). Beyond general sleep recommendations of 8-10 hours of nightly sleep (Max Hirshkowitz et al., 2015), consistent bedtime and waking times during the week have also been found to have health benefits (Gruber et al., 2014). The temporal window of sleep provided by the circadian clock and its hormonal secretion has been shown to be the most efficient time to sleep (Wyatt et al., 1999).

People's social schedules are not always consistent with healthy sleep patterns (Barnes & Drake, 2015). The difference in sleep routines between work days and free days in adults often affects not only sleep duration but also differences in bedtime (Roenneberg et al., 2012).

2.4 Sleep in adolescents

Healthy sleep patterns during adolescence are important for rest and recovery as well as for growth and maturation, which are vital for maintaining good health (R. Millman, 2005; Nixon et al., 2008). Age specific recommendations from NSF suggest that teenagers, aged 14-17, should sleep at least 8-10 hours a night (Max Hirshkowitz et al., 2015). Studies suggest that sleep duration in children and adolescents has declined in recent decades and is generally insufficient (Keyes et al., 2015; Matricciani et al., 2012; Van Cauter et al., 2008). Only 30% of high school students get the recommended 8-10 hours of sleep on school nights (Eaton et al., 2010; National Sleep Foundation, 2006).

The 2011 Sleep in America Poll reported that around 60% of adolescents in the U.S. slept less than the recommended 8-10 hours on school nights, and 77% reported having sleep problems, such as waking up feeling un-refreshed (59%) and having difficulty falling asleep (42%) (National Sleep Foundation, 2011). A previous Icelandic study using questionnaires and sleep diaries found that adolescents had shorter sleep duration than their European peers (Thorleifsdottir et al., 2002).

Additionally, poor sleep is common among adolescents, as are daytime sleepiness (R. P. Millman, 2005) and insomnia (Ohayon et al., 2000). Inadequate sleep duration in adolescents is associated with increased risk of depression and mood problems, low grades, criminal behavior, obesity and risk of suicide (Eaton et al., 2010; National Sleep Foundation, 2006).

The later the bedtime or midpoint of sleep an individual prefers, the later the chronotype for the individual concerned. For children and adolescents, the sleep-wake cycle on school days is mostly controlled by the school start time and a bedtime determined by parents; that is, the social clock. The peak of melatonin secretion during the night is used as a biological marker to assess chronotypes (Kantermann et al., 2015). Studies have shown that children are usually strongly morning oriented. During adolescence and into young adulthood, the preferred chronotype is later. However, the late chronotype generally levels off in adulthood (Fischer et al., 2017).

During puberty, biological rhythms change so that adolescents become sleepy later at night, thus needing to sleep longer in the morning (Crowley et al., 2007; Crowley & Carskadon, 2010; Phillips, 2009). A delayed sleep phase (DSP) is a common circadian sleep pattern among adolescents, characterized by finding it challenging to fall asleep in the evening and difficult to wake up at the times required by school and work schedules. DSP, along with early school start times, is believed to contribute to chronic sleep loss during the week. (Wright et al., 2012). Although biology may partly explain DSP during adolescent years, it has also been linked to a growing sense of the adolescent's autonomy (Carskadon & Acebo, 2002). Studies on adolescents have heterogeneous results and do not agree upon which sex peaks first for DSP, with ages ranging from 17-18 for girls and 16-19 for boys (Fischer et al., 2017; Randler et al., 2017). Sex differences in both circadian preference and DSP are believed to level off into adulthood (Fischer et al., 2017; Randler et al., 2017). A diagram of adolescent DSP is shown in Figure 4. Healthy sleep patterns during adolescence are important for rest and recovery as well as for growth and maturation, vital for maintaining good health (R. Millman, 2005; Nixon et al., 2008).

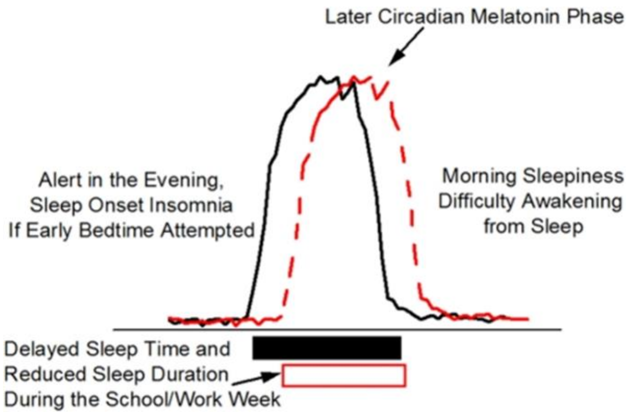


Figure 4. Diagram of adolescents' delayed sleep phase

Figure from (Wright et al., 2012).

Few studies have investigated sex differences in sleep in adolescents, and those that have are mostly based on subjective data. Studies on sex differences have focused on varying outcome measures, some have found that adolescents girls have poorer sleep than boys, determined by the Pittsburgh Sleep Quality Index (Megdal, 2007), and others point out sex differences in preferred circadian rhythm (Fischer et al., 2017; Randler et al., 2017). In a 1999 study of young adolescents, there was no significant difference between the sexes in subjectively measured weekday sleep duration and the timing of their bedtimes (Lee et al., 1999). However, girls had significantly earlier rise time than boys on weekdays. On weekend days, boys reported significantly earlier rise time than girls (Lee et al., 1999).

2.5 Physical activity in adolescents

International recommendations suggest that children and adolescents should do at least 60 minutes daily of moderate to vigorous physical activity (MVPA) (World Health Organization, 2010). Most of the daily PA should be aerobic, but vigorous activities for strengthening muscles and bones should be included at least three times per week (Lipnowski & LeBlanc, 2012; World Health Organization, 2010). According to a 2011 Icelandic study, only 9% of 15 year old adolescents fulfilled the daily recommendations (Magnusson et al., 2011). In the same study, increased skinfold thickness was associated with less time at or above daily MVPA, and children and adolescents from the capital region had longer bouts of MVPA (Magnusson et al., 2011). In a recent report by the Scientific Foundation for the PA Guidelines for Americans, higher levels of PA in children and adolescents are associated with more favorable weight status, less adiposity and better cardio-metabolic health (Powell et al., 2018). This is in line with large, population-based studies on U.S. children and adolescents, where PA has been suggested as a feasibly modifiable lifestyle factor to prevent obesity (Laurson et al., 2015) as it, together with central adiposity, has been found to associate with increased cardio-metabolic risk (Powell et al., 2018).

Sex differences have also been reported for PA. An Icelandic study from 2011 found that boys had longer intervals of MVPA than girls (Magnusson et al., 2011). This is in agreement with international findings. A study on European children and adolescents (9 and 15 years old), found boys to be more active than girls for both age groups (Riddoch et al., 2004). In California, (Babey et al., 2018), boys were more active than girls at ages 8-11 and 12-17 years. Interestingly, no sex difference was found in PA in 5-7 year old children.

2.6 Body composition in adolescents

Body fat is an essential tissue spread around the body. Its main purpose is to store energy and protect vital organs. Obesity is defined as a condition of abnormal or excessive fat accumulation in adipose tissue to the extent that health may be impaired (Garrow, 1988). Obesity has been linked to morbidity and mortality in research, which makes the World Health Organization's (WHO) overweight and obesity category appropriate as a health outcome in public health research (World Health Organization, 2000). Research highlights the importance of maintaining a normal weight throughout childhood as those who are overweight as children are more likely to be overweight as adults (World Health Organization, 2000), and metabolic risk factors can follow from childhood into adulthood (Camhi & Katzmarzyk, 2010). In addition to energy intake that exceeds energy expenditure (Romieu et al., 2017) and low levels of PA, (Powell et al., 2018) research has found evidence pointing towards decreased sleep duration as a potential causal factor in the current epidemic of obesity. Since the association between PA and sleep may be reciprocal (Chennaoui et al., 2015), it is important to study the connection between sleep patterns and PA and their association with metabolic factors in adolescents.

2.7 The role of inadequate sleep in obesity

Epidemiological studies on the association between short sleep duration and obesity during childhood and adolescence have been conducted in the past few decades (Cappuccio et al., 2010). A meta-analysis of 11 longitudinal studies reveals that subjects with shorter sleep duration had twice the likelihood of being overweight or obese as compared to subjects with longer sleep duration (Fatima et al., 2015). Inadequate sleep duration has been associated with higher BMI (Chaput & Janssen, 2016; Knutson & Lauderdale, 2009; Zinkhan et al., 2014) and more body fat (Garaulet et al., 2011). This association includes average sleep duration. School-night sleep duration, weekend sleep duration and daytime sleepiness have all been found to predict BMI independently in a sample of 12 year old adolescents (Peach et al., 2015). The strength of the association between sleep and BMI seems to be dependent upon sex, (Peach et al., 2015), with a stronger association detected in young boys and male adolescents than in girls and females (Storfer-Isser et al., 2012). In addition to negative effects on body composition, inadequate sleep duration has also been found to be associated with increased insulin resistance (Matthews et al., 2012). Short sleep affects both sides of the energy balance equation, energy intake and energy expenditure (Chaput, 2016), resulting in obesity (Taheri, 2006). The findings suggest that sleep deprivation may affect metabolic homeostasis, thus contributing to overweight and obesity (Sharma & Kavuru, 2010). A study of European adolescents found that short sleep duration is associated with higher adiposity markers, particularly in female adolescents, and the association appears to be driven by both increased food consumption and more sedentary behavior (Garaulet et al., 2011). More recently, intervention studies, although mostly built on data on adults, have provided important evidence indicating that the unfavorable effects of short sleep lead to increased food intake and that lack of sleep can increase snacking, the number of meals eaten and preference for energy-dense food items (Beebe et al., 2013; Chapman et al., 2012; Chaput, 2014; Chaput & St-Onge, 2014; Spaeth et al., 2013; A. Weiss et al., 2010). Experimental studies of sleep restriction in adults have shown that 4 hours of sleep for five nights resulted in a 1kg increase in weight as compared to a control group with normal sleep duration (Spaeth et al., 2013), and five nights of five hours of sleep resulted in an increase of 0.82 kg (Markwald et al., 2013). Markwald et al. (2013) showed that five hours of sleep for five nights resulted in a 5% increase in energy expenditure over the 24-hour period due to the energy cost of additional wakefulness, but the energy intake the following night was found to be in surplus of demand. However, a review of experimental studies on short sleep and its effect on total energy expenditure in free-living conditions, did not provide substantial evidence supporting a significant effect of short sleep on energy expenditure (Klingenberg et al., 2012).

Beyond sleep duration, poor sleep quality has been associated with higher BMI in 15 year old adolescents (Megdal, 2007). Researchers suggest that sleep timing may independently influence BMI in adolescents (Golley et al., 2013), particularly late bedtime (Golley et al., 2013). Social jetlag, defined as a shift in sleep timing between work days and weekends, is also associated with increased BMI (Roenneberg et al., 2012), indicating that sleep timing is another important component of sleep that may influence overall metabolic health (Matthews et al., 2012). Recovery sleep on non-school days, where children and adolescents compensate for short school-day sleep, may still be important for maintaining healthy weight (C. W. Kim et al., 2012; Stone et al., 2013; Wing et al., 2009).

Studies using subjective measures found an association between average sleep duration and obesity in adolescents, (Cappuccio et al., 2010; Chaput & Janssen, 2016; Fatima et al., 2015; Garaulet et al., 2011; Knutson & Lauderdale, 2009; Megdal, 2007; Roenneberg et al., 2012). However, studies based on objective measurements have concluded that different sleep parameters (quality and timing) are associated with obesity markers (He et al., 2015; Jansen et al., 2018; Spruyt et al., 2011). In children, variability in sleep duration was associated with increased BMI (Spruyt et al., 2011). Additionally, in a study on healthy adolescents, variability in sleep duration was associated with abdominal obesity (He et al., 2015). Further studies on the causal mechanisms between sleep parameters and obesity should consider more parameters than sleep duration (He et al., 2015; Spruyt et al., 2011).

2.8 The bidirectional role of physical activity and sleep in adolescents

It has been proposed that children aged 10-12 who follow sleep recommendations are more likely to maintain regular and healthy PA than those who do not sleep as suggested (Stone et al., 2013). Additionally, children who maintain a regular sleep schedule on both school days and non-school days have been found to have the most positive activity profiles (Stone et al., 2013). Recent meta-analysis on sleep and PA in children, 3-13 years old, found limited association between sleep and PA in children, although children participating in vigorous PA, compared to lower PA levels, had longer sleep duration (Antczak et al., 2020). Studies on adolescents agree that PA has a positive influence on sleep length (Youngstedt & Kline, 2006), and vigorous PA may promote better sleep in adolescents (Kalak et al., 2012; Lang et al., 2013). Lang et al. (2013) concluded in a review study on adolescents that both self-reported and objectively assessed PA predict subjective and objective measures of sleep. However, most of the studies have been cross-sectional in nature, and few have used objective measures of both sleep and PA (Lang et al., 2013).

2.9 Methodological considerations of measurements

Previous research on adolescent sleep in epidemiologic studies has mostly been based on subjective data such as sleep logs or questionnaires (Arora et al., 2013). In recent years, actigraphy has been developed and validated (de Souza et al., 2003; Sadeh, 2011; Sadeh & Acebo, 2002; Sadeh et al., 1994) as an objective method for assessing sleep patterns and estimating general qualities of sleep and activity in free-living conditions (A. R. Weiss et al., 2010). Wrist actigraphy uses a watch-like accelerometer and data is obtained by sleep detection algorithms (de Souza et al., 2003; Sadeh et al., 1994; Slater et al., 2015; A. R. Weiss et al., 2010; Zinkhan et al., 2014). A comparison of objective and subjective measurements of adolescent sleep suggests that self-report methods (Lang et al., 2015) tend to overestimate actual sleep length. This suggests that adolescents may sleep even less than previously reported (Arora et al., 2013; de Souza et al., 2003; Sadeh, 2011; Sadeh & Acebo, 2002; Sadeh et al., 1994).

The same applies to previous studies investigating the relationship between PA and sleep in adolescents. Most have been based on subjective data (Lang et al., 2013; Lang et al., 2015). Subjective measures of PA tend to be inaccurate in that they overestimate an individual’s activity (Sallis & Saelens, 2000). Wrist-worn accelerometers may provide an alternative to subjective assessment of PA since they are easy to wear and can facilitate long-term recording. Also, wrist-worn accelerometers may be preferable to hip-worn accelerometers since they can be worn overnight.

In measuring body composition, many different assessments might apply, but the most common method for estimating overweight and obesity in populations is BMI (kg/m^2) (Wellens et al., 1996). BMI is popular because it is easy to use and correlates well with body fat percentage (Wellens et al., 1996). However, BMI does not differentiate between fat and muscle tissue (Prentice & Jebb, 2001). Therefore, more accurate measures, such as skinfold thickness, doubly labeled water tests and dual energy X-ray absorptiometry (DXA) are often preferred. The advantage of DXA is its high rate of accuracy in classifying different body tissues (Andreoli et al., 2009; Dezenberg et al., 1999; Fusch et al., 1999) and a very low dose of radiation (Pietrobelli et al., 1998).

Daylight is the main signal of day and night in our environment, and thus an important indicator of the starting of the day for the internal clock. Seasons, as based on daylight, might influence sleep duration and timing. Seasonal differences in daylight and its impact on sleep duration and sleep timing were assessed among adults in Norway at 69°39’N or above. In that study, subjects had both later bedtimes by an average of 12 min and rise time, averaging 32 min, on workdays during winter than during summer (Friborg et al., 2012). The same study assessed the seasonal effect of identical sleep parameters in Ghana where there is little seasonal difference in daylight. The study found no difference in sleep across seasons in Ghana (Friborg et al., 2012). In a study of 7 year old children in New Zealand, sleep duration was shorter during summer than in other seasons (Nixon et al., 2008). Sleep timing may also change across seasons in the US. A study on adolescent sleep timing across seasons found that the midpoint of sleep in the summer was 41 minutes later than in winter and 28 and 29 minutes earlier in the spring and fall, respectively (Quante et al., 2017).

Daylight also appears to affect levels of PA in children and adolescents, at least at a young age. A Norwegian study found that 9 year old children showed a significantly higher mean PA in spring than in winter and fall but no difference was found between seasons for 15 year olds, although the older group had a higher likelihood of meeting the PA recommendations in spring than in winter (Kolle et al., 2009).

Weather conditions are known to influence PA. These differ between geographical locations and between seasons. Thus, they should be considered in a study of free-living PA. Activity has been found to be higher in the spring and summer than in the winter (Owen et al., 2009; Wennlof et al., 2005) and an inverse u-shaped curve has been shown for the relationship between outside temperature and PA (Quante et al., 2017), indicating the preferred temperature for PA is neither too hot nor too cold.

Socioeconomic status (SES) is a well-known predictor of illness and health (Adler et al., 1994), associated with both physical inactivity and obesity. Many variables such as income, education and occupation link SES to health, and those may be interrelated. Yet, it is quite common for studies to only use one variable, either income or education, (Adler et al., 1994).

2.10 Knowledge gaps and novelty of the study

Although there is growing evidence that sufficient sleep duration and stable sleep patterns are highly important for adolescent health and wellbeing (Gruber et al., 2014), studies have mostly been based on subjective data such as sleep logs or questionnaires (Arora et al., 2013), therefore possibly biasing the estimated sleep length (Lang et al., 2015). Thus, it has been suggested that adolescents may sleep even less than previously reported (Arora et al., 2013). Furthermore, to our knowledge, no studies have objectively assessed and compared sleep patterns among adolescents on school days versus non-school days.

Prior studies have indicated that PA favorably affects sleep in adolescents (Kalak et al., 2012; Lang et al., 2013; Stone et al., 2013; Youngstedt & Kline, 2006), but those have mainly depended on subjective measures. As with sleep measures, subjective PA measures are also prone to bias and studies investigating the association between sleep and PA with objective measures on both variables are lacking in the literature (Lang et al., 2015).

Based on the literature review, it is clear that, although there is a well-established association between self-reported sleep duration and obesity (Lang et al., 2013; Lang et al., 2015), the association between objective sleep duration, timing, quality and variability and obesity has not been fully investigated with objective measurements (Max Hirshkowitz et al., 2015; Jarrin et al., 2013).

2.11 Aims of the study

Based on the literature review above, the main aims of this dissertation are to:

1. Investigate objectively measured sleep duration, sleep timing and sleep quality of Icelandic adolescents at 15 years old and assess sex difference in objectively measured sleep parameters (Paper I).
2. Assess whether there is an agreement between self-reported and actigraphy-measured sleep at 15 (paper III), to assess whether the agreement between the two differs between age 15 and age 17 (Paper II) and whether the two methods differ in estimating changes in bedtime from 15-17 years of age.
3. To assess the proportion of 15 years old adolescents who fulfilled the recommended hours of PA and sleep, assess any sex differences in sleep and PA, and the possible associations between PA and sleep (Paper III and unpublished data).
4. Examine the potential associations between objectively measured sleep duration, timing, quality, and night-to-night variations on school nights with objectively measured body composition (Paper IV).

3 Methods

3.1 Study population and design

This research project, “*Heilsuhegðun ungra Íslendinga* (HHUI) or Health Behaviors of Icelandic Youth”, is a longitudinal study that tracks the status and changes of various health and sleep parameters in a cohort of adolescents born in 1999. The adolescents all originated from six elementary schools in Reykjavík. The current study will explore both longitudinal changes from age 15-17 as well as cross-sectional data from both time points. The research project, HHUI, is an independent follow up study on previous research conducted in 2006-2008, “*Lifestyle of 7-9 year old children; intervention towards better health”* (EYHS) and all participants originate from the same six elementary schools in Reykjavík. Those who completed their participation were rewarded with a 4000 and 5000 ISK (approximately $40-$50) debit card in 2015 and 2017, respectively. Figure 5 shows the categories of measurements in 2015 and 2017 used in the thesis.

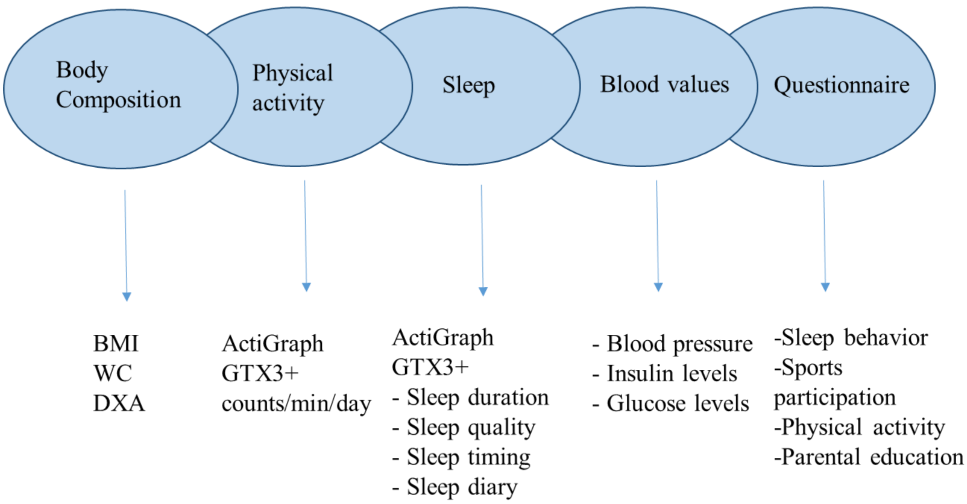


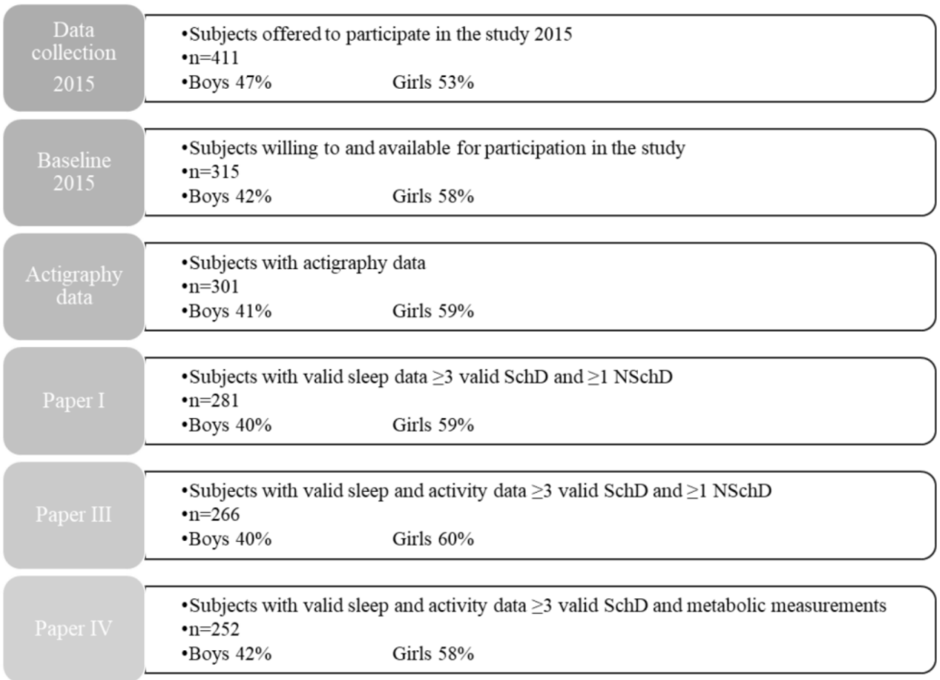
Figure 5. Data collected in Health Behaviors of Icelandic Youth 2015 and 2017

Papers I, III and IV are based on cross-sectional data gathered in 2015. Paper II is based on follow-up data from 2015-2017. The data collection in 2015 with participants aged 15 and 16 at the time took place in April-June. In 2017, the participants were aged 17 and 18 and the data collection took place from February to

May. The HHUI project was conducted by scientists at the University of Iceland in collaboration with the Department of Education and Youth at the City of Reykjavík, six elementary schools in Reykjavík, the Icelandic Heart Association and the National Institute of Diabetes, Digestive & Kidney Diseases at the National Institute of Health in the USA.

3.2 Participation and data collection in 2015

In April 2015, all 411 students (age 15-16) enrolled in 10th grade at the respective schools received an invitation letter to participate in HHUI. Students who did not attend school (sick or travelling) during days of measurements at individual schools were excluded, although students who became ill within the week, while wearing the accelerometer were not excluded. A total of 315 adolescents took part, or 77% of those invited. Of these, 42% were boys, and 58% were girls. Non-participation (n=104) was mainly due to absence from school during measurement days and lack of interest in the study. Participation in 2015 is shown in Figure 6.



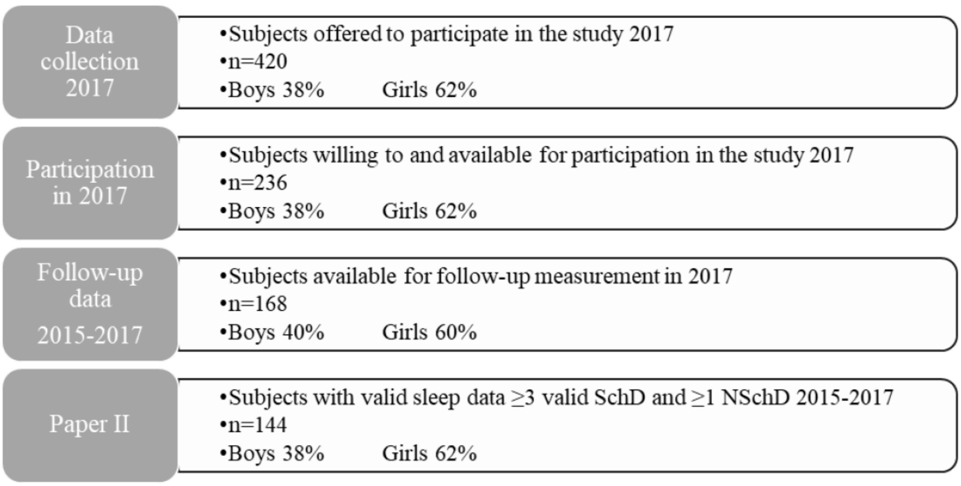
Schd; school days, NSchD; non-school days

Figure 6. Cross sectional participation in 2015

In 2015, the research team measured fitness, anthropometric data, blood pressure, and performed a maximal ergometer test and a jump test at the individual schools. At the schools, the students filled out a questionnaire on iPads. Students had accelerometers assessing PA and sleep placed on their non-dominant wrist and were given an accompanying sleep diary to fill out during the week. The sleep diaries were collected by the research team the following week. The students were driven between the schools and The Icelandic Heart Association for DXA scanning and blood sampling.

3.3 Participation and data collection in 2017

In 2017, all who had taken part in any of the previous waves of EYHS or HHUI were invited to participate in a follow-up data collection. Thereof, we were able to contact 420 subjects, 236 (56%) of whom were willing and available to cooperate during the period of measurements. From those who participated, 168 had data on both time points, 2015 and 2017, for follow-up analyses. Non-participation (n=184) in 2017 was mainly due to a lack of interest in the study, not answering the phone, not showing up or other unexplained reasons. Participation in 2017 is shown in Figure 7.



SchD; school days, NSchD; non-school days

Figure 7. Follow-up participation 2015-2017

In 2017, all participants underwent a similar procedure at the research lab for the Center of Sport and Health Sciences in Reykjavík as they had experienced at the individual schools in 2015. The participants' height and weight were measured at the Icelandic Heart Association before DXA scanning.

3.4 School schedules

School time for elementary school (15 years old) in Iceland is 37 school hours/week. The timing and duration of the school day varied little between schools and individual participants, with the school day starting for most participants between 08:10–08:20 in the morning and finished around 14:00, and the longest school day finishing at 16:00. Upper-secondary schools in Iceland (17 years old) can adopt one of two course-scheduling systems (Ragnarsdóttir & Ásgeir Jóhannesson, 2014). Class-based (traditional) schools, similar to elementary schools, offer a single daily course schedule to all students, which typically begins between 08:10–08:30 and finishes around 15:30. In unit-credit-based (college-style) schools, students can choose from several offerings of the same course occurring at various times. Students are only required to be present at school during their scheduled course times. Thus, daily schedules of unit-credit students are more individualized, like those of college students in many countries, and school start times can vary from 08:30 to 16:00.

3.5 Measurements

3.5.1 Objective sleep measures

Free-living sleep was measured via a wrist-worn raw signal accelerometer, ActiGraph GT3X+ (ActiSleep by ActiGraph Inc. Pensacola Florida, USA). Actigraphy watches were placed on the subjects' wrists at school and each subject was asked to wear the accelerometer continuously for a week. Raw triaxial data was sampled at 80 samples/sec (Hz). Actigraphy-measured sleep parameters were derived from the ActiLife software from ActiGraph (version 6.13.0.), using a sleep detection algorithm validated specifically for adolescents (Sadeh, 2011; Sadeh & Acebo, 2002; Sadeh et al., 1994). The accelerometer is a watch-like data box worn on the non-dominant wrist. The accelerometer is light (27g) and small (3.8 cm x 3.7 cmx 1.8 cm) and has been produced specifically for use in research.

In primary sleep analyses the main focus was on the nightly sleep period. Actigraphy-measured sleep duration, timing and quality were determined by the auto-detection of ActiLife's sleep analysis. Self-reported sleep logs including bedtimes and rise times were used to confirm the proximal rest intervals measured by the software. These were manually adjusted when necessary. Total rest time was compared to the recommended 8-10 hours of sleep for adolescents in this age range. Sleep parameters were computed for all valid school days (SchD) and non-school days (NSchD). Valid activity days were defined as days with ≥ 14 hours of wear-time out of a 24 h period from 12 o'clock midnight to 12 o'clock midnight the following day. Weekly averages and within-subject night-to-night variability (standard deviation) were also computed. Each participant was asked to wear the monitor on the non-dominant wrist for 7 consecutive days. Specific inclusion criteria for valid SchD and/or NSchD were set for each study depending on the topic. Naptime was not included in the analyses due to the low incidence of naps detected in our data (18 different subjects took a total of 22 naps). Actigraphy-measured sleep parameters for analysis, based on validated algorithms (Sadeh, 2011) and previous definitions (Fekedulegn et al., 2020; Martin & Hakim, 2011; Tudor-Locke et al., 2014), are defined in Table 2.

Table 2. Definitions of Actigraphy-measured sleep parameters

Sleep parameter	Definition
Total rest duration	Resting period – the time spent in bed (hours).
Total sleep duration	Actual sleep time during rest period (hours).
Variability in sleep duration	The variance of the sleep duration period (SD of of TST (min).
Sleep efficiency	Minutes of total sleep divided by minutes available for sleep multiplied by one hundred (%).
Sleep onset latency	The time it takes to accomplish the transition from full wakefulness to sleep (min).
Number of awakenings	Wake ups during the period of total rest duration (counts).
Wakening after sleep onset (WASO)	Minutes of non-sleep during total rest duration, due to awakening (min).
Bedtime	The clock time of when someone goes to bed.
Variability in bedtime	Variance of the clock time of when someone goes to bed (min).
Midpoint of sleep	The clock time at the midpoint of the sleeping period (between sleep onset and rise time).
Rise time	The clock time of when someone gets out of bed.

3.5.2 Subjective sleep parameters

Participants filled out an accompanying sleep diary during the wearing time of the accelerometers. In the sleep diary, participants logged their bedtime and rise time each day. From the questionnaire answered in 2015 (Appendix I), self-reported bedtime (assessed via Q57 and Q80) consisted of participant responses to the following questions: "What is your usual bedtime on school nights?" and "What is your usual bedtime on the weekend?" Potential answers were in half-hour increments from 20:00 to 04:00. Also, participants reported whether they were getting enough sleep, assessed with Q5, four possible responses to the question "Do you sleep enough?" were: "most of the time" (1), "half of the time" (2), "very seldom" (3)", "I sleep too much" (4).

3.5.3 Objective physical activity parameters

Free-living PA was objectively measured using triaxial raw signal Actigraph activity monitors (ActiSleep model GT3X+, ActiGraph Inc. Pensacola Florida). The accelerometer collects the data for both activity and sleep. Data for PA (total vector magnitude) during waking hours was obtained using a sampling epoch time of 60 s, with counts per minute (cpm) as a unit of activity.

3.5.4 Subjective physical activity parameters

Self-reported PA (Table 3) was based on the three following questions from the questionnaire used in 2015 (Appendix I). The questions are marked in the questionnaire as Q14, Q15 and Q17.

1. Do you participate in organized sports? (Q17); "Yes" (1), "No" (2), "I used to but not anymore" (3). For the current analysis, responses were recoded into a binary variable: 1 = "Participate in organized sports" or 0 = "do not participate in organized sports" combining options 2 and 3.
2. How many hours per week do you participate in sports or physical activity in a typical week? (Q15); "none" (1), "less than 1 hour per week" (2), "1-2 hours per week" (3), "3-4 hours per week" (4), "5-6 hours per week" (5), "more than 6 hours per week" (6), "I do not want to answer" (7). For the current analysis, responses were recoded into a binary variable: 1 = "Participate in physical activity and sport >6 hours/week" or 0 = "Participate in physical activity and sport <6hours/week"
3. How often do you participate in physical activity where you get out of breath or sweat? (Q14) with the options: "never" (1), "less than once per week" (2), "once per week" (3), "2-3 times per week" (4), "4-5 times per week" (5), "almost every day" (6). For the current analysis, responses were recoded into a binary variable: 1 = "physical activity where you sweat or breath hard >6 days/week" or 0 = "physical activity where you sweat or breath hard <6 days/week".

Table 3. Self-reported physical activity and sleep from questionnaire

Questions	Answers
How often do you participate in physical activity where you sweat or breath hard?	≤ 6 times/week ≥ 6 times/week
How many hours per week do you participate in sports or physical activity in a typical week?	≤ 6 hours/week ≥ 6 hours/week
Do you participate in organized sports?	Yes No

3.5.5 Body composition and metabolic factors

Standing height was measured with a stadiometer (Seca model 217, Seca Ltd. Birmingham, UK) to the nearest 0.1 cm. Body weight was measured on a balance scale (Seca model 813, Seca Ltd. Birmingham, UK) to the nearest 0.1 kg with participants wearing light clothes. Waist circumference (WC) was measured with an inelastic band to the nearest 0.1 cm. Measurements were performed at individual schools in 2015 and at the Icelandic Heart Association in 2017.

Body composition measurements were obtained with dual energy X-ray absorptiometry (DXA) using a GELUNAR scanner. All body composition measures took place at the Icelandic Heart Association. A single radiologist took the measurements. These measurements yielded estimates of the adolescents' total lean mass, fat mass (g) and trunk fat mass (g). Anthropometric variables used in this analysis are defined in Table 4. Overweight and obesity were classified according the World Health Organization classification. Normal range BMI is classified as the range from 18.50-24.99 kg/m^2, overweight as BMI values between 25-29.99 kg/m^2 and obesity as BMI at 30 kg/m^2 and above.

Table 4. Body composition variables

PARAMETER	DEFINITION
Body mass index (BMI)	Index for measuring weight in relation to height (kg/m^2).
Waist circumference (WC)	Measured in centimeters.
Percentage body fat	Fat mass divided by the total mass assessed with DXA and represented as a percentage.
Percentage trunk fat	Trunk fat mass divided by the total trunk mass assessed with DXA and represented as a percentage.

Resting blood pressure was measured on the left arm of seated participants, and the average of three measurements was used for analysis. Fasting blood samples were obtained using standard procedures after overnight fasting; samples were analyzed for glucose and insulin. Insulin (mU/L) in serum was measured using the INSULIN assay from Roche, a sandwich electrochemiluminescence immunoassay ECLIA on Cobas e 411 (Roche, Switzerland). The inter-assay coefficient of variation was < 5.06% using a frozen serum pool and < 2.36% using quality control samples from Roche. Glucose (mmol/L) in serum was measured using the GLUC2 assay from Roche, an enzymatic reference method with hexokinase. The measurements were performed on a Cobas e 311 (Roche, Switzerland). The inter-assay coefficient of variation was <1.65% using a frozen serum pool and <1.66% using quality control samples from Roche.

Parental education was assessed via a questionnaire and classified into two categories, at least one parent with a university degree or neither parent with a university degree.

