UNIVERSITY OF TURKU

# ABSTRACT

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| Supervisor(s) | Prof. Reima Suomi | | |


Abstract

Use of wearable devices with health and well-being related features has increased during the past years and the trend is predicted to continue in the following years as well. The technology in today's devices is capable of recording number of biosignals such as blood pressure, body and/or skin temperature, and heart rate. Wearable technology is planned, for instance, to support weight management, improve cardiovascular health and help monitoring and treatment of mental health disorders. This research aimed to find out how common it was for university students in Turku, Finland, to use wearable devices, and to discover the experienced health and well-being benefits, drawbacks or challenges related to the use of wearable devices. Additional goals were to discover the factors students valued in the adoption of wearable devices and if students used the devices in cooperation with health care professionals.

The research was done by utilizing mixed-methods approach combining features of quantitative and qualitive methods to study the topic in extensive manner. To answer the research questions, empiric data was collected using an online survey distributed to university students in Turku, Finland in fall 2020. The survey was distributed to students in the University of Turku and Åbo Akademi University in cooperation with the student associations in the two universities. The total survey sample resulted to 329 respondents with participants from both universities.

60 percent of the survey respondents used wearable devices and 40 percent did not. The most used device types were activity trackers, smart watches, and heart rate monitors. Almost all users of wearable devices stated they experienced health and well-being benefits from the use of the devices. The most common benefits were support in increasing physical activity, giving information about the state of users' health, and support in improving sleep. A third of the users stated they experienced drawbacks or challenges. The most common types of the drawbacks or challenges were the device inaccuracy in signal recording, the devices causing stress to the users, and devices feeling uncomfortable or causing skin rash. When selecting the devices, the users valued the device price, appearance and usability. Surprisingly device data privacy and data security features were relatively unimportant factors for the students in comparison to them being highlighted in the wearable device literature. Finally, only a small number of wearable device users shared the device data or used the wearable devices in cooperation with the health care professionals. The research results indicate that wearable devices provide tools with a great potential to support both students and student health care professionals in improving students' health, well-being and studying ability.



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| Key words | Wearable technology, Wearable devices, Student health, Student well-being |

TURUN YLIOPISTO

# TIIVISTELMÄ

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Tiivistelmä

Terveys- ja hyvinvointiominaisuuksia sisältävien puettavien laitteiden käyttö on kasvanut viime vuosien aikana ja trendin odotetaan jatkuvan myös tulevina vuosina. Teknologia nykyajan laitteissa kykenee mittaamaan kehon biosignaaleja, kuten verenpainetta, kehon ja/tai ihon lämpötilaa ja sykettä. Puettavaa teknologiaa on suunniteltu käytettävän esimerkiksi painonhallinnan tuessa, sydän- ja verisuoniterveydessä ja mielenterveysongelmien hoidossa sekä seurannassa. Tämän tutkimuksen tavoitteena oli selvittää, kuinka yleistä puettavien laitteiden käyttö oli yliopisto-opiskelijoilla Turussa, Suomessa ja mitä hyötyjä, haittoja tai haasteita puettavien laitteiden käytöstä koettiin. Lisäksi tavoitteina oli selvittää, mitä tekijöitä opiskelijat arvostivat puettavien laitteiden käyttöön liittyen ja olivatko opiskelijat käyttäneet laitteita yhteistyössä terveydenhuollon ammattilaisten kanssa.

Tutkimus tehtiin hyödyntäen sekamenetelmä-lähestymistapaa yhdistäen ominaisuuksia määrällisistä ja laadullisista metodeista, jotta aihetta voitiin tutkia laaja-alaisella tavalla. Tutkimuskysymyksiin vastaamiseksi kerättiin tutkimusta varten empiirinen data käyttäen internet-kyselyä, joka jaettiin yliopisto-opiskelijoille Turussa syksyllä 2020. Kysely levitettiin opiskelijoille Turun yliopistossa ja Åbo Akademissa yhteistyössä yliopistojen opiskelijajärjestöjen kanssa. Lopullinen kyselyn otos oli 329 vastaajaa sisältäen osallistujia molemmista yliopistoista.

60 prosenttia kyselyyn vastanneista käytti puettavia laitteita ja 40 prosenttia ei. Yleisimmät käytetyt laitetyypit olivat aktiivisuuden seurantalaitteet, älykellot ja sykemittarit. Lähes kaikki puettavien laitteiden käyttäjät olivat kokeneet terveyteen ja hyvinvointiin liittyviä hyötyjä laitteiden käytöstä. Yleisimmät hyödyt olivat tuki fyysisen aktiivisuuden lisäämisessä, tietoisuuden lisääminen käyttäjien terveydentilasta ja tuki unen parantamisessa. Kolmannes käyttäjistä vastasi, että he olivat kokeneet haittoja tai haasteita. Yleisimmät haittojen tai haasteiden tyypit olivat laitteiden epätarkkuus signaalien mittaamisessa, laitteet aiheuttivat stressiä käyttäjille ja laitteet tuntuivat epämukavilta tai aiheuttivat ihottumaa. Laitteita valittaessa käyttäjät arvostivat laitteen hintaa, ulkonäköä, ja käytettävyyttä. Yllättäen laitteiden tietosuoja- ja tietoturvaominaisuudet olivat suhteellisen merkityksettömiä tekijöitä opiskelijoille verrattuna siihen, kuinka korostettuja tekijöitä ne olivat puettavien laitteiden kirjallisuudessa. Lopuksi vain pieni osa puettavien laitteiden käyttäjistä jakoi laitteiden dataa tai käyttivät laitteita yhteistyössä terveydenhuollon ammattilaisten kanssa. Tutkimuksen tulokset osoittavat, että puettavat laitteet tarjoavat työkaluja, joilla on valtava potentiaali tukea sekä opiskelijoita, että opiskelijaterveydenhuollon ammattilaisia opiskelijoiden terveyden, hyvinvoinnin ja opiskelukyvyn kehittämisessä.