3.6 Ethics

Written informed consent was obtained from all participants and their parents or guardians. Strict procedures were followed to ensure confidentiality. The study was approved by the National Bioethics Committee and the Icelandic Data Protection Authority (Study number VSNb2015020013/13.07). General information on the study (HHUI) is found on the website https://heilsuhegdun.hi.is/.

3.7 Statistical analyses

All finalized, exported Actilife reports were compiled into daily and weekly averages using customized programs written with Matlab software (version R2013a). Statistical analyses were carried out using R statistical software (R, Boston

Massachusetts, USA, Version 1.1.463 - © 2009-2018 Rstudio, Inc.) with R (v3.4.2, https://www.r-project.org/) and GraphPad Prism (v7, La Jolla, CA). The level of statistical significance was set at $p<0.05$.

Descriptive statistics are presented as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. Assessment of sex differences was carried out by t-tests for independent samples and chi-square tests for categorical variables. Paired t-tests were used to compare measures on SchD and NschD and at ages 15 and 17. Characteristics and parental education regarding participants who did not repeat the study in 2017 were compared with the characteristics of those who participated at both times by t-test. A Pearson correlation coefficient (r) was used to assess the association between day length and actigraphy-measured sleep and PA.

Two-way analysis of variance (ANOVA) was used to compare the mean differences between actigraphy-measured sleep duration across categories of self-reported sleep duration ("how well do you sleep?"). Self-reported measures of the participants' usual bedtimes on SchD and NSchD were compared to average actigraphy-measured bedtimes for SchD and NSchD in 2015 and 2017. The correlation between self-reported and actigraphy-measured bedtimes was calculated with a Pearson r coefficient. Bland-Altman plots were used to assess inter-method agreement (Bland & Altman, 1986). All other comparisons were made using ANOVA with Tukey post-hoc comparisons with Bonferroni adjustments.

Two-way ANOVA was used to compare means of actigraphy-measured PA between SchD and NSchD with independent comparisons between the sexes. The interaction between SchD vs NSchD and sexes was also assessed. To compare actigraphy-measured and self-reported PA, two-way ANOVA was used to compare the mean differences between actigraphy-measured PA and categorical values self-reported PA. A chi-square test was used to assess the difference between categories of self-reported PA and sex.

One-way ANOVA was used to compare means between actigraphy-measured sleep across self-reported categorical values of PA. A t-test was used to compare means between self-reported sports participation categories. A Tukey post-hoc test with Bonferroni corrections for multiple calculations was used to assess interactions between ShcD/NSchD and sexes.

Linear regression analysis was used to assess the association between actigraphy-measured sleep variables (independent variable) and PA in counts/min/day (dependent variable).

Linear regression was also used to assess the association between actigraphy-measured sleep parameters (independent variables) and BMI (dependent variable). Separate regressions were run for boys and girls and SchD and NSchD. For further analysis on the correlations between sleep and obesity, associations between sleep variability parameters on SchD and body composition variables were calculated. Multiple linear regression with standardized coefficients, adjusted for sex, parental education and day length, was used to explore the associations of each sleep parameter (duration, bedtime, WASO and variability in sleep and bedtime) and PA with body composition parameters (percentage body fat and percentage trunk fat) and metabolic factors (insulin, glucose, blood pressure).

4 Results and discussion

The main results and discussion based on the four aims are presented in this chapter. Chapters 4.1-4.4 are based on Papers I-IV and arranged by aims 1-4. The main results are built on cross-sectional data collected in 2015, where mean age of participants was 15.9±0.3 years and longitudinal data, from 2015-2017, with mean age of participants at follow-up being 17.7±0.3 years. Characteristics for all subjects with valid sleep data (≥3 valid SchD and ≥1 NSchD) 2015 and 2017 are presented in Table 5, however, study characteristics for each paper are based on valid data criteria presented in each of the papers. This chapter, results and discussion, highlights sleep and PA characteristics measured with both objective and subjective methods and associations between sleep and metabolic factors.

Table 5. Characteristics for all subjects with valid sleep data 2015-2017

	All	**Boys**	**Girls**	**Range min-max**	**Boys vs Girls p-value**
Baseline 2015					
n (%)	**280 (100)**	**113 (40)**	**167 (60)**		
Age (years)	15.9 (0.3)	15.8 (0.3)	15.9 (0.3)	14.5-16.4	0.068
Height (cm)	171.5 (8.0)	178.2 (5.9)	166.9 (5.7)	150-194	**<0.001**
Weight (kg)	64.8 (11.3)	68.9 (11.6)	62.0 (10.2)	44.6-116.6	**<0.001**
BMI (kg/m2)	22.0 (3.2)	21.6 (3.3)	22.2 (3.2)	16.4-34.8	0.145
Fat percentage (%)	25.4 (8.9)	18.1 (7.2)	30.4 (6.1)	9.4-51.22	**<0.001**
Waist circumference (cm)	70.6 (7.5)	73.4 (7.0)	68.8 (7.2)	55.5-106.8	**<0.001**
Follow up 2017					
n (%)	**199 (100)**	**73 (37)**	**126 (63)**		
Age (years)	17.7 (0.3)	17.63 (0.3)	17.7 (0.3)	17.1-18.3	**0.019**
Height (cm)	173.3 (9.2)	182.56 (5.7)	168.0 (6.0)	153.3--200.5	**<0.001**
Weight (kg)	68.7 (13.0)	74.8 (12.5)	65.2 (12.0)	46.2-118.5	**<0.001**
BMI (kg/m2)	22.8 (3.9)	22.4 (3.4)	23.1 (4.1)	15.6-38.1	0.225

Abbreviations: n, number; BMI, body mass index.

4.1 Actigraphy-measured sleep duration, sleep quality and sleep timing in 2015

Descriptive data of actigraphy measured sleep of Icelandic adolescents is reproduced from Paper I. Actigraphy-measured sleep parameters calculated in 2015 are presented in Table 6. Average rest duration for boys and girls on SchD was 7.05±0.8 hours and average sleep duration was 6.20±0.7 hours. Participants had longer rest and sleep duration on NSchD than on SchD. The adolescents had about 80 min longer sleep duration on NSchD, which may be an attempt to recover from the short sleep duration on SchD. These results are in line with a recent review study that combined actigraphy sleep data for sleep duration for 15-18 year olds (Galland et al., 2018). The study found that sleep duration averaged 7.4 hours over the week, with 56 min longer sleep duration on NSchD, derived from sleep onset and rise times of almost one to two hours later. As current sleep recommendations are based mostly on subjective data, rest duration was used to compare actual sleep with recommendations as it reflects bedtime until rising the next morning (Chaput & Janssen, 2016). When rest duration was used as an indicator of recommended sleep time, only 10.7% of the participants in the current study reached the recommended 8-10 hours of sleep on SchD and 66.9% on NSchD.

Table 6. Sleep duration, quality and timing (Paper I)

	Boys (n=114)			Girls (n=167)			All (n=281)		
Sleep parameters	**SchD**	**NSchD**	**p**	**SchD**	**NchD**	**p**	**SchD**	**NSchD**	**p**
Sleep duration									
Rest duration	7.01±0.90	8.36±1.45	**<0.001**	7.07±0.78	8.42±1.06	**<0.001**	7.05±0.83	8.40±1.23	**<0.001**
Sleep duration	6.16±0.82	7.25±1.29	**<0.001**	6.21±0.69	7.39±0.96	**<0.001**	6.20±0.74	7.33±1.10	**<0.001**
Sleep quality									
Sleep efficiency (%)	88.0±4.4	86.8±4.2	**0.01**	87.9±4.4	87.9±5.1	0.837	87.9±4.4	87.4±4.7	**0.038**
Sleep onset latency (min)	1.6±1.0	1.6±1.1	0.79	1.5±1.0	1.6±1.2	0.767	1.6±1.0	1.6±1.2	0.737
Wakening after sleep onset (min)	50.0±21.1	66.3±24.8	**<0.001**	50.2±21.4	60.3±28.4	**<0.001**	50.1±21.2	62.7±27.1	**<0.001**
Number of awakenings (count)	18.3±6.3	23.4±9.4	**<0.001**	18.5±4.8	22.7±7.8	**<0.001**	18.4±5.5	23.0±7.8	**<0.001**
Sleep timing									
Bedtime (o'clock±min)	00:28±56	01:58±83*	**<0.001**	00:18±51	01:31±64	**<0.001**	00:22±54	01:42±74	**0.05**
Midpoint of sleep (o'clock±min)	04:00±45*	06:14±77**	**<0.001**	03:50±36	05:43±61	**<0.001**	03:54±40	05:56±69	0.158
Rise time (o'clock±min)	07:33±48*	10:32±86**	**<0.001**	07:23±33	09:57±73	**<0.001**	07:27±40	10:11±80	0.735

Abbreviations: SchD, school days; NSchD, non-school days. %, percentage. P-values for difference between SchD and NSchD are in the table. Difference between the sexes is marked *p<0.05 and **p<0.001.

Boys had significantly later bedtimes on NSchD and a later midpoint of sleep and rise times on both SchD and NSchD than girls. The boys had a 91±78 min later bedtime and 178±81 min later rise time on NSchD, with a 135±7 shift in the midpoint of sleep from SchD. The girls had a smaller shift in sleep timing between SchD and NSchD and a 73±50 min later bedtime and a 154±71 min later rise time on NSchD as compared with SchD, leading to a shift in the midpoint of sleep of 113±50 minutes. Bedtimes on SchD did not differ significantly between the sexes. Daytime naps, captured by the actigraphy, were rare, with 22 total naps taken by 18 different subjects in 2015 and only 14 total naps identified in 8 different subjects in 2017. Thus, no further analyses were performed on naps.

Sleep deficiency among adolescents may be a public health risk (Barnes & Drake, 2015) where delayed bedtimes and early school starting times lead to insufficient sleep for a large portion of the adolescent population (Wheaton et al., 2015; Wright et al., 2012). School start time is the main determinant of adolescent rise time (Knutson & Lauderdale, 2009), and The American Academy of Pediatrics (AAP) advised U.S. middle and high schools to modify start times to no earlier than 8:30 a.m. to enable students to get adequate sleep and improve their health, safety, academic achievement and quality of life (Wheaton et al., 2015). A recent U.S. study found that adolescents aged 15.5±0.6 who had a school start time of 8:30 or later had longer actigraphy-measured sleep than those who had an earlier school start time, explained by both earlier bed and later rise times (Nahmod et al., 2019).

Differences in sleep duration between SchD and NSchD are not uncommon, as short-term sleep deficiency during SchD is typically followed by longer sleep durations of recovery sleep on NSchD (Chaput & Janssen, 2016; Galland et al., 2018; Roenneberg et al., 2012). The present data supports the recovery sleep suggestion, as the adolescents slept about 1.2 hours longer on NSchD than on SchD. It also shows a shift in midpoint of sleep of about 2.3 to 1.9 hours later, for boys and girls respectively, on NSchD versus SchD. However, there was no inverse correlation between sleep duration on SchD and NSchD nor did the sleep quality markers indicate higher sleep quality on NSchD despite a significantly longer sleep duration than on SchD. One plausible explanation is that the shift in the midpoint of sleep of roughly 2 hours may have created inconsistencies in the sleep routines, hindering the ability to simultaneously increase sleep quantity and quality. A large shift in the midpoint of sleep, social jetlag, has previously been found to be associated with a higher incidence of depression (Levandovski et al., 2011), anxiety (Wittmann et al., 2010), metabolic disorders, such as obesity (Roenneberg et al., 2012) and metabolic syndrome and type II diabetes (Koopman et al., 2017). However, the difference in midpoint of sleep was not associated with BMI or other body composition markers in the current study (Table 5 in Paper I).

A previous Icelandic study did not detect any sex difference in sleep duration (Thorleifsdottir et al., 2002). Others have reported heterogeneous results, showing longer sleep for either boys or girls (Olds et al., 2010; Tsai & Li, 2004) or no sex differences (Beijamini et al., 2008). In the present study, boys have later bedtimes on NSchD and later midpoint of sleep and rise times on both SchD and NSchD. Studies assessing adolescent DSP and bedtimes present mixed results and do not agree on whether boys or girls delay their bedtimes at a younger age (Fischer et al., 2017; Randler et al., 2017; Urbanek et al., 2018). Other studies show that sex differences in sleep preferences level off into adulthood (Fischer et al., 2017; Randler et al., 2017). Sex differences in sleep timing among 15-16 year old Icelandic adolescents could be a cultural difference between the sexes in preparedness (hair and/or make up) for school as girls' rise time is significantly earlier on SchD, although their bedtime is not later. A shorter sleep duration, delayed bedtime and poorer sleep quality has been linked to more screen time (Hale & Guan, 2015; Hale et al., 2018; LeBourgeois et al., 2017). The later sleep timing for boys on NSchd could possibly be explained by extracurricular activities such as sports, music or playing computer games. Data from the same cohort indicates that an increase in reported screen time (for both sexes) is associated with later bedtimes on NSchD ($\beta=0.195$, $p=0.002$) (Hrafnkelsdottir et al., 2020).

The primary sleep analysis was on the nightly sleep period. Although participants were instructed to log sleep periods, the sleep diary did not explicitly ask about napping; therefore, naptime was not included in the analyses, due to low incidence of naps detected in the actigraphy-data. A recent study found that 62% of adolescents napped during the day and both actigraphy-detected and self-reported naps were associated with shorter and more disrupted night-time sleep (Jakubowski et al., 2017). Despite its benefits in sleep analyses, actigraphy‘s specificity is limited (Marino et al., 2013), with no currently accepted criterion for scoring actigraphy-assessed naps (Jakubowski et al., 2017). Therefore, there were no validated automated methods or confirmatory logs to determine whether short periods of inactivity outside of the primary sleep period were naps.

Daylight has been found to influence adolescent sleep duration and quality; sleep duration increases during the winter and shortens during the summer (Nixon et al., 2008; Thorleifsdottir et al., 2002). In the present study, there was no correlation between daylight and rest duration, sleep duration or sleep efficiency despite an increase in daylight from 15.1 to 20.5 hours/day over the research period. A prior study on young Icelandic adults, aged 20, found no difference in sleep duration between the winter and summer months (Kristbjarnarson et al., 1985). Another Icelandic study from 2002 found a longer sleep duration between winter and spring among pre-school children, but not among older children or adolescents (Thorleifsdottir et al., 2002).

Our findings from this study provided objective evidence to support previous Icelandic studies based on questionnaires and sleep diaries. Together, Icelandic adolescents and other age groups have both later bedtimes and shorter sleep durations than their European peers (Brychta et al., 2016; Kristbjarnarson, 1985; Thorleifsdottir et al., 2002). The late bedtimes and rise times on NSchD further indicate that Icelandic adolescents may prefer later circadian profiles than required by current school schedules, which may be set to meet adult or societal schedules.

Actigraphy has its benefits in epidemiological studies and provides a more objective view on sleep than self-reporting. It is also less invasive and complicated than polysomnography (PSG) (Ancoli-Israel et al., 2003; Meltzer & Westin, 2011; Morgenthaler et al., 2007). Actigraphy analyzes sleep–wake patterns based on the absence or presence of movement. Thus, it cannot differentiate between the two when one lies still while awake or is asleep. Studies validating actigraphy against PSG in adolescents show good sensitivity in the detection of sleep and poor specificity in detecting wakefulness (Meltzer & Westin, 2011).

4.1.1 Summary of actigraphy-measured sleep characteristics in 2015

The first aim was to describe participants' sleep patterns and it was found that the majority of the adolescents did not get the recommended amount of sleep, especially during the school week. Despite longer sleep and rest duration over the weekend (with even later bedtimes and rise times), sleep quality did not improve. The adolescents seem to prefer late bedtimes, although their fixed early morning school schedule shortens their sleep from the other end. Although there was no sex difference in sleep duration and quality, sleep timing, especially on NSchD was later for boys.

4.2 Self-reported and actigraphy measured sleep

Comparison between self-reported and actigraphy-measured sleep is part of analyses in Paper III, and the main focus of Paper II. Despite the advantages of using wrist actigraphy to objectively assess sleep, the practicality and usability of self-reported sleep measures may be preferred in different areas. This study was a unique opportunity to test the comparability of these two methods in adolescents. Self-reported sleep duration and comparisons between self-reported and actigraphy-measured sleep are presented in Tables 7 and 8, respectively.

Table 7. Self-reported sleep duration in 2015 (Paper III)

Do you sleep enough?	Boys (n=106)	Girls (n=160)	All (n=266)
Sleep too much (n, %)	2 (1.9)	1 (0.6)	3 (1.1)
Most often get enough sleep (n, %)	53 (50.0)	83 (51.9)	136 (51.1)
Half of the time get enough sleep (n, %)	28 (26.4)	39 (24.4)	67 (25.2)
Seldom get enough sleep (n, %)	23 (21.7)	37 (23.1)	60 (22.6)

Abbreviations: n, number of participants. %, percentage.

Half of the subjects (51.1%) reported sleeping enough most of the time. Those who reported getting enough sleep, had on average longer actigraphy-measured sleep. Subjects who reported getting enough sleep, spent more time in bed (rest duration) and slept longer (sleep duration) according to accelerometer measures than those who reported not sleeping enough although only 23% fulfilled sleep recommendations.

Table 8. Self-reported vs actigraphy-measured sleep in 2015 (Paper III)

	Too Much (n=3)	Most often (n=136)	Half of time (n=67)	Seldom (n=60)	p
Actigraphy-measured sleep					
Rest duration (hours)	8.0 ± 1.2	7.7 ± 0.6	7.5 ± 0.7	7.2 ± 0.7	**<0.001**
Sleep duration (hours)	6.8 ± 1.0	6.7 ± 0.6	6.6 ± 0.8	6.4 ± 0.6	**0.017**
Sleep Efficiency (%)	85.7 ± 2.0	87.2 ± 4.3	88.0 ± 4.4	88.5 ± 3.6	0.149
Achieved >= 8 hours rest duration (n, %)	1.0 (33.3)	40.0 (29.4)	12.0 (17.9)	8.0 (13.3)	0.057

Abbreviations: vs, versus. n, number. %, percentage.

There was no difference in actigraphy-measured sleep efficiency between subjects who reported sleeping enough most of the time and subjects who reported not sleeping enough. Average sleep efficiency in the present study was above the National Sleep Foundation's (National Sleep Foundation, 2017) recommended percentage of 85% of sleep efficiency. Although over 52% of participants reported usually getting enough sleep, only 23% spent the recommended time in bed over the week according to actigraphy-measured rest duration.

4.2.1 Longitudinal changes and comparisons between self-reported and actigraphy measured sleep

Longitudinal changes and comparisons between actigraphy-measured and self-reported bedtimes in 2015 and 2017 (55 boys and 89 girls combined) are presented in Table 9. Bedtimes were later on NSchD than on SchD according to both actigraphy and self-reported measures at both time points. The pattern of later bedtimes on NSchD persisted according to both measures. Self-reported and actigraphy-measured bedtimes were correlated on SchD in 2015 (r=0.36) and 2017 (r=0.47) and on NSchD in 2015 (r=0.32) and 2017 (r=0.51), all p-values <0.001.

Table 9. Comparison of objective and subjective bedtimes from 2015-2017 (Paper II)

	2015	2017	Changes between 2015-2017	p-value (2015-2017)
School Night Bedtimes				
Self-report (clock time ± min)	23:31±57.1	23:57±59.0	26.2±60.7	**<0.001**
Actigraphy (clock time ± min)	00:19±46.1	00:55±61.0	35.2±59.2	**<0.001**
Self-report – Actigraphy (min)	-48.6±54.1	-57.5±67.7	-8.9±80.6	0.9
Non-school Night Bedtimes				
Self-report (clock time ± min)	01:0±68.2	01:33±75.5	28.1±79.9	**0.001**
Actigraphy (clock time ± min)	01:4±69.9	02:26±85.5	50.4±92.9	**<0.001**
Self-report – Actigraphy (min)	-31.4±68.1	-53.7±94.4	-22.2±113.2	**0.002**

Comparison between actigraphy-measured and self-reported bedtimes 2015-2017. Data presented in mean ± SD for 144 participants (55 boys and 89 girls). Abbreviations: min, minutes.

Subjective methods of collecting sleep data have been used to assess sleep patterns in the past (Lang et al., 2015). However, self-report tends to overestimate sleep length, suggesting that adolescent sleep is even shorter than previously reported (Arora et al., 2013). Although several studies have assessed the agreement between self-report by questionnaire and actigraphy-measured sleep (Arora et al., 2013; Biddle et al., 2015; Guedes et al., 2016; Wolfson et al., 2003), it is unclear whether the two methods have comparable sensitivity to measure longitudinal change in sleep patterns. The results presented here support this theory as self-reported bedtimes were, on average, >30 minutes earlier than actigraphy-measured bedtimes. Self-report used for this study qualitatively represented habitual sleep patterns and had reasonable sensitivity to differentiate groups with longer or shorter sleep and changes from 15 to 17 years. However, the lack of accuracy to measure bed and rise times and the inability of self-report to assess actual sleep versus wakefulness makes it less useful to quantify sleep quality or measure who meets the sleep recommendation. Prior studies using objective methods have reported comparably short sleep durations for adolescents (Matthews et al., 2012; Tonetti et al., 2015). However, the late bedtimes (01:19 o'clock) at age 17 are notably later than the reported bedtimes of similarly aged groups from other countries (Hysing et al., 2013; Knutson & Lauderdale, 2009). The late bedtimes may be due, in part, to a 1.5 hour mismatch between Iceland's geographical location and its GMT time zone (Thorleifsdottir et al., 2002).

Two different methods, self-report and actigraphy, have been used to assess adolescent sleep patterns, and each has its benefits (Galland et al., 2018; Lewandowski et al., 2011). Self-report is easier to administer, lower in cost and requires less technical expertise than actigraphy-measured sleep. However, it is often affected by social expectations and recall bias (Wolfson et al., 2003). Self-reported measures of sleep may include survey questions about usual sleep habits or nightly sleep logs (Knutson & Lauderdale, 2007). Although sleep logs have been found to be more reliable than survey questions (Arora et al., 2013; Werner et al., 2008), they are also more burdensome for participants and have lower compliance (Knutson & Lauderdale, 2007). Thus, survey questions can be beneficial in larger, nationally representative studies. Several studies have assessed the agreement between self-report by questionnaire and actigraphy-measured sleep in adolescents (Arora et al., 2013; Biddle et al., 2015; Guedes et al., 2016; Wolfson et al., 2003) and their results highlight practicality, expense and compliance when choosing a methodology to study sleep patterns in adolescents.

4.2.2 Summary of self-reported and actigraphy-measured sleep

The second aim was to assess the difference between self-reported and actigraphy-measured sleep. In a cross-sectional analysis on 15 year old adolescents (Paper III), subjects who reported getting enough sleep had longer actigraphy-measured rest and sleep duration than those who reported not sleeping enough. Only 23% of the adolescents fulfilled sleep recommendations.

A comparison between self-reported and actigraphy-measured bedtimes of adolescents at ages 15 and 17 years (Paper II), found reasonable sensitivity between and within subjects and confirmed that both methods are valuable in sleep research, although self-reported bedtimes tended to be earlier than actigraphy-measured bedtimes. The two-year changes in self-reported bedtime did not correlate with changes measured by actigraphy, as more varied sleep on NSchD in 2017 challenged the accuracy, reducing sensitivity to capture longitudinal changes.

4.3 Physical activity and sleep

The emphasis of Paper III is on physical activity and sleep. Additional analyses on PA and sleep are based on unpublished data.

4.3.1 Physical activity

In addition to sleep, PA is another important factor of health which can be measured by the same wrist actigraphy monitor. The actigraphy-measured PA assessed in 2015 is presented in Table 10. Both girls and boys had significantly higher actigraphy-measured PA on SchD than on NSchD. On NSchD, girls had higher actigraphy-measured PA than boys. There was no sex difference in actigraphy-measured PA on SchD or over the entire week (all days).

Table 10. Actigraphy-measured physical activity in 2015 (Paper III)

Physical Activity	SchD (mean ± SD)	NSchD (mean ± SD)	All Days (mean ± SD)	SchD vs NSchD p	Boys vs. Girls p	Interaction p
Boys	2215.2 ± 493.0	1645.8 ± 537.3	1991.8 ± 463.4	**<0.001**	0.13	**<0.001***
Girls	2180.4 ± 520.5	1857.4 ± 506.6	2049.4 ± 474.3			

Physical activity measured as 3D-counts/min/day. Girls >Boys on non-school days (p<0.01 for post hoc test).

Self-reported PA from the questionnaires is presented in Table 11. Participation in sports was high at 71.1%, with boys' and girls' participation rates of 76.4% and 67.5% respectively. Icelandic studies on PA and sports participation have recognized an increase in PA and sports participation among 14-15 year olds (an increase of 40% in 1992 to 60% in 2014) (Eithsdottir et al., 2008; Halldórsson, 2014). In the present study, a significantly higher proportion of boys (52.8%) than girls (36.9%) participated in sports or PA ≥6 hours per week. In a U.S. study based on data from Youth Risk Behavior Surveillance Surveys from 1991 to 2007, only two thirds of the adolescents reported sufficient vigorous-intensity PA, determined by a minimum of 20 min of activity which made them breathe hard and sweat at least three times per week (Li et al., 2010).

Table 11. Self-reported physical activity and sports participation in 2015 (Paper III)

Subjective variables	Boys (n=106)	Girls (n=160)	All (n=266)	Boys vs Girls p-value (χ^2 Test)
Physical Activity				
Participate in organized sports (n, %)	81 (76.4)	108 (67.5)	189 (71.1)	0.15
Participate in physical activity or sports >6hrs/week (n, %)	56 (52.8)	59 (36.9)	115 (43.2)	**0.01**
Physical activity where you sweat or breath hard >6days/week (n, %)	42 (39.6)	47 (29.4)	89 (33.5)	0.11

Abbreviations: n, number of participants. %, percentage. P-value is calculated with χ^2 test between sexes.

The accuracy of self-reporting is influenced by the ability of the respondent to accurately recall all relevant activities. Therefore, it is subject to recall bias and may be influenced by the opinions and perceptions of the subject (Ekelund et al., 2011). In addition, different self-report methods from various questionnaires make results hard to compare. There was agreement between actigraphy-measured and self-reported PA. When self-reported and actigraphy-measured PA was compared for all days of the week, those with higher self-reported PA had, on average, 21.5% higher actigraphy-measured PA than those who reported lower PA. The comparison between actigraphy-measured and self-reported PA is presented in Table 12.

With actigraphy-measured PA, results did not differ between the sexes on SchD, but girls had higher actigraphy-measured PA on NSchD. School-based activity, such as physical education and/or outdoor classes, could possibly explain similar actigraphy-measured PA on SchD. As the questionnaire asked for PA during the whole week, self-report data could not be analyzed specifically for SchD and NSchD. When self-reported PA was used as an indicator of fulfilling the recommendation for MVPA over the week, 43.2% reported participating in PA more than 6 times a week and 33.5% reported intensity levels of sweat or hard breathing

Table 12. Actigraphy-measured vs self-reported physical activity (Paper III)

	Objective Accelerometer Results, 3D Activity Counts (mean+/- SD)						Yes/ No	Boys/ Girls	Inter-action
	Boys		Girls		All				
	Yes	No	Yes	No	Yes	No	p	p	p
Subjective Questionnaire Information									
Participate in organized sports	2099.4±438.9	1643.3±363.2	2160.4±474.0	1818.8±386.9	2134.3±459.1	1761.8±385.9	**<0.001**	0.097	0.359
Participate in physical activity or sports >6hrs/week	2134.7±398.3	1831.8±482.3	2171.1±481.2	1978.3±457.8	2153.4±441.3	1929.8±469.6	**<0.001**	0.099	0.343
Physical activity where you sweat or breath hard	2148.6 434.7	1888.9±455.8	2240.2±475.6	1970.1±452.6	2197.0±456.5	1940.7±454.2	**<0.001**	0.140	0.931

Abbreviations: vs, versus. 3D Activity Counts, 3D-counts/min/day. SD, Standard deviation.

In a review study by Eklund et al,, including studies with both objective and subjective measurements, it appears that approximately 30–40% of youth are meeting current PA guidelines although the authors estimate that self-reported methods are overestimating objectively measured PA by 72% (Ekelund et al., 2011).

There are no known standards or guidelines for interpreting or comparing intensity (Reilly et al., 2008) of wrist accelerometer data yet. Cut-off points for classifying MVPA in children and adolescents have not been determined (Y. Kim et al., 2012), which makes comparisons between studies difficult, because of difference in measurement tools. Nonetheless, an older study (2011) on Icelandic adolescents using hip-worn accelerometers (ActiGraph 7124) found a sex difference (4.5% of the boys and only 1.5% of the girls) between those who fulfilled daily recommended PA (counts/min/day) (Magnusson et al., 2011). While straightforward numerical comparison is impossible because of divergencies in measurement tools (wrist and hip actigraphy), there seem to be less sex differences in actigraphy-measured PA in 2015.

Despite self-reported measures of PA being less dependable than objective measures (Adamo et al., 2009) and having lower accuracy due to recall bias (Ekelund et al., 2011), self-reported measurements can be useful for estimating different types of PA and categorizing PA levels (Corder et al., 2008; Slinde et al., 2003). Accurate and valid methods for measuring intensity and types of PA are lacking for comparisons between studies and for determining the dose–response associations between PA and health outcomes (Wareham & Rennie, 1998).

There was positive correlation between hours of daylight and actigraphy-measured PA over the entire week in 2015 for all participants (r=0.22, p=0.005) and for girls (r=0.18, p=0.004) but not for boys separately in date collection 2015 (spring months). Data collection took place in the spring months of 2015. Spring daylight in Reykjavík goes hand-in-hand with higher temperatures. Weather and longer evenings have been studied for possibly influencing PA in children and adolescents. Those studies found that seasons with higher rain, winds, and snow and lower temperatures result in lower PA (Rich et al., 2012). A Norwegian study found no difference in PA between seasons for adolescents, although they had higher odds of meeting the PA recommendations in spring than in winter (Kolle et al., 2009).

4.3.2 Associations between physical activity and sleep

PA during the day and sleep at night are both important for health, but do they influence each other? The relationships between sleep and PA, with both self-reported and actigraphy-measured data, yielded mixed results. The study found no difference in sleep parameters between those who reached recommended levels of PA (self-reported PA) and those who did not. In further analysis, with actigraphy measures on both sleep and PA, increased PA was related to shorter sleep duration but slightly higher sleep quality and less variable sleep.

The current study found no significant relationship between actigraphy-measured PA and self-reported sleep, as seen in the bottom line of Table 13. Those reporting enough sleep did not have higher actigraphy-measured PA. In addition, adolescents with higher self-reported PA did not have significantly different actigraphy-measured sleep duration than those who reported less PA.

The comparison between actigraphy-measured sleep and PA across categories of self-reported PA is presented in Table 13. Only 11.3% of the participants fulfilled both recommendations for sleep (≥8 hours of rest duration) and PA (≥6 hours/week of self-reported PA) over the entire week and even fewer (10.9%) when sleep was limited to SchD. Adolescents with higher self-reported PA (≥6 hours/week) did not have significantly longer sleep than those who did PA ≤6 hours/week.

Table 13. Actigraphy-measured sleep and PA vs self-reported sleep and PA (Paper III)

	Participate in organized sports			**Participate in physical activity or sports >6hrs/week**			**Physical activity where you sweat or breath hard >6days/week**		
	Yes (n=189)	**No** (n=77)	**p**	**Yes** (n=115)	**No** (n=151)	**p**	**Yes** (n=89)	**No** (n=177)	**p**
Actigraphy-measured sleep									
Rest duration (min)	7.5 ± 0.7	7.6 ± 0.7	0.422	7.6 ± 0.7	7.6 ± 0.7	0.888	7.5 ± 0.6	7.6 ± 0.7	0.582
Sleep duration (min)	6.6 ± 0.6	76.7 ± 0.7	0.492	6.6 ± 0.6	6.6 ± 0.6	0.729	6.5 ± 0.6	6.6 ± 0.6	0.198
Sleep Efficiency (%)	87.7 ± 4.0	87.7 ± 4.6	0.939	87.8 ± 4.0	87.6 ± 4.4	0.813	87.1 ± 4.2	88.0 ± 4.2	0.089
Achieved >= 8Hrs TRT (n, %)	42 (22.2)	19 (24.7)	0.673	30 (26.1)	31 (20.5)	0.293	20 (22.5)	41 (23.2)	0.899
Achieved >= 8Hrs TST (n, %)	2 (1.1)	3 (3.9)	0.229	1 (0.9)	4 (2.6)	0.259	0 (0.0)	5 (2.8)	0.025
				Do you sleep enough?					
	Too Much (n=3)		**Most often (n=136)**		**Half of time (n=67)**		**Seldom (n=60)**		
Actigraphy-measured PA	2037.1 ± 301.5		2049.3 ± 441.5		1967.1 ± 540.8		2040.4 ± 458.7		0.697

Abbreviations: n, number. %, percentage. PA, physical activity.

Additional data analyses found that actigraphy-measured sleep duration was negatively associated with actigraphy-measured PA for SchD and NSchD, indicating shorter sleep for those with higher PA (Table 14). However, variability in sleep duration was lower between SchD and NSchD for individuals with higher PA. The sleep quality marker, WASO, was negatively associated with PA on NSchD with a trend towards the same association on SchD, indicating less time awake after sleep onset on all days for those with higher PA.

Table 14. Associations between actigraphy-measured physical activity and sleep (Unpublished data)

	Physical activity all days			**Physical activity on SchD**			**Physical activity on NSchD**		
Actigraphy-measured sleep	**β**	**SE**	**p**	**β**	**SE**	**p**	**β**	**SE**	**p**
Sleep duration (min)	-3.49	0.71	**0.000**	-2.02	0.71	**0.005**	-2.23	0.48	**0.000**
Variability in sleep duration (min)	-1.68	0.76	**0.028**	-1.87	0.82	**0.022**			
Sleep efficiency (%)	3.21	6.79	0.637	1.77	6.93	0.799	3.41	6.71	0.612
WASO (min)	-2.53	1.35	0.062	-1.92	1.44	0.181	-2.33	1.17	**0.047**
Day length (min)	0.76	0.25	**0.002**	0.54	0.27	**0.046**	0.79	0.28	**0.006**

Abbreviations: SchD, school days, NSchD, non-school days, WASO, wakening after sleep onset

The negative association between PA and sleep duration suggests that PA may be displacing sleep for more active individuals. However, greater PA was also associated with fewer minutes of wakefulness and a less variable sleep schedule, indicating better sleep quality. These findings suggest, as others have (Kalak et al., 2012; Lang et al., 2013; McNeil et al., 2015), that PA is important for good sleep quality, but adolescents should consider sleep guidelines more closely when designing their physical activity schedule. Future studies should test how changes in sleep patterns might influence PA. The study supports the proposition that PA may have positive effects on adolescent sleep quality, although further studies with objective measures are needed, particularly on sleep duration and timing. The results are in line with another study using actigraphy to measure both PA and sleep duration in adolescents (McNeil et al., 2015) where higher actigraphy-measured PA was associated with shorter actigraphy-measured sleep duration. Higher PA was associated with better sleep quality as measured by less sleep variability and WASO, indicating less variable sleep and shorter wakefulness after sleep onset with higher actigraphy-measured PA.

A meta-analytic review of the effects of PA on sleep found that regular exercise has a small beneficial effect on sleep duration and sleep efficiency for adults (Kredlow et al., 2015). The increased fatigue and tiredness associated with sleeping too little could result in reduced voluntary PA for some individuals. For example, decreased daytime spontaneous PA in healthy men was followed by a short-term sleep restriction (2 nights of 4 hours in bed) (Schmid et al., 2009). In prior studies on the association between PA and sleep, increased PA was found to be favorably associated with sleep duration (Youngstedt & Kline, 2006) and sleep quality (Kalak et al., 2012; Lang et al., 2013). In a recent study on Icelandic swimmers aged 16 and older, the subjects had longer sleep duration and lower WASO measured with accelerometers (GT3X+) on nights after a higher training load of morning and evening practices as compared with nights following days with lower training loads (Gudmundsdottir, 2019). NSF recommends regular PA for promoting better sleep (National Heart Lung and Blood Institute, 2012a; National Sleep Foundation), although studies among children and adolescents do not agree on the association between sleep and PA (Olds et al., 2011; Ortega et al., 2011; Stone et al., 2013). Objective studies on the relationship and association between PA and sleep are lacking, especially those using objective measures for both PA and sleep (Lang et al., 2013).

In previous subjective studies on the association between sleep and PA, PA has been found to be positively correlated with sleep duration (Lang et al., 2015; Youngstedt & Kline, 2006). Children from 10-12 years old who fulfilled sleep recommendations were also more likely to maintain a regular and healthy PA routine (Stone et al., 2013). Recent meta-analysis on sleep and PA among children, 3-13 years old, found limited association between sleep and PA in children, although children engaging in vigorous PA, had better overall sleep (Antczak et al., 2020). A recent review concluded that children and adolescents who maintain regular sleep and PA routines were in better shape and likelier to have a more favorable body composition than those who had both less PA and sleep (Saunders et al., 2016). Different measures, guidelines, weather, seasons and age of the study population could explain different outcomes for the association between sleep and PA.

4.3.3 Summary of physical activity and sleep

The third aim of the thesis was to assess the proportion of participants that fulfilled recommendations for PA and sleep as well as the possible associations between the two parameters. The proportion of adolescents meeting recommended levels of PA and sleep was assessed and only 11.3% of the participants were found to have fulfilled both recommendations. The study found no difference in sleep parameters between those who reached recommended levels of PA (self-reported PA) and those who did not (Paper III). In further analysis, with actigraphy measures on both sleep and PA, increased PA was related to shorter sleep duration but slightly higher sleep quality and less variable sleep (Unpublished data). The results highlight the importance of studying and defining various parameters of both sleep and PA for health outcomes.

4.4 Actigraphy-measured sleep, body composition and metabolic factors in 2015

The study data presented a wide range of body composition and other metabolic factors which allowed us to explore whether there was any association between sleep and health parameters in these adolescents. Participants' mean BMI was 21.9±3.0 kg/m^2 and did not differ between the sexes. The majority of the subjects (87%) had BMI below 25 kg/m^2. The prevalence of overweight (25$\leq$ BMI <30 kg/m^2) was 10%, and 2.5% were obese (BMI $\geq$ 30 kg/m^2) (World Health Organization, 2018). Mean values for body composition and metabolic risk factors are presented in Table 15.

Table 15. Participants' body composition in 2015 (Paper IV)

	All (252)	Boys (106)	Girls (146)	p (Boys vs Girls)
Characteristics				
Age, years	15.8 ± 0.3	15.8 ± 0.3	15.9 ± 0.3	0.12
Height, cm	172.0 ± 8.0	178.5 ± 6.0	167.3 ± 5.6	**<0.001**
Weight, kg	64.8 ± 10.6	68.9 ± 10.3	61.9 ± 9.7	**<0.001**
Body mass index, kg/m^2	21.9 ± 3.0	21.6 ± 2.9	22.1 ± 3.1	0.21
Body fat, %	25.1 ± 8.6	18.2 ± 6.6	30.2 ± 5.9	**<0.001**
Trunk fat, %	23.6 ± 9.6	17.0 ± 7.8	28.3 ± 7.8	**<0.001**
Waist circumference, cm*	70.6 ± 7.1	73.5 ± 6.2	68.6 ± 7.1	**<0.001**

Data presented as mean ± standard deviation; *250 participants (105 Boys, 145 Girls); Boldface type indicates significant difference (p<0.05).

There are many different approaches for body composition assessment, but the most popular method is BMI (kg/m^2). Its popularity derives from its ease of use for measurement, and how well it correlates with body fat percentage (Wellens et al., 1996). BMI can be useful in estimating the prevalence of obesity in population-based studies (World Health Organization, 2000) although BMI has drawbacks in accuracy since it does not differentiate between fat and muscle tissue (Prentice & Jebb, 2001) and thus different levels of both fat mass and fat-free mass may result in the same BMI value. The differences in BMI among thinner children and adolescents can thus be largely due to differences in fat-free mass. Body composition differs between the sexes as fat mass is higher among girls and fat-free mass is higher among boys (Freedman et al., 2005). In this study, although body composition differed significantly by sex, the results were largely in line with previous findings in adolescence (McCarthy et al., 2006; Morelli et al., 2020; Ripka et al., 2020).

Average actigraphy-measured sleep parameters (sleep duration, rest duration, bedtime, rise time or other sleep quality markers) were not associated with any of the body composition variables included in our study. However, night-to-night variability in sleep duration was positively associated with both percentage body fat and percentage trunk fat. WASO was positively associated with systolic blood pressure. PA was negatively associated with percentage trunk fat and insulin. The associations of sleep variability and PA parameters with metabolic measures, adjusted for sex, parental education and day length are presented in Table 16. All significant associations persisted when average sleep duration, WASO, nightly sleep variability and PA were included in the same model (Table 16, combined model).

Table 16. Association of metabolic risk factors to physical activity and sleep duration, quality, and variability

	Sleep duration β ± SE (p)	WASO β ± SE (p)	Variability in sleep duration, β ± SE (p)	Physical activity β ± SE (p)
Body mass index, kg/m^2				
Individual model	-0.201 ± 0.262 (0.44)	-0.812 ± 0.529 (0.13)	0.612 ± 0.332 (0.07)	0.567 ± 0.394 (0.15)
Combined model	-0.274 ± 0.26 (0.29)	-0.888 ± 0.529 (0.09)	0.518 ± 0.328 (0.12)	0.542 ± 0.382 (0.16)
Trunk fat, %				
Individual model	-0.675 ± 0.674 (0.32)	-2.427 ± 1.361 (0.08)	**1.854 ± 0.854 (0.03)**	**-2.057 ± 1.014 (0.04)**
Combined model	-0.434 ± 0.677 (0.52)	-2.189 ± 1.378 (0.11)	**2.161 ± 0.847 (0.01)**	**-2.115 ± 0.989 (0.03)**
Total body fat, %				
Individual model	-0.695 ± 0.537 (0.20)	-1.885 ± 1.084 (0.08)	**1.606 ± 0.680 (0.02)**	-1.478 ± 0.808 (0.07)
Combined model	-0.521 ± 0.539 (0.33)	-1.722 ± 1.098 (0.12)	**1.824 ± 0.673 (0.01)**	-1.514 ± 0.789 (0.06)
Waist circumference, cm				
Individual model	-0.202 ± 0.594 (0.73)	-1.729 ± 1.206 (0.15)	1.049 ± 0.765 (0.17)	-0.422 ± 0.894 (0.64)
Combined model	-0.169 ± 0.587 (0.77)	-1.724 ± 1.200 (0.15)	1.134 ± 0.752 (0.13)	-0.473 ± 0.867 (0.59)
Diastolic pressure, mmHg				
Individual model	0.202 ± 0.484 (0.68)	0.774 ± 0.982 (0.43)	0.156 ± 0.623 (0.80)	-0.964 ± 0.728 (0.19)
Combined model	0.319 ± 0.476 (0.50)	0.879 ± 0.978 (0.37)	0.284 ± 0.613 (0.64)	-1.089 ± 0.701 (0.12)
Systolic pressure, mmHg				
Individual model	1.045 ± 1.095 (0.34)	**4.865 ± 2.221 (0.03)**	-1.824 ± 1.408 (0.20)	0.835 ± 1.646 (0.61)
Combined model	0.987 ± 1.086 (0.36)	**4.865 ± 2.213 (0.03)**	-2.015 ± 1.395 (0.15)	0.642 ± 1.608 (0.69)
Glucose, mmol/L				
Individual model	-0.077 ± 0.042 (0.07)	-0.022 ± 0.086 (0.80)	-0.008 ± 0.054 (0.88)	-0.026 ± 0.064 (0.68)
Combined model	-0.074 ± 0.041 (0.08)	-0.020 ± 0.085 (0.82)	-0.008 ± 0.053 (0.89)	-0.002 ± 0.061 (0.97)
Insulin, mU/L				
Individual model	0.015 ± 0.409 (0.97)	-0.726 ± 0.826 (0.38)	0.558 ± 0.516 (0.28)	**-1.813 ± 0.613 (0.003)**
Combined model	0.255 ± 0.410 (0.53)	-0.486 ± 0.839 (0.56)	0.851 ± 0.513 (0.10)	**-1.901 ± 0.588 (0.001)**

Sleep duration is in units of hours/nights; WASO: wake after sleep onset, in hours/night; Variability in sleep duration is in units of hours; Physical activity is in units of 1000 counts/minutes of wear/day; Individual models adjusted for sex, parental education, and day length; Combined models include sleep duration, WASO, nightly variability in sleep duration, physical activity, sex, parental education, and day length; Boldface type indicates significant relationships ($p<0.05$).

In addition to the general sleep recommendations of 8-10 hours of sleep nightly (Max Hirshkowitz et al., 2015), consistency in bedtime and wake times (good sleep routine) during the week is recommended for health (Gruber et al., 2014).Variability in sleep timings can be used as a proxy for regularity in sleep schedule as it measures the variances of the individual mean timing. Associations have been found between sleep duration in obese adolescents and glucose homeostasis, as well as associations between sleep quality and insulin secretion (Koren et al., 2011). In the present study, sleep variability was associated with body composition (total fat percentage and trunk fat percentage) and WASO was associated with systolic blood pressure. Studies have indicated that good sleep routines, along with PA, prevent insulin resistance (Dorenbos et al., 2015). Higher values of PA, in the present study, were associated with lower trunk fat percentage and lower insulin. In a study on Icelandic adolescents from 2011, higher levels of MVPA were associated with more favorable body composition (Magnusson et al., 2011). Moreover, PA has been recognized for centuries as a preventive and therapeutic agent for overall metabolic health (Myers et al., 2019).

High variability in sleep duration is known to negatively impact body composition (Golley et al., 2013), highlighting the importance of consistency in sleep routines for adolescents (Gruber et al., 2014). In the present study, variability in sleep duration across SchD was independently associated with both percentage body fat and percentage trunk fat. Our results are consistent with a previous study from He et al. (2015) on variability in sleep and body composition in adolescents, where results showed that objectively measured sleep variability was associated with central obesity. In that study, the high variability was explained by weekday versus weekend variability. However, the present study identifies these same associations when restricting the analyses to nightly variability within SchD, highlighting the importance of studying sleep variability further. In an additional analysis on sleep timing, Table 17, nightly bedtime variability was association of metabolic risk factors.

Table 17. Association of metabolic risk factors to average bedtime and nightly variability in bedtime

	Bedtime β ± SE (p)	Variability in bedtime β ± SE (p)
Body mass index, kg/m²		
Individual model	0.222 ± 0.221 (0.31)	0.622 ± 0.327 (0.06)
Combined model	0.182 ± 0.220 (0.41)	0.632 ± 0.328 (0.06)
Trunk fat, %		
Individual model	0.454 ± 0.576 (0.43)	**2.286 ± 0.844 (0.007)**
Combined model	0.396 ± 0.567 (0.49)	**2.151 ± 0.843 (0.011)**
Total body fat, %		
Individual model	0.479 ± 0.458 (0.30)	**2.096 ± 0.669 (0.002)**
Combined model	0.417 ± 0.450 (0.36)	**1.987 ± 0.669 (0.003)**
Waist circumference, cm		
Individual model	0.069 ± 0.501 (0.89)	**1.483 ± 0.734 (0.044)**
Combined model	0.011 ± 0.501 (0.98)	**1.463 ± 0.740 (0.049)**
Diastolic pressure, mmHg		
Individual model	-0.093 ± 0.407 (0.82)	-0.299 ± 0.601 (0.62)
Combined model	-0.046 ± 0.408 (0.91)	-0.349 ± 0.603 (0.56)
Systolic pressure, mmHg		
Individual model	-1.342 ± 0.926 (0.15)	**-3.017 ± 1.359 (0.03)**
Combined model	-1.223 ± 0.924 (0.19)	**-2.865 ± 1.365 (0.04)**
Glucose, mmol/L		
Individual model	0.041 ± 0.035 (0.24)	0.028 ± 0.053 (0.60)
Combined model	0.041 ± 0.036 (0.26)	0.025 ± 0.053 (0.64)
Insulin, mU/L		
Individual model	0.068 ± 0.349 (0.85)	0.179 ± 0.523 (0.73)
Combined model	0.095 ± 0.343 (0.78)	0.062 ± 0.516 (0.91)

Bedtime is in units of hours from midnight; Variability in bedtime is in units of hours; Individual models adjusted for sex, parental education, and day length; Combined models include bedtime, nightly variability in bedtime, physical activity, sex, parental education, and daylength; Boldface type indicates significant relationships ($p<0.05$).

Mean bedtime was not associated with any of the body composition or metabolic parameters after adjusting for sex, parental education and day length. However, using the same covariates, bedtime variability was positively associated with WC and total body and trunk fat percentage and negatively associated with systolic blood pressure. All significant relationships persisted when average bedtime and nightly bedtime variability were included in a combined model adjusted for PA, sex, parental education and day length.

The lack of an association between average sleep on SchD, NSchD and average sleep duration over the entire week may, in part, be due to the small and homogeneous study sample, which had a relatively low prevalence of obesity (<3%), combined with a high prevalence of short sleep (~88%). The prevalence of overweight and obesity in 2015 was 13.3% (9.8% of boys and 15.7% of the girls). The study sample in 2015 had a lower prevalence of overweight and obesity as compared to a study in the Reykjavík area from 2011 (23% of boys and 21% of girls) (Jonsson et al., 2011) and a national comparison from 2010 (23% among boys and 18% among girls) (Currie C., 2012).

Studies that focus on the association between sleep duration and body composition in adolescents have shown inconsistent results. Subjectively measured sleep duration has been found to be associated with body composition (Cappuccio et al., 2010; Chaput & Janssen, 2016; Fatima et al., 2015; Garaulet et al., 2011; Knutson & Lauderdale, 2009; Megdal, 2007; Roenneberg et al., 2012), but objectively measured sleep quality and/or or sleep variability has been found to be associated with body composition (He et al., 2015; Jansen et al., 2018). It can be speculated that the association between sleep variability and increased body fat may not only be related to the well-known delay of sleep timing during weekends but also to irregular bedtimes and sleep durations on SchD. This indicates that researchers cannot assume that simply asking adolescents about their usual bedtime or sleep duration during SchD is enough to measure their sleeping patterns, particularly in relation to health-related outcomes.

The potential causal pathways between irregular sleep patterns and increased body fat are not clear. Sleep timing affects the regulatory hormone cortisol and growth hormone, as well as the appetite regulatory hormones leptin and ghrelin (Leproult & Van Cauter, 2010). Leptin levels show a minimum value in the morning and maximum value towards night (Leproult & Van Cauter, 2010), while ghrelin levels decrease during the second part of the night (Leproult & Van Cauter, 2010). A high variability in sleep schedule may affect appetite control and contribute to higher values in body composition markers. Chaput et al. (2012) point out that sleep, although the most sedentary behavior, is associated with leanness and that the energy intake associated with short sleep duration might be driven by hedonic rather than hormonal factors (Chaput, 2014; Chaput & St-Onge, 2014). Whether insufficient sleep results in adverse food consumption, or simply allows for more time available to eat, is still to be determined (Chaput, 2014).

Adolescents who have difficulty with sleep continuity or duration in adolescence years usually have issues continuing into adulthood (Dregan & Armstrong, 2010), highlighting the importance of good and consistent sleep routines from youth to adulthood. Consequently, sleep guidelines for adolescents also recommend that adolescents maintain consistent bedtimes and waking times during the week for overall health benefits (Gruber et al., 2014).

4.4.1 Summary of associations between sleep, physical activity and body composition

The fourth aim, from Paper IV, was to explore potential associations between sleep, PA, body composition and metabolic risk factors. Although sleep duration was not associated with any body composition variables or metabolic risk factors, variability in sleep and bedtime on SchD was, suggesting that not only the quantity and quality, but also the regularity of sleep may be important to adolescents' health. Higher PA was associated with more favorable body composition and metabolic profile and less variable sleep duration. The results highlight the importance of a regular sleep and PA schedule over the week for metabolic health benefits.

4.5 Strengths and limitations

This study has several strengths, one of which is the high participation rate at baseline (n=315, 77%) and this group represents 23% of the 15 year old adolescents living in Reykjavík in 2015 (1,355) (Statistics Iceland, 2018). High baseline participation can partly be explained by the data sampling process, since data was collected at the participants' schools during school hours. However, considerably fewer subjects (n=148) had valid data at both time points 2015 and 2017. A limitation to the study is low participation of repeating subjects in 2017. Participation in 2017 was based on a different study population as individuals with available data from two previous studies, HHUI and EYHS were invited to participate. The lower participation rate of repeating subjects in 2017 could be due to a different location of the study lab, subjects moving from elementary to secondary schools or changes in residential locations. Papers (I, III and IV) are cross-sectional in nature and this limits the opportunity to study causal relationships between study parameters as the temporal order of those is not clear. However, the data in paper II is based on longitudinal tracking of data from 2015 and 2017 allowing us to identify patterns of study variables over time.

Another strength of the study was the use of objective measures of sleep, PA and body composition. The Actigraph accelerometer (Actigraph Inc. Pensacola Florida) is one of the most widely used devices of its kind in sleep and activity research. The use of a wrist accelerometer to assess both PA and sleep parameters is less of a burden than a hip accelerometer for young subjects (Hjorth et al., 2012). Accelerometers from Actigraph have been extensively validated and are found to be reliable and easy to use (Ekelund et al., 2001; Freedson et al., 2005; Trost et al., 2005; Trost et al., 1998). Although wrist actigraphy has high accuracy and sensitivity compared to PSG, its specificity is limited (Marino et al., 2013), and there is currently no accepted criterion for scoring actigraphy-assessed naps (Jakubowski et al., 2017).

In sleep research, accelerometry has benefits in epidemiological studies, as it provides a more objective view on sleep than self-report and is less invasive and complicated than PSG (Ancoli-Israel et al., 2003; Meltzer & Westin, 2011; Morgenthaler et al., 2007). Studies validating actigraphy against PSG in adolescents show good sensitivity in detection of sleep and poor specificity in detecting wakefulness (Meltzer & Westin, 2011; Quante et al., 2018) and identifying sleep onset latency (Martin & Hakim, 2011; Sivertsen et al., 2006). Despite the drawbacks of using actigraphy, it has a relatively high participant-specific accuracy and is both useful and valid in estimating sleep in population based studies (Marino et al., 2013). The sleep quality marker, WASO, correlates well with PSG population based studies and provides useful information about sleep in one's natural environment.

The advantage of DXA scanning for assessing body composition is its high accuracy in classifying different body tissues (Andreoli et al., 2009; Dezenberg et al., 1999; Fusch et al., 1999) and a very low dose of radiation (Pietrobelli et al., 1998).

The main limitations include the following: The accelerometer, our principal assessment tool for PA, cannot discriminate between being sedentary and physically active if no movement occurs at the part of the body where the monitor is placed (Hildebrand et al., 2016). Also, accelerometers cannot distinguish between postural differences (Davies et al., 2012), such as standing, sitting or lying, and individual movements in a free-living scenario do not always compare directly to movements used in laboratory settings (Hildebrand et al., 2016). Although measurements of PA with accelerometers have been found to correlate positively with energy expenditure (r=0.8) (Ekblom et al., 2012), cut-points for fair recommendations and individual comparison are not readily available. Also, as a measure of sleep, wrist actigraphy has an estimated accuracy of 87% as compared to the gold-standard PSG performed in a controlled sleep lab (Marino et al., 2013), so some inaccuracy and precision could be introduced.

This study only targeted healthy Icelandic adolescents living in and around the capital Reykjavík area, which may limit its generalizability to other geographical areas and age groups.

5 Conclusion

Insufficient sleep has been linked to a variety of serious health issues, such as metabolic disorders including obesity and diabetes. PA has also been linked to both physical and mental health and wellbeing, and exercise has been prescribed since ancient times to promote metabolic health. As technological advances have paved the way for non-invasive and free-living sleep measurements, this study used wrist-worn actigraphy monitoring devices to measure free-living, 24-hour sleep and PA patterns in adolescents. In summary, results of the thesis highlight patterns of sleep and PA in Icelandic youth, two modifiable behaviors of great importance for health. Most adolescents did not get enough sleep during school nights. This, together with insufficient PA, could negatively impact their future health. This study provides the foundation for future follow-up studies and potential targets for intervention studies, while serving as a reference for public health specialists, educators, and parents to support good sleep and activity practices.

6 Future perspectives

The findings presented in this thesis were mostly based on cross-sectional and observational data on free-living sleep and PA in healthy 15 and 17 year old adolescents. Since health effects from sleep and PA may take years to manifest, we hope to follow these well-characterized subjects at multiple time points into adulthood to evaluate the prospective changes in sleep, PA and other health parameters. With a longitudinal perspective, the impact on health parameters derived from sleep and PA would reveal potential causal inferences. Interventions in sleep hygiene, such as sleep extensions or keeping regular schedules for bedtime and rise time for less variable sleep, would be necessary to test specific mechanisms.

The reports of short sleep duration from our study, suggesting both late bedtimes and early rise times in Iceland, have raised concerns among official health authorities and generated policy discussions on sleep within the society, particularly for children and adolescents. These issues are centered around the debate as to whether Iceland should adapt its time zone to its geographic location (GMT-1 hour). Such a change would offer the opportunity for a unique “natural experiment” to re-measure sleep among 16-18 year old adolescents to compare sleep duration, timing and quality, as well as PA, along with comparisons to our findings. For assessing seasonal effect on sleep and PA in Iceland, actigraphy-measures from different seasons could test seasonal effect on sleep and PA. School-based interventions, such as adjusting time schedules to a later school start or moving sports practices after school or earlier in the afternoon, or individual interventions to improve sleep hygiene, could also be designed and tested in the future for children and adolescents.

As with other studies by our group, we have collected many aspects of data in various domains in this study. Investigations are currently ongoing to explore the changes of sleep and PA at ages ranging from 15 to 17 years, and investigate whether they are linked to both physical and mental health, as well as whether other factors, such as sedentary behavior/screen times, exercise/sports participations, day lengths, and school choices may influence these parameters and their relationships.

We should also compare current results to other studies around the globe to assess whether unique internal and external factors in Iceland (genetic, cultural, day length, weather etc.) could influence sleep and activity deficiencies. More clinical sleep studies, using in-home PSG techniques, could enhance our ability to investigate sleep architecture and sleep disorders to investigate further short sleep duration, late bedtimes, variable sleep in relation to behavior and health outcomes in adolescents and other age populations in Iceland.

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Paper I

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Original Article

Sleep deficiency on school days in Icelandic youth, as assessed by wrist accelerometry

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ABSTRACT

Aims: The purpose of this study was to objectively measure, with wrist-worn actigraphy, free-living sleeping patterns in Icelandic adolescents, and to compare sleep duration, sleep quality and clock times between school days (SchD) and non-school days (NSchD) and the association between sleep and body mass index (BMI).

Methods: A cross-sectional study on 15.9-year-old (±0.3) adolescents from six schools in Reykjavík, Iceland, took place in the spring of 2015. Free-living sleep was measured on 301 subjects (122 boys and 179 girls) over seven days using wrist-worn actigraphy accelerometers. Total rest time (TRT), total sleep time (TST), sleep quality markers, and clock times for sleep were quantified and compared between SchD and NSchD and between the sexes, using paired and group *t*-tests as appropriate. Linear regression was used to assess the association between sleep parameters and BMI.

Results: On SchD, TST was 6.2 ± 0.7 h, with sleep efficiency (SLE) of 87.9 ± 4.4% for the group. On NSchD, TST increased to 7.3 ± 1.1 h ($p < 0.001$), although SLE decreased to 87.4 ± 4.7% ($p < 0.05$). On SchD and NSchD, 67% and 93% had bed times after midnight, respectively, and on SchD 10.7% met sleep recommendations (8 h/night). There was no association between BMI and average sleep parameters.

Conclusion: The majority of Icelandic adolescents did not get the recommended number of hours of sleep, especially on SchD. While TST increased on NSchD, many participants still did not achieve the recommendations. These findings provide information on the sleep patterns of adolescents and may serve as reference for development of policies and interventions to promote better sleep practices.

1. Introduction

Sleep plays an important role in adolescents' health and well-being. Adequate sleep is an essential element for proper function of body and mind, which influences quality of life. The National Sleep Foundation recommends that teenagers, aged 14–17 years old, should sleep at least 8–10 h a night [1]. Inadequate sleep duration in adolescents is associated with higher body mass index (BMI) [2,3], greater body fat [4], increased insulin resistance [5], and reduced academic performance [6].

A previous study using questionnaires and sleep diaries found that Icelandic youth had shorter sleep duration than their European peers [7]. Although subjective, self-report methods were commonly used in the past to assess adolescent sleep patterns [8], they tend to overestimate actual sleep length, suggesting that adolescents may sleep even less than previously reported [9]. Wrist actigraphy is an objective method of studying free-living sleep patterns via a watch-like accelerometer and well-validated sleep detection algorithms [10–14]. Although an actigraphy based sensor using the chosen algorithm has been validated against polysomnography (PSG), this specific device is newer to the market and has only been used in conjunction with PSG in other populations. However, it is designed and marketed specifically to researchers and not for the commercial market. It is believed that no study, to date, has objectively measured free-

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living sleeping patterns during school and non-school days in Icelandic children or adolescents.

Whilst sleep duration, or the minutes of sleep per night, is the most widely reported and studied sleep measure, emerging research has also shown that sleep timing is another important component of sleep that may influence overall metabolic health [5]. The biological circadian clock is an important regulator of sleep and other individual behaviors. However, in modern society, the sleep–wake cycle is heavily influenced by factors like school, work, or other social schedules [15,16]. The term "social jetlag" has been coined to describe the misalignment between social schedules and the circadian clock [16,17]. Consequently, along with investigating sleep duration, it is also important to study the influence of other sleep dimensions, such as sleep quality, and the consistency in bed time (BT) and wake-up time [3] on health outcomes such as BMI.

1.1. Aims of the study

The primary purpose of this study was to objectively investigate, with wrist actigraphy, free-living sleeping patterns in Icelandic adolescents. Secondary aims included: (a) assessing differences in sleep duration, sleep quality and clock times between the sexes; (b) examining differences in sleep patterns between school days (SchD) and non-school days (NSchD); and (c) investigating the association between sleep and BMI.

2. Methods

2.1. Participation

A total of 411 tenth-grade students (15–16 years old) – 47% boys and 53% girls – from six schools in Reykjavík, Iceland, received an invitation letter to participate in this study. The data collection took place in the spring of 2015 (April–June). A total of 315 pupils participated in the study (Fig. 1). Non-participation ($n = 104$) was mainly due to absence from school during measurement days and lack of interest in the study. Study participation is shown in Fig. 1.

Written informed consent was obtained from all participants and their guardians. Strict procedures were followed to ensure confidentiality. The study was approved by the National Bioethics Committee and the Icelandic Data Protection Authority (Study number: VSN b200605002&03).

2.2. Sleep parameters

Free-living sleep was measured with wrist-worn raw signal accelerometers: ActiGraph GT3X+ (ActiSleep by Actigraph Inc., Pensacola, Florida, USA). The small (3.8 cm × 3.7 cm × 1.8 cm) and light (27 g) Actigraphy watches were placed on the non-dominant wrist of each subject, at school, and each was asked to continuously wear the monitor for seven days. Raw triaxial data were sampled at 80 samples/second (Hz). Sleep parameters were derived from the Actilife software from Actigraph (Pensacola, FL, USA) (version 6.13.0.) using a sleep detection algorithm specifically validated for adolescents [13]. Wrist actigraphy has high sensitivity and moderate specificity, and overall high accuracy when compared to PSG [12], which is the gold standard in sleep research. Wrist actigraphy has been recommended for characterization of sleep parameters in population-based studies of young adults [10].

Rest and sleep durations, timing, and other sleep quality parameters (such as sleep efficiency (SLE), and wakening after sleep onset (WASO), as shown in Table 1) were first determined by auto-detection of the Actilife sleep analysis. Self-reported sleep logs of BT and rise time were then used to confirm the rest intervals determined by the software detection, and two expert scorers adjusted them, when necessary (inter-scorer variability was evaluated, data not shown). Total rest time (TRT) was compared to the recommended 8 h of sleep for adolescents in this age range [1], and the proportion of participants going to bed after midnight was also calculated. Measurements of daily sleep data for at least three valid SchD and one valid NSchD with wear time >14 h were considered valid. Naptime was not included in the analyses, due to low incidents of naps detected in the data (22 total naps taken by 18 different subjects).

2.3. Anthropometric measures

Standing height was measured with a stadiometer (Seca model 217, Seca Ltd. Birmingham, UK) to the nearest 0.1 cm. Body weight was measured on a balance scale (Seca model 813, Seca Ttd., Birmingham, UK) to the nearest 0.1 kg, with participants wearing light clothes. BMI was calculated by dividing weight by height squared (kg/m^2). All measurements were performed at individual schools.

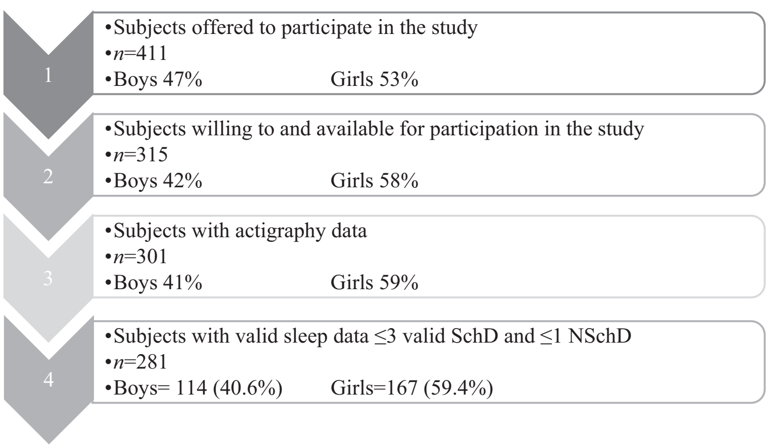

Fig. 1. Participation in the study. SchD, school days; NSchD, non-school days.

Table 1
Sleep parameters for analysis.

Abbreviation	Sleep parameter	Definition
TRT	Total rest time	Resting period: the time spent in bed (minutes)
TST	Total sleep time	Actual sleep time during rest period (minutes)
SLE	Sleep efficiency	Minutes of total sleep divided by minutes available for sleep (TST/TRT) multiplied by 100 (%)
SOL	Sleep onset latency	Time it takes from wakefulness to sleep
NOA	Number of awakenings	Wake-ups during rest period (counts)
WASO	Wakening after sleep onset	Minutes of non-sleep from the resting period (TRT) after sleep onset due to awakening/s
SFI	Total sleep fragmentation index	Summation of the movement index (percentage of epochs >0), and the fragmentation index (percentage of 1-min periods of sleep vs all periods of sleep during the sleep period) (%)
BT	Bed time	Clock time of bed time
MS	Midpoint of sleep	The clock time at the midpoint of the sleeping period (between sleep onset and rise time)
RT	Rise time	Clock time of wake up

2.4. School hours

School time for this age group in Iceland is 37 school hours/week. The timing and duration of the school day varied little between schools and individual participants, with the school day starting for most participants between 08:10–08:20 in the morning and finished around 14:00, and the latest school day finishing at 16:00.

2.5. Statistical analysis

All finalized and exported Actilife reports were compiled into daily and weekly averages using customized programs written with Matlab software (The Mathworks, Natick, MA, USA) (version R2013a). Mean ± standard deviation was reported as summary statistics. Paired *t*-tests were used for comparisons between SchD and NSchD; unpaired *t*-tests were used for between-sex comparisons. The TRT was compared with recommended sleep hours for adolescents (8–10 h). Linear regression was used to assess the association between sleep parameters (independent variables) and BMI (dependent variable). Separate regressions were run for boys and girls and SchD and NSchD. Statistical analyses were carried out using RStudio statistical software (Rstudio headquarters, Boston, MA, USA) (version 0.99.482).

3. Results

Participants' characteristics are shown in Table 2. The final sample included 114 boys and 167 girls who had valid data on the sleep parameters (measurements for ≥3 SchD and ≥1 NSchD were considered valid).

The average age of participants was 15.9 ± 0.3 years, with a BMI of 22.2 ± 3.7 kg/m^2. The prevalence of being overweight (BMI between 25 and 30 kg/m^2) was 10.4% (7.1% of boys and 12.7% of girls), and 2.9% were obese (BMI ≥30 kg/m^2, 2.7% of boys and 3.0% of girls).

The average day length was 17.6 h of daylight, with the shortest day being 15.1 h and the longest day 20.4 h. There was no relationship between day length and TST on SchD or NSchD.

Table 2
Characteristics of the study subjects.

Characteristics	Boys ($n = 114$)	Girls ($n = 167$)
	Mean ± SD	Mean ± SD
Age (years)	15.8 ± 0.3	15.9 ± 0.3
Height (cm)	178.2 ± 5.9	167.0 ± 5.7
Weight (kg)	68.9 ± 11.6	62.0 ± 10.1
BMI (kg/m^2)	21.7 ± 3.2	22.2 ± 3.2

n, number of participants; BMI, body mass index.

Sleep parameters for SchD and NSchD are summarized in Table 3. Markers of sleep quality or duration did not differ between the sexes on SchD or NSchD. All participants had shorter TRT (7.05 ± 0.83 vs 8.40 ± 1.23 h) and TST (6.19 ± 0.74 vs 7.33 ± 1.10 h) on SchD vs NSchD (both $p < 0.001$). Over the entire week, 22.1% of participants met the sleep recommendation of 8 h per night (based on TRT). Similarly, when TRT (time in bed) was compared to recommendations, 10.7% got the recommended 8 h of sleep on SchD, while 66.9% achieved the recommended sleep duration on NSchD. Despite a longer TST on NSchD, objective sleep parameters (SLE, WASO, number of awakenings (NOA) and Sleep Fragmentation Index (SFI), see Table 3) indicated lower sleep quality on NSchD than SchD ($p < 0.005$).

Clock times for sleep are summarized in Table 4. There was a shift in the sleep schedule of both sexes from SchD to NSchD. Boys went to bed 91 ± 78 min later (00:28 ± 56 min SchD vs 01:58 ± 83 min NSchD, $p < 0.001$) and rose 178 ± 81 min later on NSchD (07:33 ± 48 min SchD vs 10:32 ± 86 min NSchD, $p < 0.001$), leading to a 135 ± 66 min shift in midpoint of sleep (MS). The SchD to NSchD shifts for girls were all less than the shifts for boys (all $p < 0.02$), as girls went to bed 73 ± 50 min later (00:18 ± 51 min SchD vs 01:31 ± 64 min NSchD, $p < 0.001$) and rose 154 ± 71 min later on NSchD (07:23 ± 33 min SchD vs 09:57 ± 74 min NSchD, $p < 0.001$), with a MS shift of 113 ± 50 min. Similarly, the average bedt ime (BT) and rise time (RT) for boys was 33 min later and 35 min later than that for girls on NSchD ($p < 0.005$ and $p < 0.001$, respectively), and both were about 10 min later than that for girls on SchD ($p = 0.121$ and $p = 0.05$, respectively).

There was no association between BMI and average sleep times, SchD to NSchD sleep timing shifts, or average sleep duration in either sex (*p*-values 0.115–0.376). Results of linear regression between sleep parameters and BMI are shown in Table 5.

4. Discussion

The main findings in this study revealed that the majority of Icelandic adolescents aged 15–16 years do not get the recommended 8–10 h of sleep each night [1], especially on school nights. Although individual need for sleep may vary, sleep duration far outside the normal range should raise concerns, since sleep recommendations are established to improve overall health and well-being [18]. The main influence on insufficient sleep (averaging about 7 h in bed, with 6.2 h of actual sleep time per night) was that Icelandic adolescents appeared to have a very late BT routine (00:22). When combined with early school schedules, time for sleep was substantially suppressed on school days. The insufficient sleep on school days was only partially "recovered" by sleeping longer (about 80 min) on non-school days, although the quality of sleep was reduced. The "social jetlag" phenomenon was also present, with a shift in mid-sleep time of about 2.3 and 1.9 h later on non-school days for boys and girls, respectively.

Table 3
Sleep parameter mean values for both sexes on school days and non-school days.

Sleep parameters	Boys ($n = 114$)			Girls ($n = 167$)			All ($n = 281$)		
	SchD	NSchD	p	SchD	NchD	p	SchD	NSchD	p
Sleep duration									
TRT (hours)	7.01 ± 0.90	8.36 ± 1.45	<0.001	7.07 ± 0.78	8.42 ± 1.06	<0.001	7.05 ± 0.83	8.40 ± 1.23	<0.001
TST (hours)	6.16 ± 0.82	7.25 ± 1.29	<0.001	6.21 ± 0.69	8.42 ± 1.06	<0.001	6.20 ± 0.74	7.33 ± 1.10	<0.001
Sleep quality									
SLE (%)	88.0 ± 4.4	86.8 ± 4.2	0.01	87.9 ± 4.4	87.9 ± 5.1	0.837	87.9 ± 4.4	87.4 ± 4.7	0.038
SOL (minutes)	1.6 ± 1.0	1.6 ± 1.1	0.790	1.5 ± 1.0	1.6 ± 1.2	0.767	1.6 ± 1.0	1.6 ± 1.2	<0.001
WASO (minutes)	50.0 ± 21.1	66.3 ± 24.8	<0.001	50.2 ± 21.4	60.3 ± 28.4	<0.001	50.1 ± 21.2	62.7 ± 27.1	<0.001
NOA (count)	18.3 ± 6.3	23.4 ± 9.4	<0.001	18.5 ± 4.8	22.7 ± 7.8	<0.001	18.4 ± 5.5	23.0 ± 7.8	<0.001
SFI (%)	19.7 ± 5.8	22.3 ± 6.7	<0.001	20.1 ± 4.2	20.7 ± 7.5	0.175	19.9 ± 6.1	21.3 ± 7.2	0.846

SchD, school days; NSchD, non-school days; TRT, total rest time; TST, total sleep time; SLE, sleep efficiency; SOL, sleep onset latency; WASO, wake time after sleep onset; NOA, number of awakenings during rest period; SFI, Sleep Fragmentation Index.

Table 4
Mean sleep schedule times for both sexes on school days and non-school days.

Time of day	Boys ($n = 114$)			Girls ($n = 167$)			All ($n = 281$)		
	SchD	NSchD	p	SchD	NchD	p	SchD	NSchD	p
Bed time (o'clock ± minutes)	00:28 ± 56	01:58 ± 83*	<0.001	00:18 ± 51	01:31 ± 64	<0.001	00:22 ± 54	01:42 ± 74	0.05
Mid-sleep time (o'clock ± minutes)	04:00 ± 45*	06:14 ± 77**	<0.001	03:50 ± 36	05:43 ± 61	<0.001	03:54 ± 40	05:56 ± 69	0.158
Rise time (o'clock ± minutes)	07:33 ± 48*	10:32 ± 86**	<0.001	07:23 ± 33	09:57 ± 73	<0.001	07:27 ± 40	10:11 ± 80	0.735

SchD, school days; NSchD, non-school days.
Difference between the sexes is marked $^{*}p < 0.05$ and $^{**}p < 0.001$.

Table 5
Results of linear regression between sleep parameters and body mass index (BMI).

Linear relationship to BMI												
Sleep parameters (predictor variables)	Boys ($n = 114$)				Girls ($n = 167$)				All ($n = 281$)			
	β	SE	r	p	β	SE	r	p	β	SE	r	p
TRT SchD (hours)	−0.410	0.327	−0.12	0.21	−0.415	0.318	−0.10	0.19	−0.403	0.230	−0.10	0.08
TRT NSchD (hours)	−0.275	0.197	−0.13	0.16	0.011	0.236	0.00	0.96	−0.142	0.154	−0.06	0.35
TST SchD (hours)	−0.366	0.357	−0.10	0.31	−0.464	0.362	−0.10	0.20	−0.407	0.256	−0.09	0.11
TST NSchD (hours)	−0.346	0.221	−0.15	0.12	−0.059	0.261	−0.02	0.82	−0.197	0.171	−0.07	0.25
SLE SchD (%)	0.029	0.065	0.04	0.66	−0.015	0.057	−0.02	0.80	0.003	0.043	0.00	0.95
SLE NSchD (%)	−0.036	0.069	−0.05	0.60	−0.024	0.049	−0.04	0.63	−0.020	0.040	−0.03	0.62
SOL SchD (minutes)	−0.031	0.280	−0.01	0.91	−0.162	0.257	−0.05	0.53	−0.114	0.190	−0.04	0.55
SOL NSchD (minutes)	0.110	0.230	0.05	0.63	0.162	0.207	0.06	0.43	0.135	0.155	0.05	0.38
WASO SchD (minutes)	−0.012	0.014	−0.08	0.37	−0.004	0.012	−0.03	0.72	−0.007	0.009	−0.05	0.41
WASO NSchD (minutes)	−0.001	0.012	−0.01	0.93	0.005	0.009	0.04	0.59	0.001	0.007	0.01	0.84
NOA SchD (n)	−0.052	0.050	−0.10	0.30	−0.054	0.048	−0.09	0.26	−0.052	0.035	−0.09	0.13
NOA NSchD (n)	0.016	0.035	0.04	0.64	0.018	0.033	0.04	0.59	0.013	0.024	0.03	0.58
SFI SchD	−0.008	0.050	−0.02	0.87	−0.008	0.039	−0.02	0.85	−0.007	0.031	−0.01	0.83
SFI NSchD	0.040	0.043	0.09	0.35	−0.018	0.033	−0.04	0.59	−0.003	0.026	−0.01	0.92
BT SchD (hours)	0.347	0.308	0.11	0.26	0.250	0.292	0.07	0.39	0.258	0.213	0.07	0.23
BT NSchD (hours)	−0.024	0.207	−0.01	0.91	0.050	0.234	0.02	0.83	−0.040	0.154	−0.02	0.79
MS SchD (hours)	0.142	0.387	0.03	0.71	0.153	0.412	0.03	0.71	0.083	0.283	0.02	0.77
MS NSchD (hours)	−0.204	0.225	−0.09	0.37	0.061	0.245	0.02	0.80	−0.136	0.163	−0.05	0.41
RT SchD (hours)	−0.218	0.356	−0.06	0.54	−0.226	0.449	−0.04	0.61	−0.283	0.281	−0.06	0.31
RT NSchD (hours)	−0.302	0.199	−0.14	0.13	0.047	0.204	0.02	0.82	−0.169	0.141	−0.07	0.23
BT NSchD − BT SchD (hours)	−0.338	0.259	−0.12	0.19	0.011	0.305	0.00	0.97	−0.239	0.197	−0.07	0.23
MS NSchD − MS SchD (hours)	−0.208	0.223	−0.09	0.35	−0.181	0.299	−0.05	0.55	−0.239	0.180	−0.08	0.18
RT SchD − RT SchD (hours)	−0.263	0.212	−0.12	0.22	0.100	0.211	0.04	0.64	−0.109	0.149	−0.04	0.46

SchD, school days; NSchD, non-school days; TRT, total rest time; TST, total sleep time; SLE, sleep efficiency; SOL, sleep onset latency; WASO, wake time after sleep onset; NOA, number of awakenings during rest period; SFI, Sleep Fragmentation Index; BT, bed time; MS, midpoint of sleep; RT, rise time.

The wrist-worn actigraphy derived sleep data confirmed previous observations of short sleep duration in Icelandic adolescents on SchD using subjective measures [7]. Furthermore, the Icelandic adolescents measured in this study went to bed rather late compared with previous self-reported data from various other countries [19], which ultimately leads to shorter sleep duration. The habit of later BT is most likely cultural for Icelanders, as previous studies, both within the same age group and amongst other age groups, have also reported late BTs [7,20,21]. As early as the 1980s, Kristbjarnarson et al. surveyed Icelanders ($n = 668$) and found an average BT for 15-year-olds of 00:18 and an average nocturnal sleep of 8.1 h [20]. A follow-up study by Thorleifsdottir et al. confirmed that Icelandic adolescents (11, 13 and 15 year-olds) had later BTs and shorter nocturnal sleep than their peers in neighboring countries [7,20]. The even later BT and RT on NSchD in the present study further suggests that Icelandic adolescents may “prefer” a later circadian profile compared to what is now required by current school schedules, which may be set to meet the adults' (teachers and parents) schedules.

The present study suggests that over the course of the measured school week, 21% of Icelandic adolescents (18.6% of boys and 22.8% of girls) incurred a substantial sleep debt, defined as ≥2 h difference in TST between SchD and NSchD [22]. This is in line with the findings of an analogous actigraphy based study of adolescents aged 15–16 years in the USA, who had a similarly short TST (6.4 h overall and 6.0 h on weekdays), with a high percentage of sleep debt (35%) [22]. This differential between SchD and NSchD TST is not unusual, as short-term sleep deficiency during SchD is typically followed by longer sleep durations of "recovery" or "catch-up" sleep on NSchD [3,15]. On average, the present data seem to support the recovery sleep phenomenon, as the adolescents slept about 1.2 h longer on NSchDs than SchDs. However, it did not find an inverse correlation between TST during SchD and NSchD, and most measures indicated that sleep quality was reduced on NSchD for both sexes, despite a longer average TST. One plausible explanation is that the shift in their MS of roughly 2 h may have created inconsistency in their sleep routine, hindering their ability to simultaneously increase their sleep quantity and quality. Sleep guidelines for adolescents typically recommend that they maintain consistent BTs and wake-up times during the week for overall health benefits [23].

During puberty, biological rhythms normally change so that adolescents develop sleepiness later at night and need to sleep longer in the morning [24]. Delayed BTs and early school start result in inadequate sleep for a large portion of the adolescent population [25]. During the school week, the main determinant of RT is the start time of school [2]. This is a challenge for adolescents, where the social/cultural/biological pressures for staying up late combined with early school times reduce sleep time and are inconsistent with healthy sleep patterns [17]. The American Academy of Pediatrics advised US middle and high schools to modify start time to no earlier than 08:30, as an approach to enable students to get adequate sleep and improve their health, safety, academic achievement and quality of life [25].

A wide range of evidence, from cross-sectional associations [4,5,26] to mechanistic-based laboratory studies [27], has demonstrated links between short sleep duration and an increased risk of obesity in both children and adults. Similarly, sleep timing is thought to independently influence BMI in adolescents [28]. However, the present study did not find an association between BMI and TST, sleep timing, or shifts in sleep schedule. The lack of an association may have been due, in part, to the small and homogeneous participant population, which had a relatively low prevalence of obesity (<3%) combined with a high prevalence of short sleep (~88%). Studies that focus on the association between sleep duration and BMI in adolescents show inconsistent results. One cross-sectional analysis of a similarly aged (13–15 years) subset ($n = 1290$) of a larger Australian cohort also failed to identify a relationship between obesity prevalence and TST with subjectively assessed sleep duration [29]. However, another study showed a negative association between BMI and sleep duration for boys, but not for girls [30]. Similarly, a third study on BMI and sleep duration in young adults (mean age 27.7 ± 3.8 years, $n = 430$) demonstrated a negative association between objectively measured sleep duration and BMI [31]. Future studies should further investigate the link between sleep patterns and adiposity in this population, using more precise measurements such as the dual-energy X-ray absorptiometry, since BMI does not differentiate between lean mass and fat mass of the individual, even though it correlates well with body fat percent [32].

4.1. Strengths and limitations

It is believed that this is the first study to objectively measure free-living sleep patterns in a large sample of Icelandic youth. Actigraphy has been shown to provide more accurate sleep assessments than subjective methods, particularly during longer, free-living, population-based studies, where daily sleep logs are prone to increased non-compliance [33] and self-report tends to over-estimate sleep time [9]. However, wrist-worn actigraphy tends to underestimate waking, when subjects lay perfectly still while awake, compared to the gold standard in sleep research – PSG [12]. Although wrist actigraphy has high sensitivity and moderate specificity, and overall high accuracy when compared to PSG [12], it has only been used in conjunction with PSG in other populations than adolescents.

It should be noted that the present study compared objective assessments of total rest duration (in bed intended to sleep) to sleep duration guidelines, which have been established using self-reported data [3]. The actual sleep times were shorter than the total rest time.

There were other limitations of the present study. The school hours between schools and individuals varied slightly (<15 min), which could have possibly resulted in shorter or longer sleep on SchD for the individual at times. It is also suspected that day length and the demands of the school season might have affected the sleep length and quality in the study participants. Due to the study design, the study was conducted during spring (average day length 17.6 h) and participants were in the last year of primary school in Iceland (equivalent to American high school). The authors plan to repeat the study during a different season (e.g., winter and another school year) to assess how these factors may impact sleep in Icelandic adolescents.

5. Conclusion

The actigraphy measured sleep pattern in a group of Icelandic boys and girls aged 15–16 years revealed that the majority of them did not get sufficient sleep on school days. Icelandic boys had later BTs than girls on school days and non-school days. Collectively, these findings provide information on the sleep patterns of adolescents and may serve as reference for development of policies and interventions to promote better sleep practices.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2016.12.028.

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Paper II

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Human Kinetics
BRIEF REPORT

Longitudinal Change in Adolescent Bedtimes Measured by Self-Report and Actigraphy

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Introduction: Sleep is often quantified using self-report or actigraphy. Self-report is practical and less technically challenging, but prone to bias. We sought to determine whether these methods have comparable sensitivity to measure longitudinal changes in adolescent bedtimes. **Methods**: We measured one week of free-living sleep with wrist actigraphy and usual bedtime on school nights and non-school nights with self-report questionnaire in 144 students at 15 y and 17 y. **Results**: Self-reported and actigraphy-measured bedtimes were correlated with one another at 15 y and 17 y ($p < .001$), but reported bedtime was consistently earlier (>30 minutes, $p < .001$) and with wide inter-method confidence intervals (> ±106 minutes). Mean inter-method discrepancy did not differ on school nights at 15 y and 17 y but was greater at 17 y on non-school nights ($p = .002$). Inter-method discrepancy at 15 y was not correlated to that at 17 y. Mean change in self-reported school night bedtime from 15 y to 17 y did not differ from that by actigraphy, but self-reported bedtime changed less on non-school nights ($p = .002$). Two-year changes in self-reported bedtime did not correlate with changes measured by actigraphy. **Conclusions**: Although methods were correlated, consistently earlier self-reported bedtime suggests report-bias. More varied non-school night bedtimes challenge the accuracy of self-report and actigraphy, reducing sensitivity to change. On school nights, the methods did not differ in group-level sensitivity to changes in bedtime. However, lack of correlation between bedtime changes by each method suggests sensitivity to individual-level change was different. Methodological differences in sensitivity to individual- and group-level change should be considered in longitudinal studies of adolescent sleep patterns.

Keywords: accelerometer, questionnaire, sleep, sleep onset, teenagers

Adolescent sleep patterns are often measured with self-report (Lewandowski, Toliver-Sokol, & Palermo, 2011) or actigraphy (Galland et al., 2018). Although self-report is easier to administer, lower in cost, and requires less technical expertise than actigraphy, it is often affected by social expectations and recall bias (Wolfson et al., 2003). Self-report can be measured using a survey question about usual sleep habits or with nightly sleep logs (Knutson & Lauderdale, 2007). While sleep logs are shown to be more reliable than survey questions (Arora, Broglia, Pushpakumar, Lodhi, & Taheri, 2013; Werner, Molinari, Guyer, & Jenni, 2008), they are also more burdensome for participants and have lower compliance (Knutson & Lauderdale, 2007). Thus, survey questions can be more easily employed for larger, nationally representative studies. Several studies have assessed agreement between self-report by questionnaire and actigraphy in adolescents (Arora et al., 2013; Biddle, Robillard, Hermens, Hickie, & Glozier, 2015; Guedes et al., 2016; Wolfson et al., 2003), but it is unclear whether the two methods have comparable sensitivity to measure longitudinal change in sleep patterns. We measured bedtime by self-report and actigraphy at age 15 and 17 to determine if discrepancy between the methods is independent of age and if age-related changes in bedtime by questionnaire-based self-report correspond to those by actigraphy.

Methods

Participants

We invited 411 15-year-old students from six schools in Reykjavík, Iceland to participate; 315 agreed, and 270 had complete data.

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Two years later, 168 of the 270 agreed to repeat the measurements. Data are presented from 144 participants (89 girls) that had complete data at both time points.

The National Bioethics Committee and the Icelandic Data Protection Authority approved the study (Study number: VSNb2015020013/13.07). Written informed consent was attained from participants and guardians of underage participants. Full confidentiality was ensured, and the study was conducted in agreement with the Declaration of Helsinki.

Bedtime Measurements by Actigraphy and Self-report

Participants were instructed to wear an ActiGraph GT3X+ (Actigraph Inc., Pensacola, Florida, USA) on their non-dominant wrist for seven consecutive days during measurements at 15 y and 17 y. Data was processed with Actilife (v6.13.0, Actigraph, Pensacola, FL, USA) and Matlab (vR2016B, Mathworks, Natick, MA, USA), as detailed previously (Rognvaldsdottir et al., 2017). Sleep periods were detected with the Sadeh algorithm validated for adolescents (Sadeh, Sharkey, & Carskadon, 1994) and adjusted by two expert scorers based on visual inspection and daily participant sleep logs completed as part of the actigraphy study. Non-wear was identified as described previously (Rognvaldsdottir et al., 2017). Valid data consisted of ≥14 hours of wear on ≥3 school nights (Sunday through Thursday nights) and ≥1 non-school night (Friday and Saturday night and nights prior to holidays) (Rognvaldsdottir et al., 2017). Average actigraphy-measured bedtimes for school nights and non-school nights at each age were included in all primary analyses. The earliest actigraphy-measured bedtime for each student on school nights and non-school nights at each age were also included for comparison.

Separate from the daily sleep logs, the self-reported measure consisted of participant responses to the following survey questions administered using a tablet-based questionnaire at school prior to the actigraphy study: "What is your usual bedtime on school nights?" and "What is your usual bedtime on the weekend?" Potential answers were in half hour increments from 20:00 to 04:00.

Statistical Analysis

Associations between self-reported and actigraphy-measured bedtimes were evaluated with Pearson correlation. Bland-Altman plots were used to assess inter-method agreement (Bland & Altman, 1986). All other comparisons were made using analysis of variance with Tukey's post-hoc comparisons with Bonferroni adjustment. Using unpaired analyses, we found few sex differences in self-reported or actigraphy-measured bedtimes at either age (data not shown) and no differences in inter-method discrepancy, contrary to prior work (Guedes et al., 2016). Therefore, data from both sexes were combined and paired analyses were used for all other assessments. The significance threshold was $p = .05$. Analyses were conducted using RStudio (v1.0.153, Boston, MA, USA) with R (v3.4.2, https://www.r-project.org/) and GraphPad Prism (v7, La Jolla, CA).

Results and Discussion

Comparing Bedtimes Measured by Actigraphy and Self-Report at Age 15

Participant characteristics, average bedtimes by actigraphy and self-report, and discrepancies between methods are presented in Table 1. Self-reported and average actigraphy-measured bedtimes were correlated on school nights ($r = 0.47$, $p < .001$) and non-school nights ($r = 0.51$, $p < .001$). Bedtimes on non-school nights were later than those on school nights according to both actigraphy (as previously reported [Rognvaldsdottir et al., 2017]) and self-report (both $p < .001$; Table 1). Taken together, these results confirm previous observations that self-report and actigraphy

Table 1 Subject Characteristics and Bedtime Measures for 144 Participants (55 Boys, 89 Girls) at age 15 and 17

	15 y	17 y	Change (17 y–15 y)	*p*-value (15 y vs. 17 y)
Characteristics				
Age (y)	15.9 ± 0.3	17.7 ± 0.3	1.8 ± 0.1	<.001
Height (cm)	171.7 ± 8.2	173.4 ± 9.0	1.7 ± 2.4	.09
Weight (kg)	64.4 ± 11.3	68.5 ± 12.8	4.0 ± 5.2	.005
Body mass index (kg/m^2)	21.8 ± 3.3	22.7 ± 3.8	0.9 ± 1.6	.03
School Night Bedtimes				
Self-report (clock time ± min)	23:31 ± 57.1	23:57 ± 59.0	26.2 ± 60.7	<.001
Average by Actigraphy (clock time ± min)	00:19 ± 46.1**	00:55 ± 61.0**	35.2 ± 59.2	<.001
Earliest by Actigraphy (clock time ± min)	23:27 ± 63.3	23:56 ± 62.3	28.8 ± 81.1	<.001
Self-report – Average by Actigraphy (min)	−48.6 ± 54.1	−57.5 ± 67.7	−8.9 ± 80.6	.2
Self-report – Earliest by Actigraphy (min)	4.0 ± 76.7	1.5 ± 72.6	−2.5 ± 106.0	.8
Non-school Night Bedtimes				
Self-report (clock time ± min)	01:04 ± 68.2#	01:33 ± 75.5#	28.1 ± 79.9	.001
Average by Actigraphy (clock time ± min)	01:36 ± 69.9**,#	02:26 ± 85.5**,#	50.4 ± 92.9*	<.001
Earliest by Actigraphy (clock time ± min)	00:51 ± 64.0*,#	01:42 ± 89.8#	51.3 ± 94.4*	<.001
Self-report – Average by Actigraphy (min)	−31.4 ± 68.1#	−53.7 ± 94.4	−22.2 ± 113.2	.02
Self-report – Earliest by Actigraphy (min)	13.3 ± 69.1	−9.9 ± 100.4	−23.2 ± 114.0	.02
Night-to-night Bedtime Variability				
Actigraphy (min)	65.8 ± 36.2	73.0 ± 30.9	7.2 ± 43.2	.048

*$p < .05$ and **$p < .01$ vs. self-report during the same year. #$p < .01$ vs. school nights during the same year.

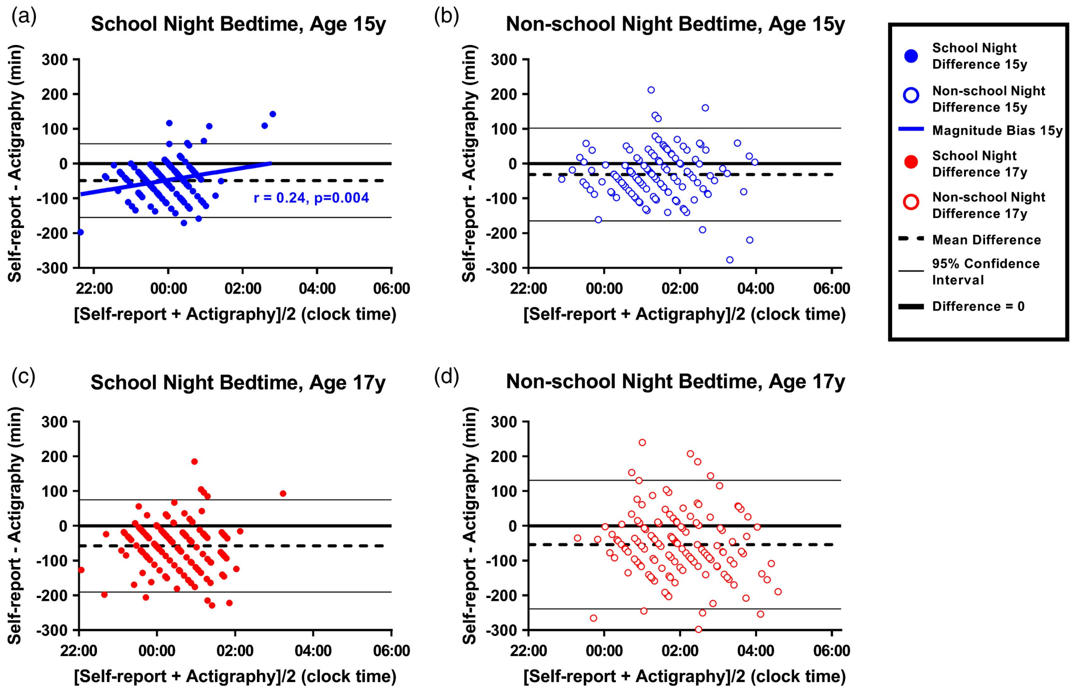

Figure 1 — Bland-Altman plots of the difference between self-reported and average actigraphy-measured bedtimes against the average of self-reported and actigraphy-measured bedtimes for 144 students. Plots are shown for: **a.** School nights at age 15 y (filled blue circles), **b.** Non-school nights at age 15 y (open blue circles), **c.** School-nights at age 17 y (filled red circles), **d.** Non-school nights at age 17 y (open red circles). Magnitude bias was only significant on school nights at 15 y.

measure the same underlying parameter in adolescents (Wolfson et al., 2003). However, self-reported bedtimes were >30 minutes earlier than average actigraphy-measured bedtimes ($p < .001$), with greater discrepancy on school nights (Table 1). The trend of reporting earlier bedtimes than those measured by actigraphy supports previous findings that self-report can be biased by social expectations and recall limitations (Wolfson et al., 2003), but it is worth noting that mean difference between self-report and actigraphy at 15 y in this study was 3.7 times greater than previous adolescent measurements on school nights (Wolfson et al., 2003). Self-reported bedtimes compare more favorably to the earliest actigraphy-measured bedtime for each participant, as we found no differences between these two measures on school nights and slightly later self-reports on non-school nights at age 15 (Table 1). These results suggest students tend to report aspirational or target bedtimes, perhaps due to expectations of achieving popular sleep guidelines, as previously suggested (Wolfson et al., 2003). Night-to-night bedtime variability, i.e. the standard deviation of actigraphy-measured bedtimes over all nights, was closer to that measured on vacation days (72.9 ± 40.0 min) than school days (43.7 ± 25.8 min) in a group of similarly aged Australian students (Bei et al., 2014) and more than double that measured in older Japanese women (32.1 ± 18.2 min) (Kim, Sasai, Kojima, & Kim, 2015), indicating high variability amongst our participants.

Individual differences between self-report and average actigraphy bedtimes ranged from −277 to +212 minutes. Bland-Altman plots showed wide confidence limits for the inter-method discrepancy (report – average of actigraphy) on school nights (±106 minutes, Figure 1a) and non-school nights (±133 minutes, Figure 1b) which were >1.8 times those observed for parent-reported bedtimes versus actigraphy in children (Werner et al., 2008), suggesting limited agreement between the methods in adolescents. Inter-method discrepancy was also directly correlated to the average of self-reported and actigraphy-measured school night bedtimes ($r = 0.24$; $p = .004$) and those with earliest average bedtimes showed the greatest inter-method discrepancy (Figure 1a). Interestingly, plotting inter-method discrepancy against actigraphy-measured bedtimes showed the opposite trend- a significant inverse correlation on school nights ($r = -0.36$; $p < .001$) and non-school nights ($r = -0.51$; $p < .001$), indicating greater inter-method discrepancy for adolescents with later actigraphy-measured bedtimes. Substituting earliest actigraphy-measured bedtimes for average actigraphy-measured bedtime in the Bland-Altman analyses reduced mean inter-method discrepancy and eliminated the correlation between inter-method discrepancy and average of self-report and actigraphy on school nights, but inter-method discrepancy confidence limits were similarly broad on school nights (±150 minutes) and non-school nights (±135 minutes).

Comparing Bedtime Measurements at Age 15 and 17

At age 17, on both school nights and non-school nights, students continued reporting bedtimes that were earlier than the average (both $p < .001$; Table 1) and closer to the earliest (both $p > .05$;

Table 1) measured by actigraphy. The pattern of going to bed later on non-school nights versus school nights persisted according to both measures (both $p < .001$; Table 1) and actigraphy-measured bedtimes became more varied ($p = .048$; Table 1). Self-reported and average actigraphy-measured bedtimes were correlated on school nights ($r = 0.36$, $p < .001$) and non-school nights ($r = 0.32$, $p < .001$), and Bland-Altman plots showed wider confidence intervals for inter-method discrepancy on school nights and non-school nights at 17 y compared to 15 y (Figures 1c and 1d, respectively). These data suggest some consistent patterns from 15 y to 17 y including a trend toward reporting an early, "target" bedtime compared to the average measured with actigraphy, a later bedtime pattern on non-school nights compared to school nights, high night-to-night variability in actigraphy-measured bedtimes, and a correlation between the two methods.

On average, inter-method discrepancy did not differ on school nights at 15 y and 17 y but was greater at 17 y on non-school nights ($p = .02$; Table 1)—findings that were consistent whether using average or earliest actigraphy-measured bedtime. Greater difficulty reporting less regular non-school night bedtime schedule could explain this discrepancy. Supporting this notion, students with greater night-to-night bedtime variability also had greater inter-method discrepancy on non-school nights at 15 y and 17 y (Figures 2b and 2d). However, mean inter-method discrepancy (using average actigraphy-measured bedtimes) was lower on non-school nights than school nights at 15 y ($p = .035$), and no different between school nights and non-school nights at 17 y. Further, the relationship between inter-method discrepancy and night-to-night bedtime variability on school nights was opposite that of non-school nights at 15 y and absent at 17 y (Figures 2a and 2c, respectively). Alternatively, 1–2 non-school nights of actigraphy may be insufficient to determine a true mean bedtime (Acebo et al., 1999; Wolfson et al., 2003). Additionally, inter-method discrepancies at 17 y were not correlated to those at 15 y and confidence intervals were broader at 17 y, suggesting that the discrepancy is inconsistent with age on an individual level.

According to both self-report and actigraphy, students went to bed later on school nights and non-school nights at 17 y compared to 15 y (all $p < .001$, Table 1), confirming that adolescents shift toward later bedtimes with age (Carskadon, 1990). Bedtimes at 17 y were correlated to those at 15 y, using either average actigraphy-measured or self-report, on school nights ($r = 0.42$ and $r = 0.45$, respectively) and non-school nights ($r = 0.30$ and $r = 0.38$, respectively; all $p < .001$), suggesting individuals had a similar preferred bedtime pattern at both ages.

On school nights, mean change in bedtimes from 15 y to 17 y measured using self-report and actigraphy were not different (Figure 3a). On non-school nights, however, self-reported bedtimes changed less than actigraphy-measured bedtimes ($p = .02$, Figure 3a, Table 1), further indicating that more varied bedtimes on non-school nights may require more nights of actigraphy or more specific questions to improve accuracy. Changes in actigraphy-measured bedtimes from 15 y to 17 y were not correlated with changes in self-reported bedtimes on either school nights or

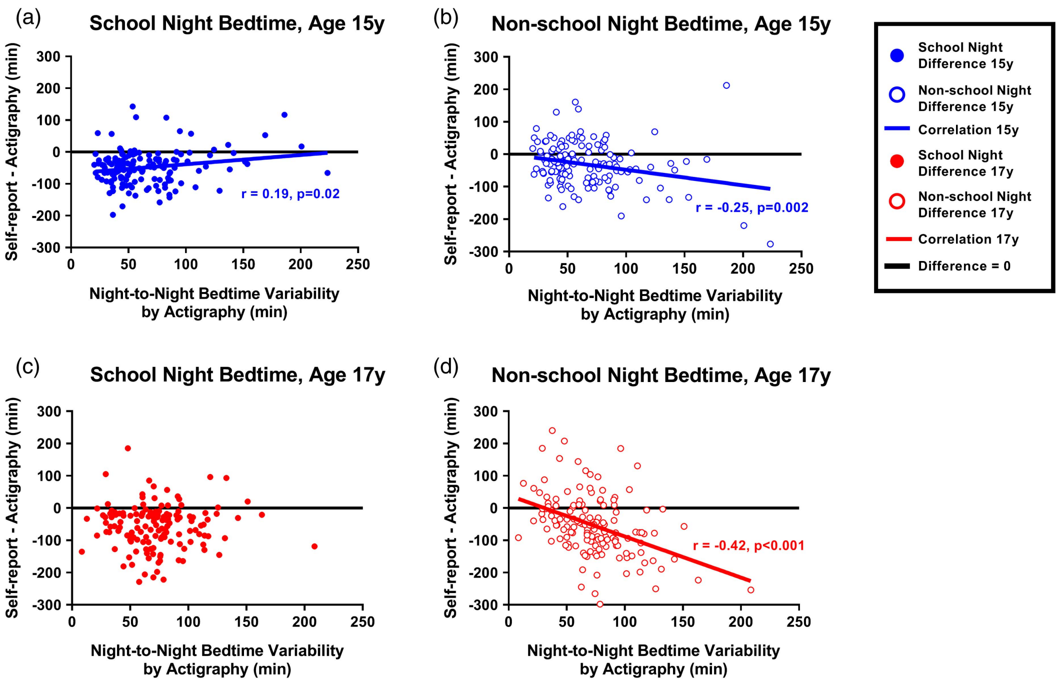

Figure 2 — The difference between self-reported and average actigraphy-measured bedtimes versus night-to-night variability of actigraphy-measured bedtimes for 144 students. Plots are shown for: **a.** School nights at age 15 y (filled blue circles), **b.** Non-school nights at age 15 y (open blue circles), **c.** School-nights at age 17 y (filled red circles), **d.** Non-school nights at age 17 y (open red circles). There was a significant positive correlation on school nights at 15 y and significant negative correlations on non-school nights at both ages.

non-school nights (Figures 3b and 3c). Findings were consistent whether using two-year changes in average or earliest actigraphy-measured bedtimes. Thus, while the methods did not differ in measurement of group-level two-year change in school night bedtime, sensitivity to detect individual-level change was different according to the lack of correlation between methods. These findings suggest that bias affecting self-report is not longitudinally consistent on an individual level.

Limitations

Students reported bedtime but not sleep duration or risetime- which could have been used to calculate reported time in bed. Sleep duration or time in bed may be more relevant to adolescent health than bedtime. However, actigraphy-based measures of bedtime and sleep duration were inversely correlated amongst our participants ($p < .001$). We did not have a measure of self-reported sleep quality or awakenings, but such measures were previously shown to have poor agreement with actigraphy amongst adolescents (Short, Gradisar, Lack, Wright, & Carskadon, 2012). Though a self-report question with 30-minute increments seemed most practical for this age group, <30-minute increments may improve agreement with actigraphy. Similarly, although self-report was restricted from 20:00 to 04:00, none of those with actigraphy-measured bedtimes ≥04:00 reported a 04:00 bedtime and no actigraphy-measured bedtimes were <22:00. The methods may have had better agreement if students reported bedtime in the past week rather than "usual" bedtime, which may be more influenced by memories or social expectations (Werner et al., 2008). Sample size was small, although it is representative of the Icelandic population at this age (4254 born in 1999) (Statistics Iceland, 2015). Additionally, participants with and without complete follow-up data did not differ in sex distribution or bedtimes at 15 y (not shown). We found no correlation between body mass index and either measure of bedtime or inter-method discrepancy, but less than 20% of the participants were overweight or obese. Similarly, 70% of participants reported having at least one parent with a college degree—a proxy of socioeconomic status (Marco, Wolfson, Sparling, & Azuaje, 2011) but they did not differ from the other students in either measure of bedtime or inter-method discrepancy. The northern latitude and homogeneous racial and ethnic composition of Iceland may also limit the generalizability of the findings.

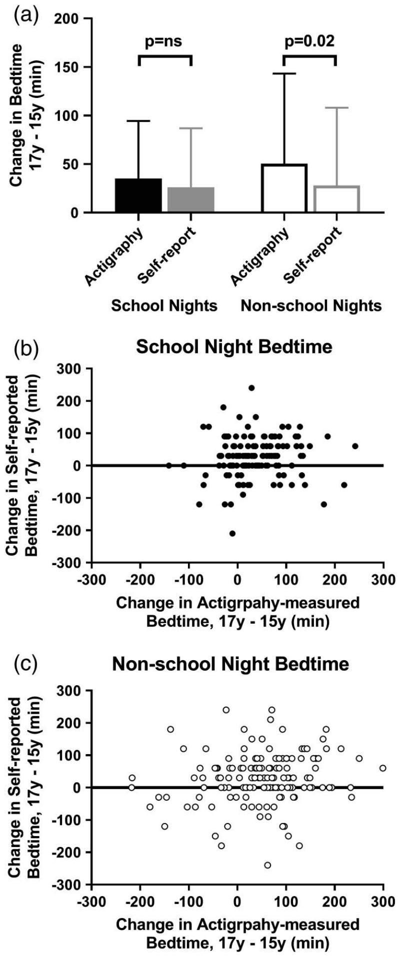

Figure 3 — Change in self-reported and average actigraphy-measured bedtimes from age 15 y to 17 y. **a.** Mean change in bedtime (17 y–15 y) measured by actigraphy was no different than that by self-report on school nights but was greater on non-school nights. **b.** Change in school night bedtimes from 15 y to 17 y measured by actigraphy was not correlated to that measured by self-report. **c.** Change in non-school night bedtimes from 15 y to 17 y measured by actigraphy was not correlated to that measured by self-report.

Conclusions

This is the first study to compare the sensitivity of self-report and actigraphy to measure longitudinal changes in adolescent bedtime. While the methods were correlated at each timepoint, the participants' self-reported bedtimes were consistently earlier, with >85% on school days and >71% on non-school days at both ages reporting earlier bedtimes than the average bedtime measured by actigraphy, suggesting the presence of report-bias. More varied non-school night bedtimes may challenge accuracies of both self-report and actigraphy, reducing sensitivity to detect changes. On school nights, group-level inter-method difference at 15 y and 17 y did not differ, nor did mean two-year change in bedtime detected by both methods. However, according to a lack of correlation between two-year changes in bedtime by self-report and actigraphy, sensitivity to detect individual-level change was different between the methods. These results suggest bias affecting self-report is not longitudinally consistent in this adolescent sample. Caution should be used when interpreting longitudinal self-reported sleep measures in populations with similar highly varied sleep schedules. Thus, along with issues of practicality, expense, and compliance, the impact of differences in sensitivity to individual- and group-level change on study outcomes should be considered when choosing a methodology to study longitudinal sleep patterns in adolescents.

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Paper III

Hreyfing og svefn reykvískra ungmenna

Vaka Rögnvaldsdóttir[1] íþrótta- og heilsufræðingur, **Berglind M. Valdimarsdóttir**[1] íþrótta- og heilsufræðingur, **Robert J. Brychta**[2] verkfræðingur, **Soffía M. Hrafnkelsdóttir**[1] lýðheilsufræðingur, **Sigurbjörn Á. Arngrímsson**[1] þjálfunarlífeðlisfræðingur, **Erlingur Jóhannsson**[1,3] lífeðlisfræðingur, **Kong Y. Chen**[2] verkfræðingur, **Sigríður L. Guðmundsdóttir**[1] íþrótta- og heilsufræðingur

ÁGRIP

Inngangur: Hreyfing og svefn eru mikilvægir áhrifaþættir heilsufars. Alþjóðlegar ráðleggingar mæla með því að börn og unglingar hreyfi sig að lágmarki 60 mínútur daglega af miðlungs eða mikilli ákefð og sofi í 8 til 10 klukkustundir á sólarhring. Tengsl hreyfingar og svefns meðal ungmenna eru ekki vel þekkt. Markmið rannsóknarinnar voru að meta: a) hversu hátt hlutfall 16 ára reykvískra ungmenna uppfyllir viðmið um hreyfingu og svefn, b) hvort tengsl séu milli hreyfingar og svefns og c) kynjamun á hreyfingu og svefni.

Efniviður og aðferðir: Alls var 411 nemendum 10. bekkjar 6 grunnskóla í Reykjavík boðin þátttaka í rannsókninni vorið 2015. Gild gögn fengust frá 106 drengjum og 160 stúlkum. Hlutlægar og huglægar mælingar á hreyfingu og svefni voru gerðar með hröðunarmælum og spurningalistum.

Niðurstöður: Um helmingur þátttakenda náði viðmiðum um hreyfingu samkvæmt niðurstöðum spurningalista. Þrátt fyrir að 51,9% teldu sig sofa nógu mikið náðu þó einungis 22,9% viðmiðum um ráðlagða svefnlengd samkvæmt hröðunarmælum. Engin tengsl fundust milli svefnlengdar og hreyfingar samkvæmt spurningalistum. Stúlkur hreyfðu sig marktækt meira en drengir á frídögum ($p<0,01$) samkvæmt hröðunarmælum en ekki var marktækur munur á meðaltali hreyfingar stúlkna og drengja yfir vikuna. Hvorki var marktækur kynjamunur á svefnlengd mældri með hröðunarmælum né spurningalista.

Ályktun: Lífsstíll íslenskra ungmenna virðist ekki endurspegla viðmið opinberra aðila um daglega hreyfingu og svefn. Einungis 22,9% náðu viðmiðum um ráðlagðan svefntíma, og 11,3% uppfylltu bæði viðmið um hreyfingu og svefn.

Inngangur

Svefn og hreyfing eru mikilvægir áhrifaþættir heilsufars. Regluleg hreyfing á unglingsárum minnkar líkur á áunnum og langvinnum lífsstílssjúkdómum síðar á ævinni.[1] Alþjóðlegar ráðleggingar miðast við að börn og unglingar hreyfi sig í að minnsta kosti 60 mínútur daglega af miðlungs eða mikilli ákefð, þar af ætti að stunda erfiðar æfingar sem styrkja bein og vöðva að lágmarki þrisvar í viku.[2] Samkvæmt hlutlægum mælingum árið 2011[3] uppfylltu aðeins 9% 15 ára íslenskra unglinga viðmið um daglega hreyfingu, en drengir hreyfðu sig meira en stúlkur af miðlungs- eða mikilli ákefð. Æskilegt er talið að ungmenni sofi í 8-10 klukkutíma á sólarhring.[4] Ríflega helmingur bandarískra ungmenna er talinn leggja sig á daginn vegna syfju.[8]

Aukin hreyfing er talin tengjast eða leiða til betri svefns.[9] Rannsóknum á unglingum ber saman um að hreyfing hafi jákvæð áhrif á svefnlengd þeirra.[10] Einnig hefur komið fram að börn (10-12 ára) sem fylgja svefnráðleggingum eru líklegri til að viðhalda reglulegum og heilbrigðum hreyfivenjum.[11] Nýleg samantektargrein ályktaði að börn og unglingar sem hreyfa sig mikið, sofa vel og eru í lítilli kyrrsetu hafi ákjósanlegra magn líkamsfitu og séu í betra formi en þau ungmenni sem eru í meiri kyrrsetu, hreyfa sig lítið og sofa minna.[12]

Á síðustu árum hafa hröðunarmælar í auknum mæli verið nýttir til mælinga á hreyfingu og svefni þar sem þeir gefa hlutlægt mat á hvoru tveggja í náttúrulegu umhverfi einstaklinga.[1,3] Mælarnir eru taldir réttmætir og áreiðanlegir við mælingar á hreyfingu og svefni hjá börnum og ungmennum.[14-17] Samanburður á hlutlægum og huglægum mælingum á svefnlengd unglinga bendir til þess að þær huglægu ofmeti svefnlengd, sem þýðir að ungmenni fá jafnvel enn styttri nætursvefn en hingað til hefur verið talið.[18] Fáar rannsóknir hafa metið tengsl hreyfingar og svefns með hlutlægum mælingum á báðum breytum.[10]

Markmið rannsóknarinnar var að meta: a) hversu hátt hlutfall 16 ára reykvískra ungmenna uppfyllir viðmið um hreyfingu og svefn, b) hvort tengsl séu á milli magns hreyfingar og svefns og ennfremur c) kynjamun á hreyfingu og svefni.

Efniviður og aðferðir

Rannsóknarsnið og val á þátttakendum

Rannsóknin er þversniðsrannsókn byggð á gögnum sem safnað var á tímabilinu apríl-júní 2015. Þátttakendur voru nemendur 10. bekkjar við 6 grunnskóla í Reykjavík, langflestir fæddir árið 1999. Alls var 411 nemendum boðin þátttaka og 315 þáðu boðið (76,6% þátttökuhlutfall). Mælingar fóru fram í hverjum skóla fyrir sig. Ungmennin og foreldrar/forráðamenn þeirra undirrituðu upplýst samþykki áður en þátttaka hófst. Vísindasiðanefnd samþykkti framkvæmd rannsóknarinnar (VSN b200605002&03).

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Spurning	Samantekt svarmöguleika
Hversu margar klukkustundir æfir þú íþróttir eða stundar líkamsrækt í venjulegri viku?	≤ 6 klst í viku ≥ 6 klst í viku
Hversu oft reynir þú á þig líkamlega þannig að þú mæðist verulega eða svitnir?	≤ 6x í viku ≥ 6x í viku
Stundar þú íþróttir?	Já Nei
Sefur þú nóg?	Ég sef of mikið Ég sef oftast nóg Ég sef nóg um helming nátta Ég sef mjög sjaldan nóg

Mynd 1. *Samantekt svarmöguleika úr spurningalista.*

Mælingar á svefni og hreyfingu með hröðunarmæli

Actigraph GT3X+ hröðunarmælar (ActiSleep by Actigraph Inc. Pensacola Florida, USA) voru notaðir til mælinga á hreyfingu og svefni þátttakenda. Þessir hröðunarmælar mæla og vista hreyfingu (slög/mín) í þremur plönum (*triaxial*). Mælarnir eru hannaðir fyrir rannsakendur og hafa ekkert notendaviðmót. Mælarnir eru litlir (3,8 cm x 3,7 cm x 1,8 cm) og léttir (27 g) kubbar festir með ól og bornir líkt og úr. Þátttakendur báru hröðunarmæli á úlnlið víkjandi handleggs samfellt í 7 sólarhringa. Hreyfibreytur og svefnbreytur voru reiknaðar í Actilife forritinu (6.13.0) frá Actigraph. Hreyfing var reiknuð sem meðaltal slaga á mínútu á dag (3D-slög/mín/dag) yfir vökutíma vikunnar. Þá nema mælarnir birtustig og því má fylgjast með breytingum á dagsbirtu yfir rannsóknartímabilið með þeim.

Við útreikninga á hvíldartíma, svefnlengd og svefnnýtingu var notast við reikniformúlu Sadeh og félaga, sérstaklega þróaðri fyrir ungmenni.[16] Réttmæti og áreiðanleiki Actilife við svefnrannsóknir hefur verið borinn saman við svefnrita (*polysomnography*, PSG) hjá öðrum aldurshópum og mælt er með að staðsetja mælana á úlnlið.[19] Ungmennin fylltu út svefndagbók þá viku sem þau báru hröðunarmælinn og var dagbókin notuð til að staðfesta svefntíma reiknaðan af Actilife og leiðrétta skekkjur á svefnmati forritsins ef þurfti.

Tafla I. *Lýsandi tölfræði.*

	Drengir (n=106)	Stúlkur (n=160)	Allir (n=266)
	Meðaltal ± SD	Meðaltal ± SD	Meðaltal ± SD
Aldur (ár)	15,8 ± 0,3	15,9 ± 0,3	15,8 ± 0,3
Hæð (cm)	178,4 ± 18,3	166,9 ± 14,4	171,5 ± 8,1
Þyngd (kg)	69,1 ± 12,8	62,0 ± 11,3	64,9 ± 11,0
LÞS (kg/m^2)	21,7 ± 3	22,2 ± 3,2	22,0 ± 3,1

Skammstafanir: n, fjöldi þátttakenda. LÞS, líkamsþyngdarstuðull. SD= Standard deviation = staðalfrávik.

Hvíldartími, sá tími sem ráðleggingar um svefnlengd (8-10 klukkustundir) eru miðaðar við,[4] var reiknaður í klukkustundum og mínútum frá þeim tíma sem viðkomandi lagðist til hvílu að kvöldi og þar til hann stóð upp að morgni. Svefnlengd er skilgreind sem sá tími sem þátttakandi sefur í klukkustundum og mínútum en svefnnýting (*sleep efficiency*) er skilgreind sem hlutfall svefnlengdar af hvíldartíma í prósentum.

Hröðunarmælarnir voru fyrirfram stilltir á upphafspunkt mælinga og hófust mælingar nokkrum klukkustundum eftir ásetningu mælis, þar sem talið var að þátttakendur væru meðvitaðir um hreyfingu sína fyrstu klukkustundina. Niðurstöður úr mælunum töldust gildar ef þátttakendur báru mælana í að minnsta kosti 14 klukkutíma á dag, í þrjá skóladaga og einn frídag. Lengsta svefnlota einstaklings dag hvern var skilgreind sem nætursvefn og aðrar svefnlotur sem daglúrar. Sadeh-reikniformúlan greinir svefn út frá 11 mínútna glugga þar sem 5 lotur aftur í tímann og næstu 5 lotur fram á við eru viðmið um hreyfingu eða kyrrsetu viðkomandi. Daglúrar voru ekki teknir með í útreikninga á svefnlengd þar sem einungis 15 manns töldust hafa sofnað að deginum, í alls 19 skipti.

Mælingar á hreyfingu og svefni með spurningalistum

Þátttakendur svöruðu spurningalista á spjaldtölvu um ýmsa þætti tengda heilsu, þar á meðal hreyfingu, þátttöku í íþróttum og líkamsrækt og svefnvenjur. Samantekt úr spurningalista varðandi líkamlega áreynslu og svefn má sjá á mynd 1.

Sem viðmið um að hreyfiráðleggingum Embættis landlæknis væri náð var notast við svar möguleikann „meira en 6 klukku-

Tafla II. *Niðurstöður úr spurningalista. Fjöldi (hlutfall).*

Hlutlægar breytur	Drengir (n=106)	Stúlkur (n=160)	Allir (n=266)	Samanburður milli kynja p-gildi (χ^2 próf)
Hreyfing				
Stundar íþróttir með íþróttafélagi	81 (76,4)	108 (67,5)	189 (71,1)	0,15
Íþróttaiðkun eða hreyfing >6 klst/viku	56 (52,8)	59 (36,9)	115 (43,2)	0,01
Reynir á þig þannig að þú svitnir eða mæðist >6 daga/viku	42 (39,6)	47 (29,4)	89 (33,5)	0,11
Sefur þú nóg?				
Ég sef of mikið	2 (1,9)	1 (0,6)	3 (1,1)	0,78
Ég sef oftast nóg	53 (50,0)	83 (51,9)	136 (51,1)	
Ég sef nóg um helming nótta	28 (26,4)	39 (24,4)	67 (25,2)	
Ég sef mjög sjaldan nóg	23 (21,7)	37 (23,1)	60 (22,6)	

Skammstafanir: n, fjöldi þátttakenda. P-gildi er reiknað með χ^2 prófi milli kynja.

Tafla III. *Niðurstöður úr hreyfimælum, skipt eftir kyni og dögum. Samanburður á milli skóladaga miðað við frídaga og á drengjum miðað við stúlkur. Víxlhrif milli skóladaga/frídaga og kyns.*

	Drengir meðaltal ± SD)			Stúlkur (meðaltal ± SD)			Skóla/frídagar	Drengir/Stúlkur	Víxlhrif
Hlutlægar breytur	Skóladaga	Frídaga	Alla daga	Skóladaga	Frídaga	Alla daga	p	p	p
Hreyfing									
Hreyfing (3D-slög/mín/dag)	2215,2 ± 493,0	1645,8 ± 537,3	1991,8 ± 463,4	2180,4 ± 520,5	1857,4 ± 506,6	2049,4 ± 474,3	<0,001	0,13	<0,001*
Svefn									
Hvíldartími (klst/dag)	7,04 ± 0,79	8,45 ± 1,36	7,77 ± 0,70	7,07 ± 0,79	8,43 ± 1,07	7,56 ± 0,68	<0,001	0,981	0,72
Svefntími (klst/dag)	6,17 ± 0,72	7,3 ± 1,2	6,6 ± 0,67	6,2 ± 0,70	7,4 ± 0,96	6,63 ± 6,2	<0,001	0,566	0,814
Svefnnýting (%)	87,9 ± 4,5	86,7 ± 4,2	87,5 ± 3,9	87,8 ± 4,5	87,9 ± 5,1	87,8 ± 4,4	0,07	0,294	0,017
Hvíldust >= 8 klst n (%)	8 (5,0)	73 (68,9)	23 (21,7)	21 (19,8)	105 (65,6)	38 (23,8)	<0,001	0,744	0,21
Sváfu >= 8 klst n (%)	1 (0,6)	27 (25,5)	2 (1,9)	0 (0,0)	38 (23,8)	3 (1,9)	<0,001	0,624	0,887

stundir á viku“ við spurningunni „*hversu margar klukkustundir æfir þú íþróttir eða stundar líkamsrækt í venjulegri viku?*“

Tölfræðiúrvinnsla

Munur á hlutföllum milli hópa í flokkabreytum úr spurningalista var kannaður með Kí-kvaðrat prófi, til dæmis munur á íþróttaþátttöku milli kynja. Tvíhliða dreifigreining var notuð til að bera saman meðaltal svefns og hreyfingar (samfelldar breytur mældar með hreyfimælum) með pöruðum samanburði milli skóladaga og frídaga annars vegar og samanburði milli drengja og stúlkna hins vegar. Þá voru víxlhrif milli skóladaga/frídaga og kyns könnuð. Tvíhliða dreifigreining var einnig notuð til að bera saman meðalhreyfingu mælda með hreyfimælum eftir þátttöku í íþróttum og hreyfingu samkvæmt spurningalista. Einhliða dreifigreining var notuð til að bera saman meðaltal svefnbreyta mældum með hreyfimælum milli flokkabreyta úr spurningalista. T-próf var notað til að bera saman svefn mældan með hreyfimælum við þátttöku í íþróttum og hreyfingu samkvæmt spurningalista. Notuð voru Tukey eftir-á-próf til að kanna mun milli hópa (þar með talin sérhver samsetning á skóla/frídögum og stúlkum/drengjum) með Bonferroni-leiðréttingu.

Pearson-fylgnistuðull var notaður til að kanna tengsl milli hreyfingar, svefns og dagsbirtu. Marktektarmörk voru skilgreind við p-gildi 0,05 eða minna. Tölfræðileg úrvinnsla fór fram með forritunum Excel og Rstudio (útgáfa 0.99.482).

Niðurstöður

Í töflu I er einkennum úrtaksins lýst. Í rannsókninni voru 266 einstaklingar með gild hreyfi- og svefngildi úr hreyfimælum, gildir dagar fyrir hreyfingu voru að meðaltali 6,1 ± 0,6 og gildar nætur fyrir svefn voru 7,1 ± 0,7. Meðalaldur þátttakenda var 15,8 ± 0,3 ár. Meðallengd dagsbirtu yfir rannsóknartímabilið var 17,6 ± 1,8 klst, stystur dagur var 15,1 klukkustund og lengstur 20,5 klukkustundir. Engin tengsl fundust milli dagsbirtu og hvíldartíma. Hins vegar fundust tengsl milli dagsbirtu og hreyfingar (3D-slög/dag/mín) yfir vikuna hjá öllum þátttakendum (r=0,18, p=0,004), stúlkum (r=0,22, p=0,005) en ekki hjá drengjum.

Tafla II sýnir niðurstöður úr spurningalistum. Marktækt hærra hlutfall drengja en stúlkna stundaði íþróttir eða líkamsrækt í 6 tíma eða meira á viku, eða 52,8% drengja á móti 36,9% stúlkna (p=0,01). Einnig sagðist hærra hlutfall drengja en stúlkna mæðast eða svitna verulega 6 sinnum í viku eða oftar. Ekki var munur milli kynja á því hversu oft þátttakendur töldu sig sofa nóg.

Tafla III sýnir hreyfingu og svefn vikunnar samkvæmt hreyfimælum. Ekki var marktækur munur á hreyfingu stúlkna og drengja alla daga vikunnar eða skóladaga, hins vegar var víxlverkun milli skóladaga/frídaga og kyns, stúlkur hreyfðu sig mark-

Tafla IV. *Huglægt mat borið saman við hlutlægt mat á hreyfingu.*

	Hlutlægt mat á hreyfingu úr hröðunarmæli (3D-slög/mín/dag)								
	Drengir		Stúlkur		Allir		Já/Nei	Drengir/ Stúlkur	Víxlhrif
	Já	Nei	Já	Nei	Já	Nei	p	p	p
Huglægt mat á hreyfingu									
Stundar íþróttir með íþróttafélagi	2099,4 ± 438,9	1643,3 ± 363,2	2160,4 ± 474,0	1818,8 ± 386,9	2134,3 ± 459,1	1761,8 ± 385,9	<0,001	0,097	0,359
Íþróttaiðkun eða hreyfing >6 klst/viku	2134,7 ± 398,3	1831,8 ± 482,3	2171,1 ± 481,2	1978,3 ± 457,8	2153,4 ± 441,3	1929,8 ± 469,6	<0,001	0,099	0,343
Reynir á þig þannig að þú svitnir eða mæðist >6 daga/viku	2148,6 ± 434,7	1888,9 ± 455,8	2240,2 ± 475,6	1970,1 ± 452,6	2197,0 ± 456,5	1940,7 ± 454,2	<0,001	0,14	0,931

3D-slög/mín/dag meðaltal af slögum á mínútu á dag.

Tafla V. *Huglægt mat á svefni samanborið við hlutlægt mat úr hröðunarmælum.*

	Huglægar svefnbreytur úr spurningalista: Sefur þú nóg? Alla daga				
	Of mikið (n=3)	Oftast (n=136)	Helming nátta (n=67)	Sjaldan (n=60)	p
Niðurstöður úr hreyfimælum fyrir alla vikuna					
Hvíldartími (klst/dag)	8,0 ± 1,2	7,7 ± 0,6	7,5 ± 0,7	7,2 ± 0,7	<0,001
Svefntími (klst/dag)	6,8 ± 1,0	6,7 ± 0,6	6,6 ± 0,8	6,4 ± 0,6	0,017
Svefnnýting (%)	85,7 ± 2,0	87,2 ± 4,3	88,0 ± 4,4	88,5 ± 3,6	0,149
Hvíldust >= 8 klst (n, %)	1,0 (33,3)	40,0 (29,4)	12,0 (17,9)	8,0 (13,3)	0,057
Sváfu >= 8 klst (n, %)	0 (0)	2,0 (1,5)	3,0 (4,5)	0 (0)	0,289
Hreyfing (3D-slög/mín/dag)	2037,1 ± 301,5	2049,3 ± 441,5	1967,1 ± 540,8	2040,4 ± 458,7	0,697

Skammstafanir: n, fjöldi, % hlutfall. 3D-slög/mín/dag, meðalslög á mínútu á dag.

tækt meira en drengir á frídögum (p<0,01). Þá hreyfðu drengir og stúlkur sig marktækt meira á skóladögum en frídögum (p<0,001).

Bæði stúlkur og drengir sváfu skemur á skóladögum (p<0,001) en frídögum. Ekki var marktækur kynjamunur á svefnlengd á skóladögum né á frídögum. Þegar hvíldartími skóladaga var borinn saman við ráðlagðan svefntíma unglinga, minnst 8 tíma nætursvefn, náðu einungis 5,0% drengja og 19,8% stúlkna ráðlögðum hvíldartíma. Á frídögum náðu 68,9% drengja og 65,6% stúlkna ráðlögðum hvíldartíma fyrir unglinga.

Í töflu IV er borin saman hreyfing sem mæld var með hreyfimælum annars vegar og metin með spurningalistum hins vegar. Stúlkur og drengir sem stunduðu íþróttir og/eða líkamsrækt í meira en 6 klukkustundir á viku hreyfðu sig einnig meira dag hvern samkvæmt hröðunarmælum, samanborið við þau sem hreyfðu sig minna en 6 tíma á viku (p<0,001). Þá mældist einnig marktækt meiri hreyfing með hröðunarmæli hjá þeim sem sögðust reyna á sig líkamlega þannig að þau mæddust eða svitnuðu að minnsta kosti 6 daga vikunnar en hjá öðrum (p<0,001). Sambærilegur munur fékkst milli þeirra sem stunduðu íþróttir með íþróttafélagi og hjá þeim sem stunduðu ekki íþróttir, sérstaklega meðal drengja. Þá mældust ungmenni sem stunduðu íþróttir með 21,1% fleiri slög samkvæmt hröðunarmælum en þeir sem stunduðu ekki íþróttir (p<0,001).

Tafla V sýnir niðurstöður fyrir samanburð á svefni mældum með hreyfimælum og svefni metnum með spurningalistum. Um helmingur þátttakenda taldi sig „oftast sofa nægilega mikið" samkvæmt spurningalista. Þessi ungmenni hvíldust og sváfu einnig lengur samkvæmt hröðunarmæli en þau sem sögðust sofa nóg „um helming nátta" eða „mjög sjaldan".

Í töflu VI eru hvíldartími og svefnlengd mæld með hreyfimæli skoðuð út frá hreyfingu samkvæmt spurningalistum. Ekki var marktækur munur á hvíldar- eða svefnlengd þeirra sem náðu viðmiðum um hreyfingu (≥6 tíma á viku) og þeirra sem ekki náðu þeim viðmiðum samkvæmt niðurstöðum spurningalista. Ekki var heldur marktækur munur á svefnlengd eftir þátttöku í íþróttum.

Einungis 11,3% þátttakenda uppfylltu viðmið um hreyfingu samkvæmt spurningalista og viðmið um svefn mældan með hreyfimæli yfir vikuna. Á skóladögum náðu einungis um 10,9% þátttakenda að uppfylla viðmið um bæði hvíldartíma og hreyfingu.

Umræða

Niðurstöður þessarar rannsóknar benda til þess að nokkuð mikið vanti upp á að íslensk ungmenni uppfylli viðmið um ráðlagða hreyfingu og svefn. Samkvæmt svörum þátttakenda við spurningalistum uppfyllti ríflega helmingur drengja en nokkuð færri stúlkur viðmið um hreyfingu. Þar sem 39,6% drengja og 29,4% stúlkna hreyfðu sig oftar en 6 sinnum í viku af það mikilli ákefð að þau mæddust eða svitnuðu má ætla að hreyfing ungmennanna komi að einhverjum hluta af miðlungs- eða mikill ákefð eins og ráðleggingar mælast til. Stúlkur hreyfðu sig meira en drengir á frídögum samkvæmt niðurstöðum úr hröðunarmælum (3D-slög/mín/dag) en ekki var marktækur munur á hreyfingu stúlkna og drengja aðra daga. Þessar niðurstöður eru frábrugðnar niðurstöðum rannsóknar frá árinu 2011[3] á hreyfingu íslenskra barna og unglinga mældri með hröðunarmælum sem bornir voru á mjöðm (ActiGraph 7124) þar sem einungis 9% 15 ára unglinga uppfylltu viðmið um ráðlagða daglega hreyfingu (>3400 slög/mín/dag). Þar kom einnig fram munur á hreyfingu kynjanna þar sem einungis 1,5% stúlkna og 14,5% drengja uppfylltu viðmiðin. Hafa ber þó í huga að breytileg skilgreining á miðlungserfiðri hreyfingu og mælitækin sem notast er við geta haft áhrif á hlutfall þeirra sem uppfylla viðmiðin. Í núverandi rannsókn var nokkuð gott samræmi milli hreyfingar samkvæmt spurningalistum og mældri með hreyfimælum, þar sem þau sem sögðust hreyfa sig meira samkvæmt spurningalista mældust einnig með 21,1% meiri meðaltalshreyfingu samkvæmt hreyfimælum en þau sem gáfu svar um minni hreyfingu. Þá má sjá að fleiri drengir en stúlkur sögðust stunda íþróttir og mæðast eða svitna 6 sinnum í viku eða oftar en stúlkur mældust þó með fleiri slög á mínútu með hreyfimælum á frídögum. Þetta gæti gefið til kynna að hreyfing stúlkna og drengja sé að einhverju leyti frábrugðin og að hreyfing stúlkna fari síður fram sem skipulögð æfing eða þjálfun en meðal drengja. Það gæti þýtt að hreyfing stúlkna sé að meðaltali af minni ákefð en hreyfing drengja. Engin viðurkennd viðmið um magn eða ákefð hreyfingar mældrar með hreyfimælum eru til, svo erfitt er að bera hreyfigögn frá úlnliðsmæli saman við almennar hreyfiráðleggingar.

Niðurstöður rannsóknar á hreyfingu barna og unglinga á Vesturlöndum benda til að hreyfing minnki um 7% árlega á aldursbilinu 7-19 ára. Mest dró úr hreyfingu stúlkna á aldursbilinu 9-12 ára en 13-16 ára hjá drengjum. Talið er að kynþroski hafi áhrif á þessar breytingar og stúlkur þroskist að meðaltali fyrr sem að

Tafla VI. *Huglægt mat á hreyfingu borið saman við hlutlægt mat á svefnbreytum.*

	Huglægar mælingar á hreyfingu fengnar úr spurningalista								
	Þátttaka í íþróttum á vegum íþróttafélags			Íþróttaiðkun eða hreyfing >6 klst/viku			Reynir á þig þannig að þú svitnir eða mæðist >6 daga/viku		
	Já (n=189)	Nei (n=77)	p	Já (n=115)	Nei (n=151)	p	Já (n=89)	Nei (n=177)	p
Svefnbreytur úr hreyfimæli									
Alla daga									
Hvíldartími (klst/dag)	7,5 ± 0,7	7,6 ± 0,7	0,422	7,6 ± 0,7	7,6 ± 0,7	0,888	7,5 ± 0,6	7,6 ± 0,7	0,582
Svefntími (klst/dag)	6,6 ± 0,6	7,67 ± 0,7	0,492	6,6 ± 0,6	6,6 ± 0,6	0,729	6,5 ± 0,6	6,6 ± 0,6	0,198
Svefnnýting (%)	87,7 ± 4,0	87,7 ± 4,6	0,939	87,8 ± 4,0	87,6 ± 4,4	0,813	87,1 ± 4,2	88,0 ± 4,2	0,089
Hvíldust >= 8 klst (n, %)	42 (22,2)	19 (24,7)	0,673	30 (26,1)	31 (20,5)	0,293	20 (22,5)	41 (23,2)	0,899
Sváfu >= 8 klst (n, %)	2 (1,1)	3 (3,9)	0,229	1 (0,9)	4 (2,6)	0,259	0 (0,0)	5 (2,8)	0,025
Skóladaga									
Hvíldartími (klst/dag)	7,1 ± 0,8	7,1 ± 0,8	0,422	7,1 ± 0,7	7,0 ± 0,8	0,888	7,1 ± 0,7	7,0 ± 0,8	0,482
Svefntími (klst/dag)	6,2 ± 0,7	6,2 ± 0,7	0,492	6,2 ± 0,7	6,2 ± 0,7	0,729	6,2 ± 0,6	6,2 ± 0,7	0,881
Svefnnýting (%)	87,9 ± 4,3	87,7 ± 4,9	0,939	87,9 ± 4,5	87,8 ± 4,5	0,813	87,1 ± 4,7	88,2 ± 4,3	0,07
Hvíldust >= 8 klst (n, %)	21 (11,1)	8 (10,4)	0,673	12 (10,4)	17 (11,3)	0,293	11 (12,4)	18 (10,2)	0,601
Sváfu >= 8 klst (n, %)	0 (0,0)	1 (1,3)	0,229	0 (0,0)	1 (0,7)	0,259	0 (0,0)	1 (0,6)	0,319
Frídaga									
Hvíldartími (klst/dag)	8,4 ± 1,2	8,6 ± 1,1	0,422	8,4 ± 1,2	8,5 ± 1.2	0,888	8,3 ± 1,2	8,5 ± 1,2	0,34
Svefntími (klst/dag)	7,3 ± 1,1	7,5 ± 1,0	0,492	7,4 ± 1,1	7,4 ± 1,1	0,729	7,3 ± 1,1	7,4 ± 1,1	0,233
Svefnnýting (%)	87,3 ± 4,6	87,6 ± 5,1	0,939	87,5 ± 4,4	87,4 ± 5,1	0,813	87,0 ± 4,6	87,6 ± 4,8	0,285
Hvíldust >= 8 klst (n, %)	125 (66,1)	53 (68,8)	0,673	76 (66,1)	102 (67,5)	0,293	57 (64,0)	121 (68,4)	0,487
Sváfu >= 8 klst (n, %)	43 (22,8)	22 (28,6)	0,229	28 (24,3)	37 (24,5)	0,259	22 (24,7)	43 (24,3)	0,94

Skammstafanir: n, fjöldi. %, hlutfall.

hluta til geti útskýrt þennan mun.[20] Í nýlegri evrópskri rannsókn[21] dró verulega úr hreyfingu af miðlungs eða mikilli ákefð frá aldrinum 9-15 ára og samhliða jókst kyrrseta, þó meira hjá drengjum en stúlkum. Þessar breytingar á hreyfingu voru þó breytilegar milli landa og landssvæða.

Hreyfing mæld með hröðunarmælum minnkaði marktækt hjá báðum kynjum á frídögum samanborið við skóladaga. Skipulögð hreyfing innan skólans gæti útskýrt þennan mun. Hafa ber þó í huga að ungmennin báru hröðunarmælinn allan sólarhringinn yfir rannsóknartímann og minni hreyfingu á frídögum má einnig skýra með auknum hvíldartíma á frídögum þar sem hvíldartíminn var tæpum tveimur klukkutímum lengri en á skóladögum.

Veðurfar og dagsbirta eru hugsanlegir áhrifaþættir hreyfingar. Erlendar rannsóknir hafa sýnt að tímabil með rigningu, vindum, lágu hitastigi og snjó geta dregið úr almennri hreyfingu barna og unglinga.[22] Þar sem rannsókn okkar fór fram að vori má gera ráð fyrir að bæði dagsbirta og veðurfar gæti hafa haft áhrif á hreyfingu ungmennanna. Tengsl dagsbirtu og hreyfingar fundust hjá hópnum þegar hreyfing yfir alla vikuna var skoðuð. Einnig fundust marktæk tengsl milli dagsbirtu og hreyfingar hjá stúlkum en ekki drengjum. Rannsóknir á hreyfingu þessa aldurshóps á mismunandi árstímum gæti varpað frekara ljósi á þessi tengsl veðurfars, hitstigs og dagsbirtu við hreyfingu.

Fæst íslensk ungmenni ná viðmiðum um svefnlengd[4] á skóladögum þegar svefn er metinn út frá hvíldartíma. Þar sem ráðleggingar um svefnlengd eru byggðar á rannsóknum sem flestar byggja á huglægum mælingum á svefni er æskilegt að bera útreiknaðan hvíldartíma unglinga, byggðan á háttatíma og fótaferðatíma, saman við almennar svefnráðleggingar þegar hlutlægum mælingum er beitt.[4] Á frídögum má sjá að ungmennin bæta við um 1,2 klukkutímum í hvíldartíma miðað við skóladaga sem er þekkt mynstur meðal unglinga.[23] Svefnbreytan svefnnýting er notuð, ásamt fleiru, til að meta gæði svefns. Stuðullinn fyrir svefnnýtingu segir til um hve hátt hlutfall af hvíldartíma viðkomandi nýtir til svefns en gerir ekki greinarmun á því hvort viðkomandi vakni oft yfir nóttina eða sé lengi að sofna. Því er svefnnýting notuð sem almenn matsbreyta fyrir svefngæði og sem slík er erfitt að setja viðmið um hátt og lágt gildi hennar.[24] Hins vegar má auðveldlega bera saman svefnnýtingu einstaklinga milli tímabila. Ekki var munur á svefnnýtingu milli kynja eða á milli frídaga og skóladaga hjá ungmennunum.

Ýmsir þættir geta haft áhrif á svefngæði og svefnlengd unglinga. Dagsbirta er þekktur áhrifavaldur og eykst svefnlengd venjulega yfir veturinn og styttist yfir sumartímann.[6,25] Í rannsókninni fannst ekki samband milli dagsbirtu og hvíldartíma, svefnlengdar eða svefnnýtingar, þrátt fyrir að daginn hafi lengt töluvert á rannsóknartímabilinu (úr 15,1 í 20,5 klukkustundir). Í íslenskri rannsókn á ungmennum um tvítugt frá árinu 1985 fannst heldur ekki munur á svefnlengd einstaklinga að vetri eða að sumri til.[26] Ekki hefur fundist munur á svefnlengd íslenskra stúlkna og drengja[6] en í erlendum rannsóknum á unglingum hafa niðurstöður um svefnlengd eftir kynjum verið misjafnar og sýnt bæði að drengir sofi lengur en stúlkur og öfugt.[27,28]

Nokkuð gott samræmi fékkst milli hlutlægra og huglægra mælinga á svefni. Þannig virtust þeir sem svöruðu í spurningalista að þeir svæfu nægilega mikið einnig sofa að meðaltali lengur samkvæmt hröðunarmæli en þeir sem sögðust sofa minna. Þrátt fyrir að svefndagbækur hafi verið gagnrýndar fyrir ónákvæmni í mælingum,[18] virðist huglægt mat unglinganna á því hvort þeir sofi nóg haldast í hendur við mælda svefnlengd þrátt fyrir að svefnlengdin nái ekki endilega viðmiðum um ráðlagða svefnlengd.

Einungis 11,3% þátttakenda uppfylltu viðmið fyrir hvort tveggja, ráðleggingar um hvíldartíma (≥8 klst/nótt) og hreyfiviðmið (≥60 mín/dag) að meðaltali yfir vikuna. Þeir sem ná viðmiðum um daglega hreyfingu, sofa ekki endilega meira en þeir sem ekki ná þeim viðmiðum. Rannsóknir þar sem gögn fyrir bæði hreyfingu og svefn eru fengin með huglægu mati og einnig þar sem hlutlægar mælingar eru notaðar fyrir báðar breytur hafa bent til þess að aukin hreyfing hafi jákvæð áhrif á svefn.[10] Þegar bornar eru saman hlutlægar og huglægar mælingar á svefnlengd unglinga virðast þær huglægu ofmeta svefnlengd.[18] Því er nauðsynlegt að kanna betur tengsl hreyfingar og svefns mældum með hlutlægum mælingum. Bandarísku svefnsamtökin mæla með reglulegri hreyfingu til að bæta svefn[29] þrátt fyrir að rannsóknir meðal barna og unglinga sýni fram á mismunandi tengsl milli svefns og hreyfingar.[11,30,31] Þá geta mismunandi mæliaðferðir milli rannsókna, árstíðir og aldur mögulega útskýrt mismunandi niðurstöður á tengslum hreyfingar og svefns.

Styrkleikar og takmarkanir

Þetta er fyrsta íslenska rannsóknin sem skoðar bæði hreyfingu og svefn ungmenna með hlutlægum mælingum. Gott þátttökuhlutfall fékkst við gagnasöfnun en alls tóku 315 nemendur þátt eða 76,6% þeirra sem boðin var þátttaka í rannsókninni. Þó höfðu einungis 266 einstaklingar gild gögn sem má skýra með lágmarkskröfum um gild gögn úr hröðunarmælum eða 14 klukkustundir á dag, þrjá skóladaga og einn frídag. Hröðunarmælar gefa nákvæmar upplýsingar um svefn og hreyfingu hjá ungmennum í sínu náttúrulega umhverfi. Þrátt fyrir aukin gæði í svefnmælingum og áreiðanleika Actigraphy-hröðunarmælanna gera mælarnir illa greinarmun á svefni og vöku þegar við liggjum fullkomlega kyrr í lengri tíma.[17] Þetta gæti verið skýring þess að daglúrar greindust aðeins hjá 15 einstaklingum en alls greindust 19 daglúrar, þar af mældist einn einstaklingur með 5 daglúra. Þegar bera á niðurstöður fyrir mælingar á svefni og hreyfingu með hröðunarmælum saman við almennar ráðleggingar um svefn og hreyfingu eru viðmiðunargildi fyrir hlutlægar mælingar af skornum skammti þar sem viðmiðin hafa í gegnum tíðina verið þróuð með huglægum mælingum eins og spurningalistum.

Þar sem rannsóknin fór fram að vori hjá nemendum 10. bekkjar er ekki hægt að útiloka að dagsbirta, veðurfar, álag og starf í skóla geti haft áhrif á svefnlengd, hvíldartíma og hreyfingu miðað við aðra árstíma. Þá er hugsanlegt að þátttaka í rannsókninni og það að bera hreyfimæli hafi haft áhrif á svefn- og hreyfivenjur þátttakenda. Að auki kunna aðrir þættir eins og andleg líðan, skjánotkun, neysla orkudrykkja og tímasetningar íþróttaæfinga að hafa haft áhrif á niðurstöðurnar.

Ályktun

Lífsstíll íslenskra ungmenna virðist ekki endurspegla viðmið opinberra aðila um daglega hreyfingu og svefn. Aðeins um helmingur ungmenna í þessari rannsókn náði viðmiðum um ráðlagða hreyfingu samkvæmt niðurstöðum spurningalista. Fá ungmenni náðu viðmiðum um ráðlagðan svefntíma og enn færri uppfylltu bæði viðmið um hreyfingu og svefn.

Þakkir

Rannsóknarhópurinn vill þakka ungmennunum sem tóku þátt í rannsókninni. Einnig þökkum við starfsfólki þátttökuskólanna sem veitti okkur mikla aðstoð og góða aðstöðu til mælinga. Þá viljum við þakka Rannís fyrir fjárhagslegan stuðning.

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ENGLISH SUMMARY

Physical activity and sleep in Icelandic adolescents

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Introduction: Physical activity and sleep are major determinants of overall health. According to international recommendations, adolescents should engage in moderate to vigorous physical activity for at least 60 min each day and sleep eight to ten hours each night. The association between physical activity and sleep in adolescents is not well known. The aim of the study was to estimate a) the proportion of Icelandic adolescents that achieves recommended physical activity and sleep, b) if there is an association between physical activity and sleep patterns, and c) sex differences in physical activity and sleep.

Material and methods: A total of 411 adolescents from the 10th grade in six schools in Reykjavik were invited to participate in a cross-sectional study in the spring of 2015. Valid data was obtained from 106 boys and 160 girls. Objective and subjective measures of physical activity and sleep were made by wrist-worn accelerometers and a questionnaire.

Results: Almost half of the participants fulfilled the physical activity recommendations according to the questionnaire. Although 51.1% reported usually getting enough sleep, only 22.9% achieved the recommended sleep length according to objective assessment. No associations were observed between sleep and subjective physical activity. Girls had higher accelerometer-measured physical activity than boys on non-school days ($p<0.01$), but weekly averages were not different between sexes. Girls and boys did not differ in subjective or objective measures of sleep.

Conclusion: The behavior of Icelandic adolescents does not reflect recommended amount of sleep and physical activity. Only 22.9% obtained the recommended sleep length and just 11.3% fulfilled recommendations of both sleep and physical activity.

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Key words: *Physical activity, sleep, accelerometers, adolescents.*

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Paper IV

PLOS ONE

RESEARCH ARTICLE

Less physical activity and more varied and disrupted sleep is associated with a less favorable metabolic profile in adolescents

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Abstract

Background

Sleep and physical activity are modifiable behaviors that play an important role in preventing overweight, obesity, and metabolic health problems. Studies of the association between concurrent objective measures of sleep, physical activity, and metabolic risk factors among adolescents are limited.

Objective

The aim of the study was to examine the association between metabolic risk factors and objectively measured school day physical activity and sleep duration, quality, onset, and variability in adolescents.

Materials and methods

We measured one school week of free-living sleep and physical activity with wrist actigraphy in 252 adolescents (146 girls), aged 15.8±0.3 years. Metabolic risk factors included body mass index, waist circumference, total body and trunk fat percentage, resting blood pressure, and fasting glucose and insulin levels. Multiple linear regression adjusted for sex, parental education, and day length was used to assess associations between metabolic risk factors and sleep and activity parameters.

Results

On average, participants went to bed at 00:22±0.88 hours and slept 6.2±0.7 hours/night, with 0.83±0.36 hours of awakenings/night. However, night-to-night variability in sleep duration was considerable (mean ± interquartile range) 0.75±0.55 hours) and bedtime (0.64 ±0.53 hours) respectively. Neither average sleep duration nor mean bedtime was associated with any metabolic risk factors. However, greater night-to-night variability in sleep duration and bedtime was associated with higher total body and trunk fat percentage, and less physical activity was associated with higher trunk fat percentage and insulin levels.

Conclusion

Greater nightly variation in sleep duration and in bedtime and less physical activity were associated with a less favorable metabolic profile in adolescents. These findings support the idea that, along with an adequate amount of physical activity, a regular sleep schedule is important for the metabolic health of adolescents.

Introduction

The prevalence of overweight in the world has nearly tripled from 1975–2016, with over 39% of adults and 18% of children and adolescents being overweight or obese [1]. Greater total body and central adiposity is associated with increased risk of cardio-metabolic comorbidities, such as hypertension and diabetes [2, 3]. Prevalence of metabolic syndrome is high among obese children and adolescents and increases with higher central obesity [4]. Along with diet, sleep and physical activity have been identified as important modifiable risk factors implicated in the development of overweight, obesity, and metabolic health problems [5].

The importance of adequate sleep for health and daily functioning in adolescents is well established [6, 7], although most studies are based on subjective data. Most national and international guidelines focus on recommendations for sleep duration, since prior research has demonstrated that insufficient sleep duration during adolescence is associated with a variety of cognitive, psychological, and health risks, including higher body mass index (BMI) [8–10], greater body fat [11], and increased insulin resistance [12]. However, emerging evidence suggests that sleep quality [13–15] and timing may also affect adolescent cardiometabolic risk factors [7]. For instance, later bedtimes are associated with greater BMI [10, 16], body fat [11] and higher systolic blood pressure in children and adolescents [17]. Markers of irregular sleep schedules, such as high variability in sleep duration or greater shifts in sleep timing and duration on weekends, have also been associated with greater adiposity and abdominal obesity [18, 19] and higher BMI and insulin levels [20] in children and adolescents. Studies also suggest that long-term exposure to a disrupted sleep schedule [21] or low physical activity [22] can increase the risk of developing metabolic syndrome, while higher levels of physical activity in children and adolescents are associated with favorable body mass index, lower adiposity, and better cardio-metabolic health [23, 24]. However, adolescent sleep and physical activity are commonly assessed using self-report [25] which tends to overestimate sleep length and physical activity level, suggesting that adolescents likely sleep less [26] and are less active [27] than previously reported.

In one of the few studies to measure adolescent sleep and body composition with objective measures, He *et. al.* (2015) found that more variable sleep patterns, but not shorter sleep duration, was associated with greater central adiposity [18]. However, this study did not include a measure of physical activity, and sleep variability was computed over the entire week. We [28] and others [29, 30] have shown that adolescent sleep patterns are quite different on school nights and non-school nights, thus inclusion of non-school nights likely increases calculated sleep variability. Since studies with simultaneous objective measures of metabolic risk factors and school day sleep and activity are sparse, it is not known whether physical activity and sleep contribute to a better cardiometabolic profile independently.

The aim of the study was to examine associations between metabolic risk factors and concurrent objective measures of free-living sleep and physical activity among Icelandic adolescents. We hypothesized that less activity, shorter sleep duration, poorer sleep quality, and more varied sleep schedules will associate with less favorable cardiometabolic profiles.

Methods

Study design and data collection

All students attending the second grade in six of the largest primary schools in Reykjavik, Iceland were invited to participate in a longitudinal cohort studying health, cardiovascular fitness, and physical activity initiated at seven to eight years of age (N = 320, 82% participated) [31]. In April of 2015, all 411 students (age 15–16) enrolled in the 10th grade at the respective schools received an invitation letter to participate, regardless of their participation in earlier waves of the study. Previous participants who had changed schools were excluded. During April-June, one week of concurrent measurement of sleep and activity with wrist actigraphy was introduced [28]. Anthropometry, blood pressure measurements, questionnaires, and wrist accelerometers were administered at the schools. Students were driven to The Icelandic Heart Association for dual-energy X-ray absorptiometry (DXA) scanning and blood sampling.

Three hundred and fifteen students agreed to participate (response rate 77%), and 252, or 18.6% of the 15 year-olds living in Reykjavik in 2015 (1355) [32], complete data for questionnaire, body composition, sleep, and physical activity measurements. However, participants with and without complete sleep and activity data did not differ in terms of sex distribution, parental education, age, body composition, or cardiometabolic risk markers (S1 Table). Additionally, two participants were missing waist circumference measurements, 4 did not have valid blood pressure measurements, and 13 refused blood draws for serum glucose and insulin. Study participation is shown in Fig 1.

The current study is an exploratory analysis of the 252 participants with complete data whose sleep and physical activity patterns we have previously reported on in greater detail [28]. Written informed consent was obtained from all participants and their guardians. The study was approved by the National Bioethics Committee, the Icelandic Data Protection Authority (Study number: VSNb2015020013/13.07), and the Icelandic Radiation Safety Authority. The study was conducted in agreement with the guidance provided in the Declaration of Helsinki.

Sleep and physical activity parameters

Free-living sleep and physical activity were measured with a wrist-worn accelerometer (GT3X +, Actigraph Inc., Pensacola, FL, USA). The accelerometer was placed on the non-dominant wrist at school and the participant was asked to wear it continuously for a week. Physical activity counts and sleep duration, timing, and quality, were computed with Actilife software version 6.13.0 (Actigraph). The Sadeh algorithm, validated for adolescents [33], was used to detect sleep onsets and awakenings, which were visually inspected and adjusted as necessary by two expert scorers based on daily sleep logs maintained during the week of actigraphy. Wear time and vector magnitude of physical activity counts from 12 midnight to 12 midnight the next day [34] were computed in MATLAB (version R2013a MathWorks, Natick, MA, USA) using previously described algorithms [28, 35]. Since only one week of accelerometer data was collected, we focused our analysis on school days (Monday-Friday) and nights (Sunday-Thursday) and did not include data for weekends or holidays. Participants with ≥3 school days and wear time ≥14 hours were included in analyses of sleep. The longest nightly sleep period beginning between 12 noon and 12 noon the next day was used in the analyses. The

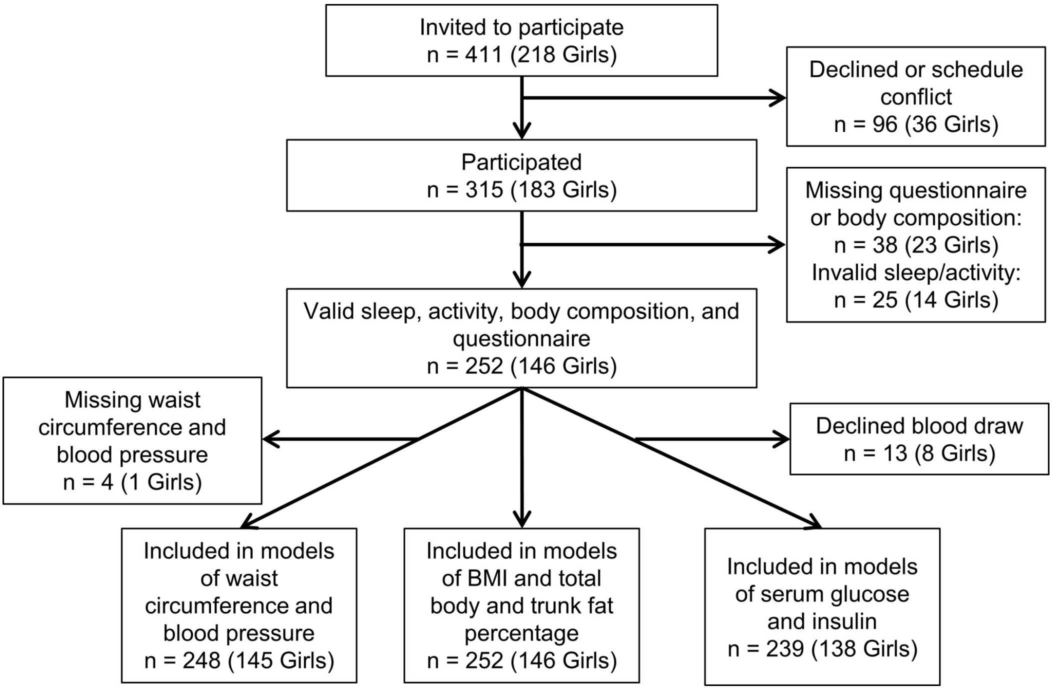

Fig 1. Flow chart describing study participation.

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wear time requirement is in line with a recent systematic review of accelerometer data collection that recommend a minimum wear time of 10 h/day but also noted 24 h assessment for sleep and activity may require longer wear times than studies focused only on waking activity [36]. Sleep and activity parameters are defined in Table 1.

Body composition

Height, weight, and waist circumference was measured at participants' schools. Standing height was measured with a stadiometer (Seca model 217, Seca Ltd. Birmingham, UK) to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 kg using a scale (Seca model 813, Seca Ltd. Birmingham, UK) with participants wearing light clothes. BMI was calculated by dividing weight by height squared (kg/m^2). Waist circumference was measured to the nearest

Table 1. Sleep and physical activity parameters.

Actigraphy parameter	Definition
Sleep duration	Time spent asleep between sleep onset and awakening (hours/night)
Variability in sleep duration	Night-to-night variation (standard deviation) of sleep duration (hours)
Bedtime	Time of sleep onset (clock time)
Variability in bedtime	Night-to-night variation (standard deviation) of sleep onset (hours)
WASO	Wake time after sleep onset (hours/night)
Physical activity	Activity/wear time (3D-counts/minutes of wear/day)

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0.1 cm using a tape measure next to skin at the narrowest place between the lowest rib and the iliac crest. Fat-free and fat mass were measured with dual-energy X-ray absorptiometry (DXA) using a GE LUNAR scanner (General Electric Lunar iDXA) at the Icelandic Heart Association. All DXA measurements were performed by a certified radiologist. Body fat percentage was calculated by dividing total fat mass by the total body mass (fat mass + lean mass + bone mineral content) and trunk fat percentage was calculated by dividing the total trunk fat mass by total trunk mass. Resting blood pressure was measured on the left arm of seated participants and the average of three measurements was used for analysis.

Serum measures

Fasting blood samples were obtained using standard procedures after overnight fasting; samples were analyzed for glucose and insulin. Insulin (mU/L) in serum was measured using the INSULIN assay from Roche, a sandwich electrochemiluminescence immunoassay ECLIA on Cobas e 411 (Roche, Switzerland). The inter-assay coefficient of variation was $< 5.06\%$ using a frozen serum pool and $< 2.36\%$ using quality control samples from Roche. Glucose (mmol/L) in serum was measured using the GLUC2 assay from Roche, an enzymatic reference method with hexokinase. The measurements were done on a Cobas e 311 (Roche, Switzerland). The inter-assay coefficient of variation was $<1.65\%$ using a frozen serum pool and $<1.66\%$ using quality control samples from Roche.

Survey questions and environmental data

Students provided the educational attainment of both mother and father from the following options (presented in Icelandic): 1 = “elementary degree”, 2 = “secondary degree”, 3 = “trade school degree”, 4 = “university degree”, 5 = “other”, 6 = “do not know”, 7 = “do not want to answer”. For the current analysis, responses were recoded into a binary variable: 1 = “parent with a university degree” or 0 = “no parent with a university degree”, as described previously [37]. Information on day length (hours of day light) was obtained from National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory Solar Calculator [38]. Information on ethnicity was not collected in this study since the population of Iceland is traditionally ethnically homogenous. For example, during data collection in 2015, only 8% of 15 years old adolescents in Reykjavik were of non-Icelandic origin [39].

Statistical analyses

T-test for independent samples was used to assess whether participant characteristics, sleep parameters, and physical activity differed between the sexes, unless otherwise noted. Separate multiple linear regression models adjusted for sex, parental education, and day length, were used to explore the associations of each sleep and activity parameter with body composition parameters (BMI, total body fat percentage and trunk fat percentage) and metabolic risk factors (insulin, glucose, blood pressure). In further analysis, body composition and metabolic risk factors were included as response variables while sleep duration, WASO, sleep variability, and physical activity were all simultaneously included as predictor variables in models additionally adjusted for sex, parental education, and day length. In a separate analysis, body composition and metabolic risk factors were again included as response variables while bedtime and bedtime variability were simultaneously included as predictor variables in models additionally adjusted for physical activity, sex, parental education, and day length. Regression analyses were repeated separately by sex for response variables found to be significantly different for boys and girls. Sleep and bedtime variability were log-transformed prior to regression analyses to correct for skewed distributions. Statistical analyses were carried out in Rstudio

(Boston, MA, USA, Version 1.1.456) using R statistical software (https://www.r-project.org/, Version 3.5.1). Statistical significance level was set at $p<0.05$.

Results

Participant characteristics are shown in Table 2. Although boys were taller and heavier than girls, BMI (overall mean = 21.9±3.0 kg/m^2) did not differ between the sexes. Overall, 87% of the participants had BMI below 25 kg/m^2, 10% had $25\leq$ BMI <30 kg/m^2, and 2.5% had BMI $\geq$ 30 kg/m^2. Boys had lower total body and trunk fat percentage, smaller waist circumference, and slightly higher systolic pressure, but there were no sex differences in age, parental educational attainment, or serum insulin and glucose levels. Participants with and without a parent with a university degree did not differ in characteristics, body composition, blood pressure, or serum insulin and glucose.

Sleep and physical activity parameters did not differ between the sexes (Table 3) or between those with or without a parent with a university degree. On average, participants spent 7.05 ± 0.82 hours in bed on school nights, going to bed at 00:22 ± 0.88 hours and rising at 07:27 ± 0.62 hours. While in bed, participants were awake 0.83 ± 0.36 hours and asleep 6.19 ± 0.73 hours. Night-to-night variations in bedtime and sleep duration (median ± interquartile range) were 0.75 ± 0.55 hours and 0.64 ± 0.53 hours, respectively.

The association of metabolic risk factors to physical activity and sleep duration, quality, and variability are shown in Table 4. Average sleep duration was not associated with body composition or metabolic parameters. However, the nightly variability of sleep duration was positively associated with both total body and trunk fat percentages. Physical activity was negatively associated with trunk fat percentage and fasting insulin levels. Neither physical activity nor any of the sleep parameters was associated with fasting plasma glucose. WASO, an indicator of sleep quality, was not associated with any metabolic risk factors.

When average sleep duration, WASO, and physical activity were added as covariates, the significant associations between variability in sleep and total and trunk fat percentage did not persist (Table 4, combined model). However, the negative associations between physical activity and trunk fat percentage and fasting insulin levels remained significant, with standardized β values, presented as β [95% confidence intervals], of -0.114 [-0.218, -0.010] and -0.203 [-0.332, -0.074], respectively. When boys and girls were analyzed separately, the negative relationships between physical activity and total body and trunk fat percentage persisted for boys but not girls (S2 Table).

The association of metabolic risk factors to average bedtime and nightly bedtime variability is shown in Table 5. Mean bedtime was not associated with any of the body composition or metabolic parameters after adjusting for sex, parental education, and day length. However, using the same covariates, bedtime variability was positively associated with BMI, waist circumference, total body and trunk fat percentage. All significant relationships persisted when average bedtime and nightly bedtime variability were included in a combined model, adjusted for physical activity, sex, parental education, and day length. Standardized β values for the log-transformed bedtime variability in the significant outcomes, presented as β [95% confidence intervals] were 0.140 [0.014, 0.267] for BMI, 0.137 [0.016, 0.257 for waist circumference,0.060 [0.070, 0.250] for total body fat percentage, and 0.161 [0.060,0.263] for trunk fat percentage. When girls and boys were analyzed separately, the associations between bedtime variability and total body and trunk fat percentage remained significant for girls but not boys (S3 Table). The relationship between bedtime variability and waist circumference was not significant for either sex when analyzed separately.

Table 2. Participants characteristics.

		All (252)	Boys (106)	Girls (146)	p (Boys vs Girls)
Subjects Characteristics					
	Age, years	15.8 ± 0.3	15.8 ± 0.3	15.9 ± 0.3	0.12
	Height, cm	172.0 ± 8.0	178.5 ± 6.0	167.3 ± 5.6	<**0.001**
	Weight, kg	64.8 ± 10.6	68.9 ± 10.3	61.9 ± 9.7	<**0.001**
	Body mass index, kg/m^2	21.9 ± 3.0	21.6 ± 2.9	22.1 ± 3.1	0.21
	Body fat, %	25.1 ± 8.6	18.2 ± 6.6	30.2 ± 5.9	<**0.001**
	Trunk fat, %	23.6 ± 9.6	17.0 ± 7.8	28.3 ± 7.8	<**0.001**
	Waist circumference, cm*	70.6 ± 7.1	73.5 ± 6.2	68.6 ± 7.1	<**0.001**
	Diastolic pressure, mmHg*	70.9 ± 5.4	70.2 ± 5.6	71.4 ± 5.1	0.21
	Systolic pressure, mmHg*	114.4 ± 9.7	118.6 ± 9.9	111.6 ± 8.3	<**0.001**
	Glucose, mmol/L**	4.9 ± 0.5	4.9 ± 0.4	4.9 ± 0.5	0.57
	Insulin, mU/L**	9.7 ± 4.7	8.4 ± 3.7	10.6 ± 5.2	0.73
	Parent with university degree, N (%)	193 (76.6%)	83 (78.3%)	110 (75.3%)	0.69

Data presented as mean ± standard deviation

*248 participants (103 Boys, 145 Girls)

**239 participants (101 Boys, 138 Girls); Boldface type indicates significant difference ($p<0.05$).

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Discussion

We studied the free-living sleep and physical activity patterns on school days in a sample of 15-year-old Icelandic boys and girls, and, as hypothesized, we found that greater nightly variation in sleep duration and bedtime, and less physical activity was associated with less favorable indicators of metabolic health. Surprisingly, neither mean bedtime nor average sleep duration on school nights was associated with any of the cardiometabolic risk factors measured in our study. These findings support the idea that, along with an adequate amount of physical activity, a regular sleep schedule is important for metabolic health of adolescents.

We found that the participants in our study had considerable nightly variation in sleep duration (0.75 hours) and bedtime (0.64 hours) on school nights and that higher nightly

Table 3. Summary sleep and physical activity parameters.

	All (252)	Boys (106)	Girls (146)	p (Boys Vs. Girls)
Time in bed, hours/night	7.05 ± 0.82	6.99 ± 0.84	7.09 ± 0.80	0.34
Sleep duration, hours/night	6.19 ± 0.73	6.13 ± 0.78	6.24 ± 0.70	0.28
Bedtime, hh:mm ± hours	00:22 ± 0.88	00:28 ± 0.90	00:18 ± 0.87	0.12
Rise time, hh:mm ± hours	07:27 ± 0.62	07:30 ± 0.68	07:24 ± 0.57	0.25
WASO, hours/night	0.83 ± 0.36	0.83 ± 0.35	0.83 ± 0.36	0.98
Variability in sleep duration, hours*	0.75 ± 0.55	0.77 ± 0.53	0.76 ± 0.57	0.48
Variability in bedtime, hours*	0.64 ± 0.53	0.74 ± 0.52	0.61 ± 0.58	0.26
Activity, (counts/min of wear time) x 1000	2.21 ± 0.50	2.24 ± 0.47	2.18 ± 0.52	0.42
Wear time, hours/night	23.76 ± 0.39	23.69 ± 0.50	23.81 ± 0.29	**0.03**
Valid days, days	4.6 ± 0.6	4.5 ± 0.7	4.7 ± 0.5	0.13
Day length, hours/day	17.46 ± 1.87	17.35 ± 1.86	17.54 ± 1.88	0.42

Data presented as mean ± standard deviation unless otherwise noted; p-values are the result of unpaired T-test unless otherwise noted; WASO: wake after sleep onset

*Sleep variability data presented as median ± interquartile range and p-values are results of Mann-Whitney tests due to skewed distributions; Boldface type indicates significant difference ($p<0.05$).

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Table 4. Association of metabolic risk factors to physical activity and sleep duration, quality, and variability.

		Sleep duration	WASO	Nightly variability in sleep duration	Physical activity
		B [95% CI] (p)	B [95% CI] (p)	B [95% CI] (p)	B [95% CI] (p)
Body mass index, kg/m^2					
	Individual model	-0.275 [-0.786, 0.237] (0.3)	-0.889 [-1.932, 0.154] (0.1)	1.164 [-0.293, 2.622] (0.1)	0.543 [-0.210, 1.295] (0.2)
	Combined model	-0.150 [-0.671, 0.371] (0.6)	-0.817 [-1.860, 0.226] (0.1)	1.255 [-0.223, 2.733] (0.1)	0.535 [-0.238, 1.309] (0.2)
Trunk fat, %					
	Individual model	-0.435 [-1.767, 0.898] (0.5)	-2.187 [-4.901, 0.527] (0.1)	**4.214 [0.441, 7.987] (0.03)**	**-2.115 [-4.063, -0.167] (0.03)**
	Combined model	-0.535 [-1.879, 0.809] (0.4)	-2.440 [-5.130, 0.249] (0.1)	3.490 [-0.323, 7.302] (0.07)	**-2.178 [-4.172, -0.183] (0.03)**
Total body fat, %					
	Individual model	-0.521 [-1.582, 0.539] (0.3)	-1.722 [-3.885, 0.442] (0.1)	**3.587 [0.584, 6.590] (0.02)**	-1.514 [-3.069, 0.041] (0.06)
	Combined model	-0.575 [-1.646, 0.496] (0.3)	-1.898 [-4.040, 0.244] (0.1)	3.000 [-0.037, 6.037] (0.05)	-1.586 [-3.174, 0.003] (0.05)
Waist circumference, cm					
	Individual model	-0.169 [-1.324, 0.986] (0.8)	-1.724 [-4.088, 0.640] (0.2)	2.438 [-0.879, 5.755] (0.1)	-0.473 [-2.181, 1.235] (0.6)
	Combined model	-0.112 [-1.295, 1.071] (0.9)	-1.742 [-4.118, 0.634] (0.1)	2.245 [-1.141, 5.631] (0.2)	-0.463 [-2.217, 1.291] (0.6)
Diastolic pressure, mmHg					
	Individual model	0.355 [-0.565, 1.275] (0.4)	1.200 [-0.711, 3.111] (0.2)	-0.112 [-2.786, 2.561] (0.9)	-1.078 [-2.432, 0.276] (0.1)
	Combined model	0.228 [-0.716, 1.172] (0.6)	1.091 [-0.828, 3.011] (0.3)	-0.262 [-2.980, 2.455] (0.8)	-0.976 [-2.373, 0.422] (0.2)
Systolic pressure, mmHg					
	Individual model	0.450 [-1.104, 2.005] (0.6)	1.305 [-1.928, 4.537] (0.4)	-1.925 [-6.433, 2.582] (0.4)	0.721 [-1.575, 3.016] (0.5)
	Combined model	0.477 [-1.123, 2.077] (0.6)	1.391 [-1.863, 4.645] (0.4)	-1.562 [-6.169, 3.045] (0.5)	0.823 [-1.546, 3.192] (0.5)
Glucose, mmol/L					
	Individual model	-0.076 [-0.168, 0.017] (0.1)	-0.018 [-0.208, 0.172] (0.9)	-0.152 [-0.416, 0.111] (0.3)	0.011 [-0.125, 0.147] (0.9)
	Combined model	-0.085 [-0.180, 0.010] (0.1)	-0.016 [-0.206, 0.174] (0.9)	-0.182 [-0.450, 0.087] (0.2)	-0.026 [-0.166, 0.114] (0.7)
Insulin, mU/L					
	Individual model	0.254 [-0.552, 1.061] (0.5)	-0.486 [-2.138, 1.166] (0.6)	1.034 [-1.259, 3.328] (0.4)	**-1.901 [-3.060, -0.743] (0.001)**
	Combined model	0.038 [-0.775, 0.851] (0.9)	-0.721 [-2.352, 0.910] (0.4)	0.546 [-1.754, 2.847] (0.6)	**-1.893 [-3.098, -0.689] (0.002)**

Sleep duration is in units of hours/nights; WASO: wake after sleep onset, in hours/night; Variability in sleep duration was log transformed, units are $\log_{10}$(hours); Physical activity is in units of (average daily counts/minutes of wear) x 1000; B represent unstandardized regression coefficients; CI: confidence interval; Individual models adjusted for sex, parental education, and day length; Combined models include sleep duration, WASO, nightly variability in sleep duration, physical activity, sex, parental education, and day length; Boldface type indicates significant relationships ($p<0.05$).

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variability in these parameters was related to greater measures of adiposity. These findings are consistent with previous studies of sleep variability and metabolic health, although to date study of this relationship in adolescents has been sparse. He et al. (2015), also found that high variability in sleep duration was associated with greater central adiposity in a group of similarly aged adolescents, even after controlling for food intake [18]. However, there were several notable differences in our regression analyses: (1) we included a measure of physical activity, a well-documented contributor to body composition and metabolic health, and (2) we excluded non-school nights of sleep, when sleep patterns are typically less regular and very different from school night for adolescents [40]. The exclusion of non-school nights from our analysis may partly explain the lower night-to-night variation in sleep duration for our participants compared to He et al. (2015) (0.75 hours vs. 1.2 hours) [18]. Despite these differences, we observed a similar robust association between sleep duration and bedtime variability and adiposity. For instance, our combined regression model indicates that a 30 min increase in variability in nightly sleep duration would lead to a 1.1% increase in trunk fat and a 0.9% increase in total body fat. All else being equal, a participant in the ninetieth percentile of night-to-night sleep variability in our cohort (the ninetieth percentile, with variability of 1.49 hours over the

Table 5. Association of metabolic risk factors to average bedtime and nightly variability in bedtime.

		Bedtime	Nightly variability in bedtime
		B [95% CI] (p)	B [95% CI] (p)
Body mass index, kg/m^2			
	Individual model	0.222 [-0.213, 0.658] (0.3)	**1.488 [0.209, 2.766] (0.02)**
	Combined model	0.116 [-0.324, 0.557] (0.6)	**1.445 [0.142, 2.748] (0.03)**
Trunk fat, %			
	Individual model	0.456 [-0.678, 1.590] (0.4)	**5.489 [2.200, 8.779] (0.001)**
	Combined model	0.143 [-0.985, 1.272] (0.8)	**5.315 [1.975, 8.655] (0.002)**
Total body fat, %			
	Individual model	0.481 [-0.422, 1.383] (0.3)	**4.899 [2.292, 7.506] (0.003)**
	Combined model	0.196 [-0.699, 1.092] (0.7)	**4.721 [2.070, 7.372] (0.001)**
Waist circumference, cm			
	Individual model	0.070 [-0.917, 1.057] (0.9)	**3.267 [0.393, 6.141] (0.03)**
	Combined model	-0.142 [-1.144, 0.860] (0.8)	**3.332 [0.388, 6.275] (0.03)**
Diastolic pressure, mmHg			
	Individual model	-0.184 [-0.973, 0.606] (0.6)	-0.851 [-3.173, 1.470] (0.5)
	Combined model	-0.100 [-0.904, 0.704] (0.8)	-0.840 [-3.204, 1.524] (0.5)
Systolic pressure, mmHg			
	Individual model	-0.400 [-1.733, 0.932] (0.6)	-3.495 [-7.394, 0.404] (0.1)
	Combined model	-0.201 [-1.557, 1.156] (0.8)	-3.353 [-7.342, 0.635] (0.1)
Glucose, mmol/L			
	Individual model	0.036 [-0.043, 0.115] (0.4)	-0.02 [-0.256, 0.216] (0.9)
	Combined model	0.038 [-0.042, 0.118] (0.4)	-0.039 [-0.279, 0.202] (0.8)
Insulin, mU/L			
	Individual model	0.071 [-0.616, 0.758] (0.8)	0.783 [-1.273, 2.839] (0.5)
	Combined model	0.062 [-0.623, 0.747] (0.9)	0.646 [-1.407, 2.698] (0.5)

Bedtime is in units of hours from midnight; Variability in bedtime was log transformed, units are log10(hours); B represent unstandardized regression coefficients; CI: confidence interval; Individual models adjusted for sex, parental education, and day length; Combined models include bedtime, nightly variability in bedtime, physical activity, sex, parental education, and day length; Boldface type indicates significant relationships ($p<0.05$).

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school week) could be expected to have 2.4 percentage points higher body fat than a participant in the lower range of our cohort (the tenth percentile, with variability of 0.33 hours over the school week). Similarly, the upper range of bedtime variability (the ninetieth percentile, with variability of 1.39 hours over school week) could be expected to have 3.4 percentage points higher body fat than those in the lower range of the cohort (the tenth percentile, with variability of 0.27 hours over the school week). The similarity between relationships with variability in sleep duration and bedtime was also not surprising, since the two measures were highly correlated ($r = 0.72$, $p<0.0001$). These findings reinforce the idea that adolescents should maintain a regular sleep schedule.

Contrary to our hypothesis, we did not observe a relationship between mean bedtime or average sleep duration and metabolic risk factors. While a number of previous studies have noted a positive association between self-reported short sleep and obesity in adolescents [41–43], some more recent studies find a lack of this relationship while measuring sleep with actigraphy [17, 18]. In agreement with our findings, He et al. (2015) found that high variability in sleep duration, but not mean sleep duration, was associated with greater central adiposity [18]. However, we did not find an association between average bedtime and blood pressure, as demonstrated by Mi, et al. (2019) in a group of mostly younger adolescents (12.4 ± 2.6 y) [17]. Several population-based studies employing self-report sleep measures have observed U-shaped distributions between sleep duration and markers of obesity [42, 43] and metabolic syndrome [44]. These studies benefitted from large sample-populations and broad ranges of body composition and reported sleep duration. We found no evidence for such U-shaped relationships, but our Icelandic cohort was smaller and more homogenous, with a low prevalence (12%) of overweight and obesity and a high prevalence (88%) of short school night sleep [28]. Thus, our results may reflect a more subtle relationship between sleep parameters and body composition than found in studies with larger samples, broader ranges of sleep duration, and greater prevalence of overweight and obesity.

The positive influence of physical activity and the metabolic health of adolescents is well documented [45]. Our finding that wrist-actigraphy measured physical activity was inversely associated with trunk fat percentage and serum insulin levels is largely confirmatory of previous work and consistent with our hypothesis. To put these findings in perspective, all else being equal, one would expect those with a physical activity in the upper range of the cohort (the ninetieth percentile with 2800 counts/min of wear time each day) to have 5.4 mU/L lower fasting insulin and 3.8 percentage points lower trunk fat than those in the lower range of the cohort (the tenth percentile, with1600 counts/min of wear each day). Although these are substantial cross-sectional differences, they are smaller than the changes in these measures observed during aerobic exercise interventions in adolescents [46].

Body composition and systolic blood pressure differed significantly by sex but were largely in line with previous findings in adolescence [47–49]. Considering these differences, we performed additional sex-specific regression analyses for systolic blood pressure, waist circumference, and total body and trunk fat percentage. We did not find any significant sex-specific associations for systolic blood pressure or waist circumference, although the reduced sample-size may have played a role. We did observe that physical activity was more strongly associated with total body and trunk fat for boys, while variability in bedtime was more strongly associated with body composition for girls. Study of larger samples are needed to confirm and explain the sex-based differences in these associations.

The potential causal pathways between irregular sleep patterns and increased body fat are not yet clear. Study of healthy non-overweight children (5–12 years), Burt et al. (2014), found that shorter sleep duration and poor sleep continuity were associated with overeating and other behavior related to obesity risk [50]. Sleep timing, duration, and quality are known to affect regulatory hormones, such as cortisol and growth hormone, as well as appetite regulatory hormones leptin and ghrelin [51]. Thus, high variability in sleep schedule may affect appetite control and contribute to greater adiposity and markers of poorer metabolic health. However, we did not have a measure of food intake and, thus, cannot explore potential relationships between diet, sleep variability, and metabolic health. Additionally, based on our cross-sectional study design, we cannot rule out reverse causality.

A strength of this study is the objective measurement of sleep patterns, physical activity, and body composition. Most previous studies of sleep in this age group have relied on self- or parent-report of typical time in bed or bed- and rise-times. Self-reported measures tend to over-report sleep time [26, 52] and under-report awakenings during sleep [52]. Wrist actigraphy has been validated against laboratory-based polysomnography in this age group and shown to have higher accuracy than self-report for sleep duration [53] and awakenings [54]. DXA is a highly accurate method of classifying body tissues and assessing regional body fat distribution [55–57].

This study has some limitations. The sample size was relatively small (n = 251). However, it represents 18.6% of the 15-year-old population of Reykjavik in 2015 (n = 1355) [32]. This was an exploratory analysis, following up on our previous work [28], and it was not powered to detect a pre-specified outcome. However, our interpretation of the results was not altered by the results of a Benjamini-Hochberg analysis [58] of the 96 comparisons summarized in Tables 4 and 5, using a false discovery rate (Q) of 0.25, since the p-values of all associations noted as significant were below the Benjamini-Hochberg critical p-value of 0.0335. The cross-sectional nature precludes study of the temporal relationships between sleep, physical activity, and metabolic factors. All measurements were collected from spring until early summer, a period of drastic change in day length and weather in Iceland which could affect sleep timing [59] and physical activity level [59, 60]. Earlier analyses of this cohort found no association between sleep duration and day length [28] but a positive association between physical activity and day length [35]. We attempted to mitigate the influence of day length by statistically controlling for it in all regression models. Finally, our sample is mostly lean and racially and ethnically homogeneous, potentially limiting the generalizability of the results to other populations.

Conclusion

Greater nightly variation in bedtime and sleep duration and less physical activity was associated with higher fat accumulation and higher insulin levels in 15-year-old adolescents, highlighting the importance of physical activity and maintaining a regular sleep schedule. Further research is needed to determine the longitudinal relationship between sleep, physical activity, and metabolic health from adolescence into adulthood.

Supporting information

S1 Table. Comparison of participants with complete and incomplete sleep and activity data.
(DOCX)

S2 Table. Association of metabolic risk factors to physical activity and sleep duration, quality, and variability for boys and girls.
(DOCX)

S3 Table. Association of metabolic risk factors to average bedtime and nightly variability in bedtime for boys and girls.
(DOCX)

S1 Data.
(CSV)

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Table S1. Comparison of participants with complete and incomplete sleep and activity data

	Incomplete Data	Complete Data	p-value
Participants, N (% Female)	25 (56.0%)	252 (57.9%)	1.0
Parent with university degree, N (%)	17 (68.0%)	193 (76.6%)	0.5
Age, years	15.9 ± 0.3	15.8 ± 0.3	0.2
Height, cm	171.9 ± 7.7	172.0 ± 8.0	0.9
Weight, kg	66.4 ± 14.6	64.8 ± 10.6	0.6
Body mass index, kg/m^2	22.4 ± 4.0	21.9 ± 3.0	0.6
Trunk fat, %	24.6 ± 10.6	23.6 ± 9.6	0.7
Total body fat, %	26.3 ± 9.5	25.1 ± 8.6	0.6
Waist circumference, cm*	71.0 ± 9.8	70.6 ± 7.1	0.9
Diastolic pressure, mmHg*	70.4 ± 5.6	70.8 ± 5.5	0.7
Systolic pressure, mmHg*	114.6 ± 10.0	115.1 ± 12.8	0.8
Glucose, mmol/L**	4.9 ± 0.3	4.9 ± 0.5	0.7
Insulin, mU/L**	10.8 ± 7.4	9.7 ± 4.7	0.5

Data presented as mean ± standard deviation unless otherwise noted; *250 participants (105 boys, 145 girls) with complete data; **24 (11 boys, 13 girls) participants with incomplete data, 239 participants (101 boys, 138 girls) with complete data.

Table S2. Association of metabolic risk factors to physical activity and sleep duration, quality, and variability for boys and girls.

	Sleep duration B [95% CI] (p)	WASO B [95% CI] (p)	Nightly variability in sleep duration B [95% CI] (p)	Physical activity B [95% CI] (p)
Trunk fat, %				
Boys				
Individual model	-0.553 [-2.532, 1.425] (0.6)	-2.472 [-6.865, 1.921] (0.3)	3.709 [-2.467, 9.884] (0.2)	**-4.647 [-7.762, -1.533] (0.004)**
Combined model	-1.064 [-2.995, 0.867] (0.3)	-2.448 [-6.695, 1.798] (0.3)	2.116 [-3.957, 8.189] (0.5)	**-4.708 [-7.922, -1.494] (0.005)**
Girls				
Individual model	-0.382 [-2.218, 1.454] (0.7)	-2.208 [-5.722, 1.307] (0.2)	4.219 [-0.686, 9.125] (0.1)	-0.496 [-3.010, 2.019] (0.7)
Combined model	-0.064 [-1.985, 1.857] (0.9)	-2.284 [-5.842, 1.275] (0.2)	4.036 [-1.074, 9.146] (0.1)	-0.540 [-3.150, 2.069] (0.7)
Total body fat, %				
Boys				
Individual model	-0.487 [-2.162, 1.188] (0.6)	-2.174 [-5.891, 1.543] (0.2)	3.588 [-1.629, 8.804] (0.2)	**-3.562 [-6.219, -0.906] (0.009)**
Combined model	-0.877 [-2.521, 0.767] (0.3)	-2.165 [-5.781, 1.45] (0.2)	2.391 [-2.78, 7.562] (0.4)	**-3.55 [-6.286, -0.813] (0.012)**
Girls				
Individual model	-0.601 [-1.988, 0.785] (0.4)	-1.605 [-4.266, 1.055] (0.2)	3.289 [-0.421, 6.999] (0.1)	-0.196 [-2.100, 1.708] (0.8)
Combined model	-0.353 [-1.806, 1.099] (0.6)	-1.605 [-4.296, 1.087] (0.2)	2.997 [-0.868, 6.862] (0.1)	-0.301 [-2.275, 1.672] (0.8)
Waist circumference, cm				
Boys				
Individual model	-0.293 [-1.88, 1.294] (0.7)	-2.447 [-5.973, 1.08] (0.2)	1.557 [-3.479, 6.592] (0.5)	-2.428 [-5.009, 0.153] (0.1)
Combined model	-0.556 [-2.143, 1.032] (0.5)	-2.342 [-5.864, 1.18] (0.2)	0.737 [-4.305, 5.780] (0.8)	-2.425 [-5.078, 0.228] (0.1)
Girls				
Individual model	-0.083 [-1.762, 1.596] (0.9)	-1.291 [-4.526, 1.945] (0.4)	2.874 [-1.668, 7.417] (0.2)	0.682 [-1.615, 2.978] (0.6)
Combined model	0.327 [-1.442, 2.096] (0.7)	-1.103 [-4.391, 2.185] (0.5)	3.206 [-1.542, 7.955] (0.2)	0.822 [-1.580, 3.223] (0.5)
Systolic pressure, mmHg				
Boys				
Individual model	0.090 [-2.425, 2.605] (0.9)	-0.393 [-6.031, 5.246] (0.89)	0.604 [-7.387, 8.595] (0.881)	1.043 [-3.111, 5.196] (0.62)
Combined model	0.191 [-2.392, 2.775] (0.9)	-0.429 [-6.159, 5.301] (0.882)	0.94 [-7.265, 9.145] (0.821)	1.177 [-3.14, 5.493] (0.59)
Girls				
Individual model	0.762 [-1.200, 2.723] (0.4)	2.875 [-0.971, 6.720] (0.1)	-3.593 [-8.949, 1.764] (0.2)	0.213 [-2.469, 2.896] (0.9)
Combined model	0.517 [-1.538, 2.572] (0.6)	2.952 [-0.953, 6.857] (0.1)	-3.211 [-8.770, 2.349] (0.3)	0.491 [-2.295, 3.277] (0.7)

Table S3. Association of metabolic risk factors to average bedtime and nightly variability in bedtime for boys and girls.

	Bedtime B [95% CI] (p)	Nightly variability in bedtime B [95% CI] (p)
Trunk fat, %		
Boys		
Individual model	0.772 [-0.996, 2.54] (0.4)	4.298 [-1.048, 9.644] (0.1)
Combined model	0.726 [-0.995, 2.447] (0.4)	3.087 [-2.196, 8.369] (0.2)
Girls		
Individual model	0.339 [-1.171, 1.849] (0.7)	**6.028 [1.703, 10.354] (0.007)**
Combined model	-0.22 [-1.757, 1.317] (0.8)	**6.249 [1.729, 10.768] (0.007)**
Total body fat, %		
Boys		
Individual model	0.703 [-0.793, 2.199] (0.4)	4.279 [-0.225, 8.783] (0.1)
Combined model	0.621 [-0.841, 2.082] (0.4)	3.335 [-1.151, 7.82] (0.1)
Girls		
Individual model	0.423 [-0.718, 1.565] (0.5)	**5.070 [1.816, 8.323] (0.002)**
Combined model	-0.039 [-1.195, 1.118] (0.9)	**5.123 [1.722, 8.525] (0.003)**
Waist circumference, cm		
Boys		
Individual model	0.481 [-0.949, 1.911] (0.5)	2.519 [-1.756, 6.795] (0.2)
Combined model	0.490 [-0.945, 1.924] (0.5)	1.850 [-2.477, 6.177] (0.4)
Girls		
Individual model	-0.197 [-1.58, 1.186] (0.8)	3.760 [-0.251, 7.771] (0.1)
Combined model	-0.590 [-2.015, 0.835] (0.4)	4.183 [-0.002, 8.368] (0.05)
Systolic pressure, mmHg		
Boys		
Individual model	-0.328 [-2.598, 1.941] (0.8)	-3.382 [-10.168, 3.404] (0.3)
Combined model	-0.214 [-2.529, 2.100] (0.9)	-3.126 [-10.106, 3.855] (0.4)
Girls		
Individual model	-0.587 [-2.213, 1.04] (0.5)	-3.192 [-7.938, 1.555] (0.2)
Combined model	-0.326 [-2.015, 1.364] (0.7)	-2.964 [-7.919, 1.991] (0.2)

Sleep duration is in units of hours/nights; WASO: wake after sleep onset, in hours/night; Variability in sleep duration was log transformed, units are $\log_{10}$(hours); Physical activity is in units of (average daily counts/minutes of wear) x 1000; B represent unstandardized regression coefficients; CI: confidence interval; Individual models adjusted for sex, parental education, and day length; Combined models include sleep duration, WASO, nightly variability in sleep duration, physical activity, sex, parental education, and day length; Boldface type indicates significant relationships ($p<0.05$).

Appendix I

Questionnaire HHUI 2015

Appendix I

Questionnaire for HHUI 2015

Heilsuhegðun ungra Íslendinga

Ágæti þátttakandi,   Rannsóknin Heilsuhegðun ungra Íslendinga er unnin af hópi kennara og nemenda við Háskóla Íslands með tilstyrk Rannsóknasjóðs Íslands. Meginmarkmið rannsóknarinnar er að varpa ljósi á þær breytingar sem verða á líkamlegu ástandi, félagslegri stöðu og líðan ungs fólks frá grunnskóla til fullorðinsára. Fyrri mælingar fóru fram árin 2006 og 2008, og er þessi spurningalisti lagður fyrir þá sem tóku þátt í þeim mælingum sem og nýja þátttakendur.   Þátttaka í rannsókninni er vitaskuld frjáls en miklu máli skiptir að sem flestir taki þátt. Rannsóknin beinist að stöðu hópsins í heild og þeim breytingum sem orðið hafa. Spurningalistinn er því nafnlaus og svör verða aldrei rakin til einstaklinga. Þessi spurningalisti er staðlaður og einstakar spurningar geta því átt illa við um þig persónulega. Stundum getur verið erfitt að velja bara eitt svar og stundum er ekkert svar sem á nákvæmlega við. Í þeim tilvikum þarft þú að velja það svar sem er næst því að eiga við. Við biðjum þig um að svara öllum spurningum en þú getur þó sleppt þeim spurningum sem þú treystir þér alls ekki til að svara.   Lesið verður úr svörum með rafrænum hætti og spurningalistum verður eytt að úrvinnslu lokinni. Erlingur Jóhannsson prófessor við Háskóla Íslands er stjórnandi rannsóknarinnar og ber ábyrgð á framkvæmd hennar. Hann veitir allar frekari upplýsingar í síma 897 1115 eða með tölvupósti erljo@hi.is.

Kærar þakkir fyrir þátttökuna,
Erlingur S. Jóhannsson, Sigríður Lára Guðmundsdóttir,   Sigurbjörn Árni Arngrímsson, Erla Svansdóttir , Sunna Gestsdóttir, Margrét H. Indriðadóttir, Vaka Rögnvaldsdóttir

Q70 Bakgrunnsupplýsingar

Q2 Ertu karl eða kona?
❍ Karl (1)
❍ Kona (2)

Q3 Hvaða ár ertu fæddur?
❍ 1998 (2)
❍ 1999 (3)
❍ 2000 (4)

Q7 Hverjir búa á sama heimili og þú? Merktu við allt sem við á. (Ef þú býrð á mörgum stöðum svarar þú fyrir aðalheimili)
❑ Báðir foreldrar (1)
❑ Móðir mín (2)
❑ Faðir minn (3)
❑ Móðir og hennar maki (4)
❑ Faðir og hans maki (5)
❑ Systkini mín, stjúpsystkini eða fóstursystkini (6)
❑ Aðrir, hverjir? (7) ____________________
❑ Ég vil ekki svara (8)

Q6 Hvaða námi ætlar þú að ljúka? Merktu við allt sem við á

- ☐ Grunnskólaprófi (1)
- ☐ Stúdentsprófi (2)
- ☐ Iðnréttindum/starfsréttindum (3)
- ☐ Háskólaprófi (4)
- ☐ Öðru, hvaða námi? (5) ____________________
- ☐ Ég vil ekki svara (6)

Q5 Hver er/var menntun föður þíns? Merktu við allt sem við á

- ☐ Grunnskólapróf (2)
- ☐ Stúdentspróf (3)
- ☐ Iðnréttindi/starfsréttindi (4)
- ☐ Háskólapróf (5)
- ☐ Önnur (6)
- ☐ Veit það ekki (7)
- ☐ Ég vil ekki svara (8)

Q8 Hver er/var menntun móður þinnar? Merktu við allt sem við á

- ☐ Grunnskólapróf (1)
- ☐ Stúdentspróf (2)
- ☐ Iðnréttindi/starfsréttindi (3)
- ☐ Háskólapróf (4)
- ☐ Önnur (5)
- ☐ Veit það ekki (6)
- ☐ Ég vil ekki svara (7)

Q81 Ert þú með greiningu á einhverju af eftirfarandi:

	Já (1)	Nei (2)
Ofvirkni með athyglisbrest (ADHD) (1)	❍	❍
Athyglisbrest (ADD) (2)	❍	❍
Lesblindu (Dyslexia) (3)	❍	❍
Á einhverfurófi (Autistic spectrum disorder) (4)	❍	❍

Q9 Hversu margar klukkustundir á dag gerir þú eftirtalið að jafnaði á virkum dögum?

	Ekkert (1)	Um ½ klst. (2)	1-2 klst. (3)	2-3 klst. (4)	3-4 klst. (5)	4-5 klst. (6)	Meira en 5 klst. (7)
Spilar tölvuleiki (t.d. á netinu, heimilistölvu, Playstation) (1)	❍	❍	❍	❍	❍	❍	❍
Horfir á sjónvarp, DVD eða myndefni af netinu (2)	❍	❍	❍	❍	❍	❍	❍
Ert á netinu (t.d. skoða vefsíður, Facebook eða lesa/skrifa tölvupóst) (3)	❍	❍	❍	❍	❍	❍	❍
Hlustar á tónlist í útvarpi, af diski eða af netinu (4)	❍	❍	❍	❍	❍	❍	❍
Lest bækur, tímarit, dagblöð eða annað prentað efni (5)	❍	❍	❍	❍	❍	❍	❍
Notar tölvu í annað en að vera á netinu eða spila tölvuleiki (6)	❍	❍	❍	❍	❍	❍	❍

Q11 Hversu margar klukkustundir á dag gerir þú eftirtalið að jafnaði um helgar?

	Ekkert (1)	Um ½ klst. (2)	1-2 klst. (3)	2-3 klst. (4)	3-4 klst. (5)	4-5 klst. (6)	Meira en 5 klst. (7)
Spilar tölvuleiki (t.d. á netinu, heimilistölvu, Playstation) (1)	❍	❍	❍	❍	❍	❍	❍
Horfir á sjónvarp, DVD eða myndefni af netinu (2)	❍	❍	❍	❍	❍	❍	❍
Ert á netinu (t.d. skoða vefsíður, Facebook eða lesa/skrifa tölvupóst) (3)	❍	❍	❍	❍	❍	❍	❍
Hlustar á tónlist í útvarpi, af diski eða af netinu (4)	❍	❍	❍	❍	❍	❍	❍
Lest bækur, tímarit, dagblöð eða annað prentað efni (5)	❍	❍	❍	❍	❍	❍	❍
Notar tölvu í annað en að vera á netinu eða spila tölvuleiki (6)	❍	❍	❍	❍	❍	❍	❍

Q12 Hversu vel eiga eftirfarandi staðhæfingar við um þig?

	Á mjög illa við um mig (1)	Á frekar illa við um mig (2)	Hvorki né (3)	Á frekar vel við um mig (4)	Á mjög vel við um mig (5)
Ég á auðvelt með að fá hlýju og umhyggju frá fjölskyldu minni (1)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá andlegan stuðning frá fjölskyldu minni (2)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá peninga að láni hjá fjölskyldu minni ef ég þarf (3)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá aðstoð hjá fjölskyldu minni ef á þarf að halda (4)	❍	❍	❍	❍	❍

Q13 Hversu vel eiga eftirfarandi staðhæfingar við um þig?

	Á mjög illa við um mig (1)	Á frekar illa við um mig (2)	Hvorki né (3)	Á frekar vel við um mig (4)	Á mjög vel við um mig (5)
Ég á auðvelt með að fá hlýju og umhyggju frá vinum mínum (1)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá andlegan stuðning frá vinum mínum (2)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá peninga að láni hjá vinum mínum ef ég þarf (3)	❍	❍	❍	❍	❍
Ég á auðvelt með að fá aðstoð hjá vinum mínum ef á þarf að halda (4)	❍	❍	❍	❍	❍

Q71 Eftirfarandi spurningar eru um íþróttir og líkamsrækt

Q14 Eftirfarandi spurningar eru um íþróttir og líkamsrækt.

	Aldrei (1)	Sjaldnar en einu sinni í viku (2)	1 sinni í viku (3)	2-3 sinnum í viku (4)	4-5 sinnum í viku (5)	Svo til á hverjum degi (6)
Hve oft stundar þú íþróttir (æfir eða keppir) með íþróttafélagi? (1)	❍	❍	❍	❍	❍	❍
Hversu oft stundar þú íþróttir eða æfingar sem ekki eru á vegum íþróttafélags? (2)	❍	❍	❍	❍	❍	❍
Hversu oft reynir þú á þig líkamlega þannig að þú mæðist verulega eða svitnir? (3)	❍	❍	❍	❍	❍	❍

Q15 Hversu margar klukkustundir æfir þú íþróttir eða stundar líkamsrækt í venjulegri viku?

❍ Ekkert (1)
❍ Minna en eina klukkustund á viku (2)
❍ Eina til tvær klukkustundir á viku (3)
❍ Þrjár til fjórar klukkustundir á viku (4)
❍ Fimm til sex klukkustundir á viku (5)
❍ Meira en sex klukkustundir á viku (6)
❍ Ég vil ekki svara (7)

Q17 Stundar þú íþróttir?

- ❍ Já (1)
- ❍ Nei (2)
- ❍ Ég gerði það áður en ekki lengur (3)

Q16 Af hvaða ástæðum stundar þú íþróttir? Merktu í einn reit í hverri línu

	Mjög ósammála (1)	Fremur ósammála (2)	Hvorki né (3)	Fremur sammála (4)	Mjög sammála (5)
Til að halda mér í góðu formi (1)	❍	❍	❍	❍	❍
Til að bæta færni mína í íþróttinni (2)	❍	❍	❍	❍	❍
Til að skemmta mér (3)	❍	❍	❍	❍	❍
Til að bæta heilsuna (4)	❍	❍	❍	❍	❍
Til að fitna ekki (5)	❍	❍	❍	❍	❍
Til að líta betur út (6)	❍	❍	❍	❍	❍
Til að fá aukinn kraft og orku (7)	❍	❍	❍	❍	❍
Til að eignast vini (8)	❍	❍	❍	❍	❍
Til að vera með vinum mínum (9)	❍	❍	❍	❍	❍
Til að grenna mig (10)	❍	❍	❍	❍	❍
Til að vera hluti af liði/hóp (11)	❍	❍	❍	❍	❍
Njóta þess að gera það sem ég er góð/ur í (12)	❍	❍	❍	❍	❍

Q18 Hvenær stundaðir þú síðast íþróttir eða líkamsrækt?

- ❍ Ég hef aldrei stundað íþróttir eða líkamsrækt (1)
- ❍ Ég stundaði íþróttir eða líkamsrækt í þessari viku (2)
- ❍ Ég stundaði íþróttir eða líkamsrækt í þessum mánuði (3)
- ❍ Ég stundaði íþróttir eða líkamsrækt á þessu ári (4)
- ❍ Ég stundaði íþróttir eða líkamsrækt fyrir meira en ári síðan (5)
- ❍ Ég stundaði íþróttir eða líkamsrækt fyrir meira en tveimur árum (6)
- ❍ Ég vil ekki svara (7)

Q20 Af hvaða ástæðum hættir þú?

- ❍ Það var of dýrt (1)
- ❍ Það tók of mikinn tíma (2)
- ❍ Það var of hættulegt (3)
- ❍ Það var of leiðinlegt (4)
- ❍ Ég var ekki nógu góð/ur (5)
- ❍ Ég meiddist (6)
- ❍ Ég var ekki velkomin/n (7)
- ❍ Ég var of mikið úti að skemmta mér (8)
- ❍ Vinur/vinir mínir hættu í íþróttum (9)
- ❍ Það voru gerðar of miklar kröfur um getu (10)
- ❍ Það voru gerðar of miklar kröfur um lífsstíl (11)
- ❍ Annað, hvað? (12) ____________________

Q21 Hefur þú einhvern tímann þurft að sleppa æfingum eða keppni með íþróttafélagi vegna íþróttameiðsla? Ef þú hefur orðið fyrir fleiri en einum meiðslum skaltu svara fyrir alvarlegustu meiðslin.

- ❍ Nei, aldrei (1)
- ❍ Já, styttra en eina viku (2)
- ❍ Já, í 1-3 vikur (3)
- ❍ Já, lengur en þrjár vikur (4)
- ❍ Já, ég hætti fyrir fullt og allt vegna íþróttameiðsla (5)
- ❍ Hef aldrei æft íþróttir (6)

Q22 Hversu sammála eða ósamála ertu eftirfarandi fullyrðingum?

	Mjög ósammála (1)	Fremur ósammála (2)	Hvorki né (3)	Fremur sammála (4)	Mjög sammála (5)
Mér finnst ég hreyfa mig nógu mikið (1)	❍	❍	❍	❍	❍
Ég er góð(ur) í íþróttum miðað við jafnaldra mína (2)	❍	❍	❍	❍	❍

Q72 Líkamlegt ástand

Q23 Myndir þú segja að heilsa þín væri...?

- ❍ Framúrskarandi (1)
- ❍ Góð (2)
- ❍ Þokkaleg (3)
- ❍ Léleg (4)

Q24 Myndir þú segja að líkamlegt þrek (úthald) þitt væri...?

- ❍ Framúrskarandi (1)
- ❍ Gott (2)
- ❍ Þokkalegt (3)
- ❍ Lélegt (4)

Q25 Hefur þyngd þín breyst eitthvað síðustu 12 mánuði?

	Nánast ekkert (1)	1-3 kíló (2)	4-6 kíló (3)	7-9 kíló (4)	10 kíló eða meira (5)
Ég hef þyngst um... (1)	❍	❍	❍	❍	❍
Ég hef lést um... (2)	❍	❍	❍	❍	❍

Q26 Hversu þung(ur) ert þú án fata?Merktu við þyngd í kílóum

- ❍ 40 eða minna (75)
- ❍ 41 (76)
- ❍ 42 (77)
- ❍ 43 (78)
- ❍ 44 (79)
- ❍ 45 (80)
- ❍ 46 (81)
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- ❍ 118 (153)
- ❍ 119 (154)
- ❍ 120 (155)
- ❍ 121 (156)
- ❍ 122 eða meira (157)

Q27 Hversu þung/ur vildir þú helst vera?

	Sátt/ur eins og ég er (1)	1-3 kíló (2)	4-6 kíló (3)	7-9 kíló (4)	10 kíló eða meira (5)
Ég vildi helst þyngjast um... (1)	❍	❍	❍	❍	❍
Ég vildi helst léttast um... (2)	❍	❍	❍	❍	❍

Q28 Hversu há(r) ert þú á sokkleistunum? Merktu við hæð í sentimetrum

- ❍ 130 eða lægri (59)
- ❍ 131 (60)
- ❍ 132 (61)
- ❍ 133 (62)
- ❍ 134 (63)
- ❍ 135 (64)
- ❍ 136 (65)
- ❍ 137 (66)
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- 200 (129)
- 201 (130)
- 202 (131)
- 203 eða hærri (132)

Q29 Hefur þú farið í megrun sl. 12 mánuði?

- Nei, aldrei (1)
- Einu sinni (2)
- Tvisvar (3)
- Þrisvar eða oftar (4)

Q30 Hefur þú gert eitthvað af eftirtöldu til að hafa stjórn á þyngd þinni á síðastliðnum 12 mánuðum?

	Já (1)	Nei (2)	Ég vil ekki svara (3)
Líkamsrækt (1)	❍	❍	❍
Sleppt máltíðum (2)	❍	❍	❍
Ekki borðað neitt í heilan sólarhring eða lengur (3)	❍	❍	❍
Borðað minna af sælgæti (4)	❍	❍	❍
Borðað minna af fitu eða feitum mat (5)	❍	❍	❍
Drukkið minna af gosdrykkjum (6)	❍	❍	❍
Drukkið meira af vatni (7)	❍	❍	❍
Drukkið próteindrykki (8)	❍	❍	❍
Borðað meira af ávöxtum og/eða grænmeti (9)	❍	❍	❍
Takmarkað mig við einn eða fleiri fæðuflokka (t.d. aðeins borðað ávexti og grænmeti, aðeins vökva, aðeins prótein) (10)	❍	❍	❍
Gubbað því sem ég hafði borðað (11)	❍	❍	❍
Notað megrunarpillur eða hægðalyf (12)	❍	❍	❍
Reykt tóbak (13)	❍	❍	❍
Megrun undir eftirliti sérfræðings (14)	❍	❍	❍
Annað (15)	❍	❍	❍

Q31 Hversu vel eiga eftirfarandi fullyrðingar við um þig?

	Á mjög vel við um mig (1)	Á frekar vel við um mig (2)	Á frekar illa við um mig (3)	Á mjög illa við um mig (4)
Þegar ég hugsa um hvernig ég muni líta út í framtíðinni er ég ánægð(ur) (1)	❍	❍	❍	❍
Mér finnst ég oftast vera ófríð(ur) og óaðlaðandi (2)	❍	❍	❍	❍
Ég er ánægð(ur) með líkama minn (3)	❍	❍	❍	❍
Ég er ánægð(ur) með þær líkamlegu breytingar sem hafa átt sér stað hjá mér undanfarin ár (4)	❍	❍	❍	❍
Mér finnst ég vera sterk(ur) og hraust(ur) (5)	❍	❍	❍	❍

Q32 Hversu oft borðar þú þessar máltíðir að jafnaði á viku?

	Nær aldrei (1)	1-2 sinnum í viku (2)	3-4 sinnum í viku (3)	5-6 sinnum í viku (4)	Nánast á hverjum degi (5)
Morgunmat (1)	❍	❍	❍	❍	❍
Hádegismat (2)	❍	❍	❍	❍	❍
Nesti að heiman (3)	❍	❍	❍	❍	❍
Kvöldmat (4)	❍	❍	❍	❍	❍
Bita milli máltíða (5)	❍	❍	❍	❍	❍

Q33 Hversu oft varðst þú var/vör við eftirfarandi vanlíðan eða óþægindi síðastliðna viku?

	Nær aldrei (1)	Sjaldan (2)	Stundum (3)	Oft (4)	Nær alltaf (5)
Höfuðverk (1)	❍	❍	❍	❍	❍
Svima (2)	❍	❍	❍	❍	❍
Verk í baki (3)	❍	❍	❍	❍	❍
Ógleði eða ólgu í maga (4)	❍	❍	❍	❍	❍
Doða eða sting einhvers staðar í líkamanum (5)	❍	❍	❍	❍	❍
Verk í maga (6)	❍	❍	❍	❍	❍
Liðverki (7)	❍	❍	❍	❍	❍
Skjálfta (8)	❍	❍	❍	❍	❍
Verki í höndum eða fótum (9)	❍	❍	❍	❍	❍
Taugaóstyrk (10)	❍	❍	❍	❍	❍
Skyndilegrar hræðslu án nokkurrar ástæðu (11)	❍	❍	❍	❍	❍
Þú varst uppspennt/uppspenntur (12)	❍	❍	❍	❍	❍
Þú varst leið/leiður eða hafðir lítinn áhuga á því að gera hluti (13)	❍	❍	❍	❍	❍
Þú hafðir litla matarlyst (14)	❍	❍	❍	❍	❍
Þér fannst þú einmana (15)	❍	❍	❍	❍	❍
Þú grést auðveldlega eða langaði til að gráta (16)	❍	❍	❍	❍	❍
Þú áttir erfitt með að sofa eða sofna (17)	❍	❍	❍	❍	❍
Þú varst niðurdregin/niðurdreginn eða döpur/dapur (18)	❍	❍	❍	❍	❍
Þú varst ekki spennt/spenntur fyrir að gera neitt (19)	❍	❍	❍	❍	❍
Þér fannst þú hægfara eða hafa lítinn mátt (20)	❍	❍	❍	❍	❍
Þér fannst framtíðin vonlaus (21)	❍	❍	❍	❍	❍
Þú hugsaðir um að fyrirfara þér (22)	❍	❍	❍	❍	❍

Q73 Skólamál

Q34 Hvað býrðu langt frá skólanum í kílómetrum?

- ❍ minna en 2 km (1)
- ❍ 2-4 km. (2)
- ❍ 4-6 km. (3)
- ❍ 6-8 km. (4)
- ❍ 8 km eða lengra (5)

Q68 Hvað ertu lengi að ganga í skólann?

- ❍ minna en 5 mín. (1)
- ❍ 5-10 mín. (2)
- ❍ 10-15 mín. (3)
- ❍ 15-20 mín (4)
- ❍ 20-25 mín. (5)
- ❍ 25-30 mín. (6)
- ❍ lengur en 30 mín (7)

Q35 Hvernig ferð þú oftast í skólann?

- ❍ Er keyrð/keyrður (1)
- ❍ Með strætó/skólabíl (2)
- ❍ Á hjóli (3)
- ❍ Geng eða hleyp (4)

Q36 Hvað gerir þú vanalega (oftast) í frímínútum í skólanum?

- ❍ Sit (spjalla/les/spila) (1)
- ❍ Hreyfi mig (hleyp um eða tek þátt í leikjum) (2)
- ❍ Geri annað (t.d. geng um, rölti út í sjoppu, eða harka) (3)

Q37 Hversu vel eða illa telur þú þig standa í námi miðað við jafnaldra þína?

- ❍ Mjög vel (1)
- ❍ Frekar vel (2)
- ❍ Í meðallagi (3)
- ❍ Frekar illa (4)
- ❍ Mjög illa (5)

Q38 Hvað notar þú mikinn tíma í heimavinnu, heima hjá þér á dag?

- ❍ Þrjá klukkutíma eða meira (1)
- ❍ U.þ.b. tvo klukkutíma (2)
- ❍ U.þ.b. klukkutíma (3)
- ❍ Minna en hálftíma (4)
- ❍ Vinn aldrei heimavinnu heima hjá mér (5)

Q39 Hversu sammála eða ósammála ertu eftirfarandi fullyrðingum um nám þitt?

	Mjög ósammála (1)	Frekar ósammála (2)	Hvorki né (3)	Frekar sammála (4)	Mjög sammála (5)
Mér líkar mjög vel í skólanum (1)	❍	❍	❍	❍	❍
Ég stend mig mjög vel í skólanum (2)	❍	❍	❍	❍	❍
Ég hef mikinn áhuga á náminu (3)	❍	❍	❍	❍	❍
Ég skrópa oft í tímum (4)	❍	❍	❍	❍	❍
Mér leiðist oft í skólanum (5)	❍	❍	❍	❍	❍
Mér líður oft illa í skólanum (6)	❍	❍	❍	❍	❍

Q74 Lífsviðhorf

Q40 Hér fyrir neðan eru ýmsar staðhæfingar um hvað þér finnst um sjálfa/sjálfan þig

	Mjög sammála (1)	Frekar sammála (2)	Frekar ósammála (3)	Mjög ósammála (4)
Ég er almennt ánægð/ur með sjálfa/sjálfan mig (1)	❍	❍	❍	❍
Stundum finnst mér ég einskis virði (2)	❍	❍	❍	❍
Mér finnst ég hafa marga góða eiginleika (3)	❍	❍	❍	❍
Ég get gert margt jafn vel og flestir aðrir (4)	❍	❍	❍	❍
Mér finnst ég ekki geta verið stolt/stoltur af mörgu (5)	❍	❍	❍	❍
Stundum finnst mér ég sannarlega vera gagnslaus (6)	❍	❍	❍	❍
Mér finnst ég vera a.m.k. jafn mikils virði og aðrir (7)	❍	❍	❍	❍
Ég vildi að ég gæti borðið meiri virðingu fyrir sjálfum/sjálfri mér (8)	❍	❍	❍	❍
Allt í allt finnst mér ég vera misheppnaður/misheppnuð (9)	❍	❍	❍	❍
Ég hef jákvæða afstöðu til sjálfs/sjálfrar mín (10)	❍	❍	❍	❍

Q41 Hversu vel finnst þér eftirfarandi staðhæfingar eiga við um þig?

	Á mjög vel við um mig (1)	Á frekar vel við um mig (2)	Á frekar illa við um mig (3)	Á mjög illa við um mig (4)
Ég þarf tíma til að jafna mig á feimni minni við nýjar aðstæður (1)	❍	❍	❍	❍
Mér finnst erfitt að vinna þegar fylgst er með mér (2)	❍	❍	❍	❍
Ég verð auðveldlega vandræðaleg/vandræðalegur (3)	❍	❍	❍	❍
Mér finnst ekkert erfitt að tala við ókunnuga (4)	❍	❍	❍	❍
Ég er kvíðin/kvíðinn þegar ég tala frammi fyrir hópi af fólki (5)	❍	❍	❍	❍
Ég verð óróleg/órólegur í stórum hópi fólks (6)	❍	❍	❍	❍

Q42 Hversu sammála eða ósammála ert þú eftirfarandi fullyrðingum?

	Mjög ósammál a (1)	Ósammál a (2)	Frekar ósammál a (3)	Hvork i né (4)	Frekar sammál a (5)	Sammál a (6)	Mjög sammál a (7)
Líf mitt er að flestu leyti nálægt því sem ég óska mér (1)	❍	❍	❍	❍	❍	❍	❍
Aðstæður lífs míns eru frábærar (2)	❍	❍	❍	❍	❍	❍	❍
Ég er ánægð/ánægðu r með lífið (3)	❍	❍	❍	❍	❍	❍	❍
Hingað til hef ég fengið það mikilvægasta sem ég vil í lífinu (4)	❍	❍	❍	❍	❍	❍	❍
Ef ég gæti lifað lífi mínu upp á nýtt myndi ég næstum engu breyta (5)	❍	❍	❍	❍	❍	❍	❍

Q75 Tannheilsa

Q43 Hversu oft burstar þú tennurnar þínar að jafnaði?

- ❍ tvisvar á dag (1)
- ❍ einu sinni á dag (2)
- ❍ sjaldnar en einu sinni á dag (3)

Q44 Notar þú flúortöflur, munnskol með flúori eða flúortyggjó?

- ❍ Nei (1)
- ❍ Já (2)

Q45 Hversu oft?

- ❍ 1 sinni á dag (1)
- ❍ 2 sinnnum á dag (2)
- ❍ 3 sinnum á dag eða oftar (3)
- ❍ 2-3 sinnum í viku (4)
- ❍ 1 sinni í mánuði (5)
- ❍ 2-4 sinnum í mánuði (7)

Q46 Skolar þú munninn með vatni eftir tannburstun?

- ❍ Já (1)
- ❍ Nei (2)

Q47 Hversu oft notar þú tannþráð, tannstöngul eða millitannabursta til að hreinsa tennurnar þínar?

- ❍ Aldrei (1)
- ❍ Einu sinni í viku eða sjaldnar (2)
- ❍ 2-3 sinnum í viku (3)
- ❍ Daglega (4)

Q48 Hefur þú farið til tannlæknis síðan 15. maí 2013?

- ❍ Já (1)
- ❍ Nei (2)

Q49 Hefur þú ofnæmi?

- ❍ Nei (1)
- ❍ Já, fyrir latexi (2)
- ❍ Já, annað ofnæmi, hvað? (lyf, frjókorn, hnetur, annað) (3)

Q50 Hefur þú einhvern langvinnan sjúkdóm?

- ❍ Nei (1)
- ❍ Já (2)

Q51 Hvaða sjúkdóm?

Q52 Tekur þú lyf daglega?

- ❍ Nei (1)
- ❍ Já (2)

Q53 Hvað heita lyfin sem þú tekur?

Q54 Hversu marga daga í viku gerir þú eftirfarandi að jafnaði? Merktu við dagafjölda á viku

	Aldrei (1)	Einn dag (2)	Tvo daga (3)	Þrjá daga (4)	Fjóra daga (5)	Fimm daga (6)	Sex daga (7)	Sjö daga (8)
Drekkur sykraðan gosdrykk (1)	❍	❍	❍	❍	❍	❍	❍	❍
Drekkur sykurlausan gosdrykk (2)	❍	❍	❍	❍	❍	❍	❍	❍
Drekkur mjólk (3)	❍	❍	❍	❍	❍	❍	❍	❍
Drekkur ávaxtasafa (4)	❍	❍	❍	❍	❍	❍	❍	❍
Tekur lýsi eða lýsistöflur (5)	❍	❍	❍	❍	❍	❍	❍	❍
Tekur vítamín með D vítamíni (6)	❍	❍	❍	❍	❍	❍	❍	❍
Borðar nammi og sætindi (7)	❍	❍	❍	❍	❍	❍	❍	❍

Q55 Drekkur þú mjólk?

- ❍ Já (1)
- ❍ Nei (2)

Q56 Hvernig mjólk drekkur þú?

Q76 Svefnvenjur

Q57 Hvenær ferðu venjulega að sofa á virkum dögum?

- ❍ 20:00 (7)
- ❍ 20:30 (8)
- ❍ 21:00 (9)
- ❍ 21:30 (10)
- ❍ 22:00 (11)
- ❍ 22:30 (12)
- ❍ 23:00 (13)
- ❍ 23:30 (14)
- ❍ 00:00 (15)
- ❍ 00:30 (16)
- ❍ 01:00 (17)
- ❍ 01:30 (18)
- ❍ 02:00 (19)
- ❍ 02:30 (20)
- ❍ 03:00 (21)
- ❍ 03:30 (22)
- ❍ 04:00 (23)

Q80 Hvenær ferðu venjulega að sofa um helgar?

- ❍ 20:00 (7)
- ❍ 20:30 (8)
- ❍ 21:00 (9)
- ❍ 21:30 (10)
- ❍ 22:00 (11)
- ❍ 22:30 (12)
- ❍ 23:00 (13)
- ❍ 23:30 (14)
- ❍ 00:00 (15)
- ❍ 00:30 (16)
- ❍ 01:00 (17)
- ❍ 01:30 (18)
- ❍ 02:00 (19)
- ❍ 02:30 (20)
- ❍ 03:00 (21)
- ❍ 03:30 (22)
- ❍ 04:00 (23)

Q58 Sefur þú nóg?

- Oftast (1)
- Um helming nátta (2)
- Mjög sjaldan (3)
- Ég sef of mikið (4)

Q59 Hversu oft áttu erfitt með að einbeita þér í skólanum/vinnu vegna þreytu?

- Sjaldan eða aldrei (1)
- Kannski einu sinni í viku (2)
- Einu sinni á dag (3)
- Oft á dag (4)

Q77 Líkamlegur þroski

Q60 Á unglingsárum koma tímablil þar sem maður vex hratt. Hefur þú tekið eftir að því að þú hafir tekið vaxtarkipp?

- ❍ Nei, hef ekki tekið vaxtarkipp (1)
- ❍ já, hef nýlega byrjað að taka vaxtarkipp (2)
- ❍ já, hef greinilega verið í vaxtarkipp undanfarið (3)
- ❍ já, ég held að ég sé búin/búinn með mesta vaxtarkippinn (4)

Q61 Ert þú byrjuð að hafa blæðingar?

- ❍ Já (1)
- ❍ Nei (2)
- ❍ Veit ekki (3)

Q62 Hvað varstu gömul þegar þú byrjaðir á blæðingum? Vinsamlega segðu nákvæma tölu dæmi: 13 ára og 4 mánaða

Aldur í árum (1)	❍ 6 (1)	❍ 7 (2)	❍ 8 (3)	❍ 9 (4)	❍ 10 (5)	❍ 11 (6)	❍ 12 (7)	❍ 13 (8)	❍ 14 (9)	❍ 15 (10)	❍ 16 (11)	❍ 17 (12)	❍ 18 (13)	❍ 19 (14)	❍ 20 (15)
Aldur í mánuðum (2)	❍ 1 (1)	❍ 2 (2)	❍ 3 (3)	❍ 4 (4)	❍ 5 (5)	❍ 6 (6)	❍ 7 (7)	❍ 8 (8)	❍ 9 (9)	❍ 10 (10)	❍ 11 (11)	❍ 12 (12)	❍ (13)	❍ (14)	❍ (15)

Q63 Hefurðu reglulegar blæðingar?

- ❍ Já (1)
- ❍ Nei (2)
- ❍ Veit ekki (3)

Q66 Hversu margir dagar líða frá 1. degi bæðinga til 1. dags næstu blæðinga?

- ❍ 24 dagar (1)
- ❍ 25 dagar (2)
- ❍ 26 dagar (3)
- ❍ 27 dagar (4)
- ❍ 28 dagar (5)
- ❍ 29 dagar (6)
- ❍ 30 dagar (7)
- ❍ 31 dagur (8)
- ❍ 32 dagur (9)

Q67 Hversu margir dagar líða frá 1. degi blæðinga til 1. dags næstu blæðinga? allt frá _______ dögum til _______ daga

Q64 Hefur þú misst úr blæðingar (án þess að vera ófrísk eða vegna notkunar getnaðarvarnarpillu)?

- ❍ Nei, aldrei (1)
- ❍ já, 6-12 mánuði (2)
- ❍ Já, 2-5 mánuði (3)
- ❍ Já, meira en ár (4)

Q78 Kærar þakkir fyrir þátttökuna   Rannsóknarstofa í íþrótta- og heilsufræðum Menntavísindasvið Háskóla Íslands

Appendix II

Questionnaire HHUI 2017

Appendix II
Questionnaire 2017

Heilsuhegðun ungra Íslendinga 2017

This survey is currently LOCKED to prevent invalidation of collected responses! Please unlock your survey to make changes.

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☐ **Q69**

Heilsuhegðun ungra Íslendinga

Ágæti þátttakandi,
Rannsóknin ***Heilsuhegðun ungra Íslendinga*** er unnin af hópi kennara og nemenda við Háskóla Íslands með tilstyrk Rannsóknasjóðs Íslands. Meginmarkmið rannsóknarinnar er að varpa ljósi á þær breytingar sem verða á líkamlegu ástandi, félagslegri stöðu og líðan ungs fólks frá grunnskóla til fullorðinsára. Fyrri mælingar fóru fram árin 2006 og 2008, og er þessi spurningalisti lagður fyrir þá sem tóku þátt í þeim mælingum sem og nýja þátttakendur.
Þátttaka í rannsókninni er vitaskuld frjáls en miklu máli skiptir að sem flestir taki þátt. Rannsóknin beinist að stöðu hópsins í heild og þeim breytingum sem orðið hafa. Spurningalistinn er því nafnlaus og svör verða aldrei rakin til einstaklinga. Þessi spurningalisti er staðlaður og einstakar spurningar geta því átt illa við um þig persónulega. Stundum getur verið erfitt að velja bara eitt svar og stundum er ekkert svar sem á nákvæmlega við. Í þeim tilvikum þarft þú að velja það svar sem er næst því að eiga við. Við biðjum þig um að svara öllum spurningum en þú getur þó sleppt þeim spurningum sem þú treystir þér alls ekki til að svara.
Lesið verður úr svörum með rafrænum hætti og spurningalistum verður eytt að úrvinnslu lokinni. Erlingur Jóhannsson prófessor við Háskóla Íslands er stjórnandi rannsóknarinnar og ber ábyrgð á framkvæmd hennar. Hann veitir allar frekari upplýsingar í síma 897 1115 eða með tölvupósti erljo@hi.is.
Kærar þakkir fyrir þátttökuna,

Erlingur Jóhannsson prófessor (ábyrgðamaður rannsóknarinnar), Sigurbjörn Árni Arngrímsson prófessor, Sigríður Lára Guðmundsdóttir dósent, Erla Svansdóttir nýdoktor og Bryndís Benediktsdóttir læknir og prófessor. Sunna Gestsdóttir nýdoktor, Rúna Stefánsdóttir sérfræðingur og Sigríður Sigurjónsdóttir sérfræðingur Menntavísindastofnunar. Doktorsnemar eru Vaka Rögnvaldsdóttir og Soffía Hrafnkelsdóttir, auk meistaranemanna Bjarna Þorleifssonar, Bjarkar Guðmundsdóttur og Guðrúnar Magnúsdóttur.

☐ **Q70**

Bakgrunnsupplýsingar

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☐ **Q56**

Hver er kennitalan þín?

☐ Hvert er þátttökunúmerið þitt? **Q57**

Q2 Ertu karl eða kona?

0

O Karl

O Kona

Q3 Hvaða ár ertu fædd/-ur?

0

1998 ▼

Hverjir búa á sama heimili og þú?
Merktu við allt sem við á.
(Ef þú býrð á mörgum stöðum svarar þú fyrir það heimili sem þú verð mestum tíma á)

0

- □ Báðir foreldrar
- □ Móðir mín
- □ Faðir minn
- □ Móðir og hennar maki
- □ Faðir og hans maki
- □ Systkini mín, stjúpsystkini eða fóstursystkini
- □ Aðrir, hverjir?

1 ~ •

- □ Ég vil ekki svara

Q83

0

Hvaða námi ætlar þú að ljúka? ***Merktu við allt sem við á.***

- □ Stúdentsprófi
- □ Iðnréttindum/starfsréttindum
- □ Háskólaprófi
- □ Öðru, hvaða námi? z
- □ Ég vil ekki svara

Hver er/var menntun föður þíns?
Merktu við allt sem við á .

0

- □ Grunnskólapróf
- □ Stúdentspróf
- □ Iðnréttindi/starfsréttindi
- □ Háskólapróf
- □ Önnur
- □ Veit það ekki
- □ Ég vil ekki svara

Q8 0 Hver er/var menntun móður þinnar? ***Merktu við allt sem við á.***

- ☐ Grunnskólapróf
- ☐ Stúdentspróf
- ☐ Iðnréttindi/starfsréttindi
- ☐ Háskólapróf
- ☐ Önnur
- ☐ Veit það ekki
- ☐ Ég vil ekki svara

Q81 0 Ert þú með greiningu á einhverju af eftirfarandi:

	Já	Nei
Ofvirkni með athyglisbrest (ADHD)		
Athyglisbrest (ADD)	O	O
Lesblindu (Dyslexia)	O	O
Á einhverfurófi (Autistic spectrum disorder)	O	O

Q85 0 Hefur þú einhvern langvinnan sjúkdóm?

O Nei

O Já

O Veit ekki/Vil ekki svara

u **Display This Question:**

If Hefur þú einhvern langvinnan sjúkdóm? Já Is Selected

Q86 0 Hvaða sjúkdóm?

z

Q87 0 Tekur þú lyf daglega?

O Nei

O Já

O Veit ekki/Vil ekki svara

u **Display This Question:**

Tekur þú lyf daglega? Já Is Selected v **If**

Q88 0 Hvað heita lyfin sem þú tekur?

z

Hversu margar klukkustundir á dag gerir þú eftirtalið að jafnaði **m helgar**?

0

	Ekkert	Um / klst.	1-2 klst.	2-3 klst.	3-4 klst.	4-5 klst.	Meira en 5 klst.
Spilar tölvuleiki (t.d. á netinu, heimilistölvu, Playstation eða í snjallsíma)	o	o	o	o	o	o	o
Horfir á sjónvarp, DVD eða myndefni af netinu eða í snjallsíma	o	o	o	o	o	o	o
Ert á netinu (t.d. skoða vefsíður, Facebook, Twitter, Snapchat eða lesa/skrifa tölvupóst eða texta í snjallsímanum)	o	o	o	o	o	o	o
Hlustar á tónlist í útvarpi, af diski, úr snjallsíma eða af netinu	o	o	o	o	o	o	o
Lest bækur, tímarit, dagblöð eða annað prentað efni	o	o	o	o	o	o	o
Notar tölvu í annað en að vera á netinu eða spila tölvuleiki	o	o	o	o	o	o	o

☐ **Q9** Hversu margar klukkustundir á dag gerir þú eftirtalið að jafnaði á **virkum dögum**? 0

	Ekkert	Um / klst.	1-2 klst.	2-3 klst.	3-4 klst.	4-5 klst.	Meira en 5 klst.
Spilar tölvuleiki (t.d. á netinu, heimilistölvu, Playstation eða í snjallsíma)	o	o	o	o	o	o	o
Horfir á sjónvarp, DVD eða myndefni af netinu eða í snjallsíma	o	o	o	o	o	o	o
Ert á netinu (t.d. skoða vefsíður, Facebook Twitter, Snapchat eða lesa/skrifa tölvupóst eða texta í snjallsímanum)	o	o	o	o	o	o	o
Hlustar á tónlist í útvarpi, af diski, úr snjallsíma eða af netinu	o	o	o	o	o	o	o
Lest bækur, tímarit, dagblöð eða annað prentað efni	o	o	o	o	o	o	o
Notar tölvu í annað en að vera á netinu eða spila tölvuleiki	o	o	o	o	o	o	o

☐ **Q55** Hversu oft að meðaltali **síðastliðnar tvær vikur** hefur þú verið að stunda "media multitasking" (t.d horft á sjónvarpið og verið í símanum á sama tíma)?

0 O Nær aldrei

U Sjaldan

O Stundum

O Oft

O Nær alltaf

Q12

0

Hversu vel eiga eftirfarandi staðhæfingar við um þig tengt fjölskyldu þinni?

	Á mjög illa við um	Á frekar illa við um mig	Hvorki né	Á frekar vel við um mig	Á mjög vel við um mig
Ég á auðvelt með að fá hlýju og umhyggju frá fjölskyldu minni	o	o	o	o	o
Ég á auðvelt með að fá andlegan stuðning frá fjölskyldu minni	o	o	o	o	o
Ég á auðvelt með að fá peninga að láni hjá fjölskyldu minni ef ég þarf	o	o	o	o	o
Ég á auðvelt með að fá aðstoð hjá fjölskyldu minni ef á þarf að halda	o	o	o	o	o

Q13

0

Hversu vel eiga eftirfarandi staðhæfingar við um þig tengt vinum þínum?

	Á mjög illa við um mig	Á frekar illa við um mig	Hvorki né	Á frekar vel við um mig	Á mjög vel við um mig
Ég á auðvelt með að fá hlýju og umhyggju frá vinum mínum	o	o	o	o	o
Ég á auðvelt með að fá andlegan stuðning frá vinum mínum	o	o	o	o	o
Ég á auðvelt með að fá peninga að láni hjá vinum mínum ef ég þarf	o	o	o	o	o
Ég á auðvelt með að fá aðstoð hjá vinum mínum ef á þarf að halda	o	o	o	o	o

Page Break

Eftirfarandi spurningar eru um íþróttir og líkamsrækt

0

Eftirfarandi spurningar eru um íþróttir og líkamsrækt.

Q14

0

	Aldrei	Sjaldnar en einu sinni í viku	1 sinni í viku	2-3 sinnum í viku	4-5 sinnum í viku	Svo til á hverjum degi
Hve oft stundar þú íþróttir (æfir eða keppir) með íþróttafélagi?	o	o	o	o	o	o
Hversu oft stundar þú íþróttir eða æfingar sem ekki eru á vegum íþróttafélags?	o	o	o	o	o	o
Hversu oft reynir þú á þig líkamlega þannig að þú mæðist verulega eða svitnir?	o	o	o	o	o	o

☐ Q15

Hversu margar klukkustundir æfir þú íþróttir eða stundar líkamsrækt í **venjulegri viku**?

ø

O Ekkert

U Minna en eina klukkustund á viku

U Eina til tvær klukkustundir á viku

U Þrjár til fjórar klukkustundir á viku

U Fimm til sex klukkustundir á viku

U Meira en sex klukkustundir á viku

U Ég vil ekki svara

☐ Q17

Stundar þú íþróttir?

0

O Já

U Nei

U Ég gerði það áður en ekki lengur, hætti fyrir hvað mörgum árum?

u

Display This Question:
If Stundar þú íþróttir? Já Is Selected

☐ Q16

Af hvaða ástæðum stundar þú íþróttir? *Merktu í einn reit í hverri línu.*

	Mjög ósammála	Fremur ósammála	Hvorki né	Fremur sammála	Mjög sammála
Til að halda mér í góðu formi	O	o	o	o	o
Til að bæta færni mína í íþróttinni	O	o	o	o	o
Til að skemmta mér	O	o	o	o	o
Til að bæta heilsuna	o	o	o	o	o
Til að fitna ekki	o	o	o	o	o
Til að líta betur út	o	o	o	o	o
Til að fá aukinn kraft og orku	o	o	o	o	o
Til að eignast vini	o	o	o	o	o
Til að vera með vinum mínum	o	o	o	o	o
Til að grenna mig	o	o	o	o	o
Til að vera hluti af liði/hóp	o	o	o	o	o
Njóta þess að gera það sem ég er góð/ur í	o	o	o	o	o

Display This Question:

If Stundar þú íþróttir? Ég gerði það áður en ekki lengur, hætti fyrir hvað mörgum árum? Is Selected

☐ Q18 ø

Hvenær stundaðir þú síðast íþróttir eða líkamsrækt?

U Ég hef aldrei stundað íþróttir eða líkamsrækt

U Ég stundaði íþróttir eða líkamsrækt í þessari viku

U Ég stundaði íþróttir eða líkamsrækt í þessum mánuði

U Ég stundaði íþróttir eða líkamsrækt á þessu ári

U Ég stundaði íþróttir eða líkamsrækt fyrir meira en ári síðan

O Ég stundaði íþróttir eða líkamsrækt fyrir meira en tveimur árum

O Ég vil ekki svara

Display This Question:

If Stundar þú íþróttir? Ég gerði það áður en ekki lengur, hætti fyrir hvað mörgum árum? Is Selected

Ef þú hættir, af hvaða ástæðum hættir þú?

☐ Q20 0

O Það var of dýrt

O Það tók of mikinn tíma

O Það var of hættulegt

O Það var of leiðinlegt

U Ég var ekki nógu góð/ur

U Ég meiddist

U Ég var ekki velkomin/n

U Ég var of mikið úti að skemmta mér

U Vinur/vinir mínir hættu í íþróttum

U Það voru gerðar of miklar kröfur um getu

U Það voru gerðar of miklar kröfur um lífsstíl

U Annað, hvað?

☐ **Hefur þú einhvern tímann þurft að sleppa æfingum eða keppni með íþróttafélagi vegna Q21 íþróttameiðsla síðastliðin tvö ár?**

0 ***Ef þú hefur orðið fyrir fleiri en einu m meiðslum skaltu svara fyrir alvarlegustu meiðslin.***

U Nei, aldrei

U Já, styttra en eina viku

U Já, í 1-3 vikur

U Já, lengur en þrjár vikur

(J Já, ég hætti fyrir fullt og allt vegna íþróttameiðsla

U Hef aldrei æft íþróttir

☐ Q22 **Hversu sammála eða ósammála ertu eftirfarandi fullyrðingum?**

0

	Mjög ósammál	Fremur ósammála	Hvorki né	Fremur sammála	Mjög sammála
Mér finnst ég hreyfa mig nógu mikið	O	O	o	o	o
Ég er góð(ur) í íþróttum miðað við jafnaldra mína	O	o	o	o	o

☐ Q72

Líkamlegt ástand

☐ Q23 Myndir þú segja að heilsa þín væri...?

- Framúrskarandi
- Góð
- Þokkaleg
- Léleg

☐ Q24 Myndir þú segja að líkamlegt þrek (úthald) þitt væri...?

- Framúrskarandi
- Gott
- Þokkalegt
- Lélegt

☐ Q27 Hversu þung/ur vildir þú helst vera?

	Sátt/ur eins og ég er	1-3 kíló	4-6 kíló	7-9 kíló	10 kíló eða meira
Ég vildi helst þyngjast um...	O	o	o	o	o
Ég vildi helst léttast um...	O	o	o	o	o

☐ Q29 Hefur þú farið í megrun **síðastliðna 12**

- Nei, aldrei
- Einu sinni
- Tvisvar
- Þrisvar eða oftar

☐ Q30 Hefur þú gert eitthvað af eftirtöldu til að hafa stjórn á þyngd þinni á **síðastliðnum 12 mánuðum**?

0

	Já	Nei	Ég vil ekki svara
Líkamsrækt	o	o	o
Sleppt máltíðum	o	o	o
Ekki borðað neitt í heilan sólarhring eða lengur	o	o	o
Borðað minna af sælgæti	o	o	o
Borðað minna af fitu eða feitum mat	o	o	o
Drukkið minna af gosdrykkjum	o	o	o
Drukkið meira af vatni	o	o	o
Drukkið próteindrykki	o	o	o
Borðað meira af ávöxtum og/eða grænmeti	o	o	o
Takmarkað mig við einn eða fleiri fæðuflokka (t.d. aðeins borðað ávexti og grænmeti, aðeins vökva, aðeins prótein)	o	o	o
Gubbað því sem ég hafði borðað	o	o	o
Notað megrunarpillur eða hægðalyf	o	o	o
Reykt tóbak	o	o	o
Megrun undir eftirliti sérfræðings	o	o	o
Annað	o	o	o

☐ Q31 Hversu vel eiga eftirfarandi fullyrðingar við um þig?

	Á mjög vel við um mig	Á frekar vel við um mig	Á frekar illa við um mig	Á mjög illa við um mig
Þegar ég hugsa um hvernig ég muni líta út í framtíðinni er ég ánægð(ur)	o	o	o	o
Mér finnst ég oftast vera ófríð(ur) og óaðlaðandi	o	o	o	o
Ég er ánægð(ur) með líkama minn	o	o	o	o
Ég er ánægð(ur) með þær líkamlegu breytingar sem hafa átt sér stað hjá mér undanfarin ár	o	o	o	o
Mér finnst ég vera sterk(ur) og hraust(ur)	o	o	o	o

☐ Q32 Hversu oft borðar þú þessar máltíðir að jafnaði **á viku?**

	Nær aldrei	1-2 sinnum í viku	3-4 sinnum í viku	5-6 sinnum í viku	Nánast á hverjum degi
Morgunmat	o	o	o	o	o
Hádegismat	o	o	o	o	o
Nesti að heiman	o	o	o	o	o
Kvöldmat	o	o	o	o	o
Bita milli máltíða	o	o	o	o	o

Q33

ø

Hversu oft varðst þú var/vör við eftirfarandi vanlíðan eða óþægindi síðastliðna viku?

	Nær aldrei		Sjaldan	Stundum	Oft	Nær alltaf
Höfuðverk	O	O	O	O	O	
Svima	O	O	O	O	O	
Verk í baki	O	O	O	O	O	
Ógleði eða ólgu í maga	O	O	O	O	O	
Doða eða sting einhvers staðar í líkamanum	O	O	O	O	O	
Verk í maga	O	O	O	O	O	
Liðverki	O	O	O	O	O	
Skjálfta	O	O	O	O	O	
Verki í höndum eða fótum	O	O	O	O	O	
Taugaóstyrk	O	O	O	O	O	
Skyndilegrar hræðslu án nokkurrar ástæðu	O	O	O	O	O	
Þú varst uppspennt/uppspenntur	O	O	O	O	O	
Þú varst leið/leiður eða hafðir lítinn áhuga á því að gera hluti	O	O	O	O	O	
Þú hafðir litla matarlyst	O	O	O	O	O	
Þér fannst þú einmana	O	O	O	O	O	
Þú grést auðveldlega eða langaði til að gráta	O	O	O	O	O	
Þú áttir erfitt með að sofa eða sofna	O	O	O	O	O	
Þú varst niðurdregin/niðurdreginn eða döpur/dapur	O	O	O	O	O	
Þú varst ekki spennt/spenntur fyrir að gera neitt	O	O	O	O	O	
Þér fannst þú hægfara eða hafa lítinn mátt	O	O	O	O	O	
Þér fannst framtíðin vonlaus	O	O	O	O	O	
Þú hugsaðir um að fyrirfara þér	O	O	O	O	O	
Verki í herðum og öxlum	O	O	O	O	O	
Verki í mjóbaki	O	O	O	O	O	

Q84

0

Hve löngum tíma á dag varðir þú að jafnaði **sitjandi** í síðastliðinni viku-**frá mánudegi til föstudags**?

Vinsamlegast teldu með tímann sem þú situr í skólanum, vinnunni, heima og í frítíma (hér getur talist með tími sem setið er við skrifborð, matarborð, í heimsókn, við lestur eða fyrir fram sjónvarp, tölvu eða snjalsíma).

- O Minna en klukkustund á dag
- O Um 1 klukkustund á dag
- O Um 2-3 klukkustundir á dag
- O Um 4-5 klukkustundir á dag
- O Um 6-7 klukkustundir á dag
- O Um 8-10 klukkustundir á dag
- O Um 11-13 klukkustundir á dag
- O Um 14-16 klukkustundir á dag

O Meira en 16 klukkustundir á dag

☐ Q58 ø

Hve löngum tíma á dag varðir þú að jafnaði **sitjandi** síðastliðna helgi- **laugardag og sunnudag**?
Vinsamlegast teldu með tímann sem þú situr í skólanum, vinnunni, heima og í frítíma (hér getur talist með tími sem setið er við skrifborð, matarborð, í heimsókn, við lestur eða fyrir fram sjónvarp, tölvu eða snjalsíma).

U Minna en klukkustund á dag

U Um 1 klukkustund á dag

U Um 2-3 klukkustundir á dag

U Um 4-5 klukkustundir á dag

U Um 6-7 klukkustundir á dag

U Um 8-10 klukkustundir á dag

U Um 11-13 klukkustundir á dag

O Um 14-16 klukkustundir á dag

O Meira en 16 klukkustundir á dag

Page Break

Skólamál

☐ Q73 0

☐ Hvernig ferð þú oftast í skólann? **Q35**

O Er keyrð/keyrður

O Með strætó/skólabíl

O Á hjóli

U Geng eða hleyp

☐ Q37 Hversu vel eða illa telur þú þig standa í námi miðað við jafnaldra þína?

O Mjög vel

U Frekar vel

U Í meðallagi

U Frekar illa

O Mjög illa

Q39

0

Hversu sammála eða ósammála ertu eftirfarandi fullyrðingum um nám þitt?

	Mjög ósammál	Frekar ósammála	Hvorki né	Frekar sammála	Mjög sammála
Mér líkar mjög vel í skólanum	O	o	o	o	o
Ég stend mig mjög vel í skólanum	O	o	o	o	o
Ég hef mikinn áhuga á náminu	o	o	o	o	o
Ég skrópa oft í tímum	o	o	o	o	o
Mér leiðist oft í skólanum	o	o	o	o	o
Mér líður oft illa í skólanum	o	o	o	o	o

Lífsviðhorf

Q74

0

Q40

0

Hér fyrir neðan eru ýmsar staðhæfingar um hvað þér finnst um sjálfa/sjálfa n þig

	Mjög sammála	Frekar sammála	Frekar ósammála	Mjög ósammála
Ég er almennt ánægð/ur með sjálfa/sjálfan mig	o	o	o	o
Stundum finnst mér ég einskis virði	o	o	o	o
Mér finnst ég hafa marga góða eiginleika	o	o	o	o
Ég get gert margt jafn vel og flestir aðrir	o	o	o	o
Mér finnst ég ekki geta verið stolt/stoltur af mörgu	o	o	o	o
Stundum finnst mér ég sannarlega vera gagnslaus	o	o	o	o
Mér finnst ég vera a.m.k. jafn mikils virði og aðrir	o	o	o	o
Ég vildi að ég gæti borðið meiri virðingu fyrir sjálfum/sjálfri mér	o	o	o	o
Allt í allt finnst mér ég vera misheppnaður/misheppnuð	o	o	o	o
Ég hef jákvæða afstöðu til sjálfs/sjálfrar mín	o	o	o	o

☐ Q41

Hversu vel finnst þér eftirfarandi staðhæfingar eiga við um þig?

0	Á mjög vel við um mig	Á frekar vel við um mig	Á frekar illa við um mig	Á mjög illa við um mig
Ég þarf tíma til að jafna mig á feimni minni við nýjar aðstæður	o	o	o	o
Mér finnst erfitt að vinna þegar fylgst er með mér	o	o	o	o
Ég verð auðveldlega vandræðaleg/vandræðalegur	o	o	o	o
Mér finnst ekkert erfitt að tala við ókunnuga	o	o	o	o
Ég er kvíðin/kvíðinn þegar ég tala frammi fyrir hópi af fólki	o	o	o	o
Ég verð óróleg/órólegur í stórum hópi fólks	o	o	o	o

☐ Q42

Hversu sammála eða ósammála ert þú eftirfarandi fullyrðingum?

	Mjög ósammála	Ósammála	Frekar ósammála	Hvorki né	Frekar sammála	Sammála	Mjög sammála
Líf mitt er að flestu leyti nálægt því sem ég óska mér	o	o	o	o	o	o	o
Aðstæður lífs míns eru frábærar	o	o	o	o	o	o	o
Ég er ánægð/ánægður með lífið	o	o	o	o	o	o	o
Hingað til hef ég fengið það mikilvægasta sem ég vil í lífinu	o	o	o	o	o	o	o
Ef ég gæti lifað lífi mínu upp á nýtt myndi ég næstum engu breyta	o	o	o	o	o	o	o

Page Break

Q54

Hversu marga daga **í viku** gerir þú eftirfarandi að jafnaði? *Merktu við dagafjölda á viku*

	Aldrei	Einn dag	Tvo daga	Þrjá daga	Fjóra daga	Fimm daga	Sex daga	Sjö daga
Drekkur sykraðan gosdrykk	o	o	o	o	o	o	o	o
Drekkur sykurlausan gosdrykk	o	o	o	o	o	o	o	o
Drekkur mjólk	o	o	o	o	o	o	o	o
Drekkur ávaxtasafa	o	o	o	o	o	o	o	o
Tekur lýsi eða lýsistöflur	o	o	o	o	o	o	o	o
Tekur vítamín með D vítamíni	o	o	o	o	o	o	o	o
Borðar nammi og sætindi	o	o	o	o	o	o	o	o

Page Break

Q76

Svefnvenjur

Hvenær ferðu venjulega að sofa á **virkum**

20:00

0

Q80

Hvenær ferðu venjulega að sofa **um helgar?**

20:00 ▼

Q58

Finnst þér þú sofa nóg?

- Oftast
- Um helming nátta
- Mjög sjaldan
- Ég sef of mikið

Q59

Hversu oft áttu erfitt með að einbeita þér í skólanum/vinnu vegna þreytu?

- Sjaldan eða aldrei
- Kannski einu sinni í viku
- Einu sinni á dag
- Oft á dag

☐ Spurningarnar á þessum kvarða eru um tilfinningar þínar og hugsanir **síðastliðinn Q89 mánuð**.

Vinsaml egast merktu í viðeigandi reit eftir því hversu oft þú hugsaðir eða þér leið á ákveðin hátt.

	Aldrei	Næstum aldrei	Stundum	Nokkuð oft	Mjög oft
Hversu oft síðastliðinn mánuð hefur þú farið úr jafnvægi vegna einhvers sem kom óvænt uppá?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist sem þú værir ekki fær um að hafa stjórn á mikilvægum hlutum í lífi þínu?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist þú vera taugaóstyrk(ur) og stressuð/aður?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þú verið örugg(ur) um getu þína til að fást við eigin vandamál?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist hlutirnir ganga þér í hag?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist að þú gætir ekki ráðið við allt það sem þú þurftir að gera?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þú getað haft stjórn á hlutum í lífi þínu sem hafa pirrað þig?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist þú hafa vald á hlutunum?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þú orðið reið(ur) vegna einhvers sem þú gast ekki haft áhrif á?	o	o	o	o	o
Hversu oft síðastliðinn mánuð hefur þér fundist vandamálin hrannast upp þannig að þú gætir ekki sigrast á þeim?	o	o	o	o	o

Page Break

Q78
0

Kærar þakkir fyrir þátttökuna

Rannsóknarstofa í íþrótta- og heilsufræðum Menntavísindasvið Háskóla Íslands

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