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| Asiasanat | Puettava teknologia, Puettavat laitteet, Opiskelijaterveys, Opiskelijahyvinvointi |

UNIVERSITY OF TURKU
Turku School of Economics

# USE OF WEARABLE DEVICES FOR HEALTH AND WELL-BEING PURPOSES AMONG UNIVERSITY STUDENTS IN TURKU

Master´s Thesis
in Information Systems Science

Author:
Joonas Raina

Supervisors:
Prof. Reima Suomi

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Helsinki

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# 1 INTRODUCTION

## 1.1 Background

Use of wearable devices and technology increased during the past several years in various areas of people's daily lives. According to Statista, a statistics provider, the amount of connected wearable devices grew from 325 million pieces in 2016 to 722 million pieces in 2019. It is predicted that the amount of smart watches, fitness bands or other wearable devices increases in the future as well and that the number of connected devices reaches one billion pieces by 2022. (Statista 2019a.) Vandrico Inc (Vandrico Inc 2020), a database for wearable devices, lists out over 400 different wearable devices from over 250 companies. Vandrico Inc defines four features that a wearable device must have. First, the device must be worn on the body throughout its use. Second, the device must be controllable by the user either done actively or passively. Third, the device must augment knowledge, facilitate learning or enhance experience. Fourth, the device must give users the freedom to act naturally and not to be limited to a fixed area. The different types of wearable devices have a wide range of use cases from health care and wellness to military services. Arguably most known wearable devices are fitness and health tracking devices such as Fitbit and Apple Watch which track for instance users' steps, heart rate and stairs climbed (Li et al. 2016). Other examples of use for wearables devices are education bracelet Jewelbot, pet health tracker Fitbark and workplace ergonomic device Kinetic (Lee & Lee 2015). Wearable technology can be utilized in military use for positioning and giving feedback to the military leadership about location and movement of the soldiers (Lee et al. 2017; Shi et al. 2019). This research focuses on wearable devices that have impact on health and well-being areas.

With the recent technological advancements, such as microchips becoming smaller and battery technology taking huge steps forward, there are each year increasing number of health and well-being wearable devices in the market. However, wearable technology is not a new thing in health care. In 1962 Holter monitor, which main use purpose is electrocardiography tracking, was released to commercial production (Kennedy 2006). Other type of wearable device in health care, that has been long in the market, is portable hearing aid helping people with poor hearing (Lukowicz. et al 2004). Now there exist numerous different ways how wearable devices could be used in health care by recording data from the signals that the human body and the environment produces. The devices are packaged in modern device designs that have come far since the first Holter monitors. The technology in today's wearable devices is capable of recording number of biosignals such as blood pressure, body and/or skin temperature, oxygen saturation, and heart rate which can be used for health and well-being monitoring (Pantelopoulos & Bourbakis

2009). Wearable technology was planned to fight obesity and support weight management (Shuger et al 2014), improve cardiovascular health (Yingling et al. 2014), and help in motor neuron disease monitoring (Bonato et al. 2003). The technology can be used to monitor social interactions of the user, which are meaningful in mental health monitoring, and sleep quality, which is used in use cases to support mental and physical recovery (Piwek et al. 2016). Utilizing wearable devices for health monitoring of the biosignals has potential to revolutionize health care by providing low-cost solutions for all-day, unobtrusive personal health monitoring and could enable early detection and better treatment of various medical conditions (Pantelopoulos & Bourbakis 2009). One of the advantages of utilizing wearable devices is that clinicians can collect data from home or other daily environments in which the patient operates at. This is a great benefit in comparison to being able to get data from clinically supervised environments with limited capabilities related to, for instance, the limited time period of clinical monitoring (Bonato 2005).

One potential area in which utilization of wearable devices can be increased is university student's health and well-being in Finland. There are several areas of student health in which trends indicate that the situation with emerging health issues is going worse. University students show increasing amount of psychological problems. In total 44.2 percent of students in Finland said they experience psychological symptoms such as depression, worry or signs of burnout in weekly or more frequent basis. Since the year 2000 the number of students that reported to have experienced these symptoms grew with 6.5 percentage points. The number of obese students grew also in the 2000s. When using BMI (Body Mass Index) scale as measurement, over one-fourth of the students were obese in comparison to the 18 percent of the students in 2000. Overall 27.9 percent of the students felt like their physical well-being was only moderate or below and 22.6 percent felt like their health was moderate or below. (Kunttu et al 2016.) As these new types of health issues emerge it is important to find new treatment and monitoring methods to identify the potential predispositions and early signs of symptoms in order to prevent issues emerging to serious conditions. Additionally, it is valuable to seek and provide new tools for students which motivate to apply healthy lifestyle and habits. The development and use of new tools for improving the health and well-being of people is important in early stages of health disorders or unhealthy habits as possible. If the health problems are not being treated and managed in the groups and ages of university students, there is a risk that the health issues worsen when the students move into working life. For instance, in addition of being a problem for university students, psychological problems are one of the biggest reasons for sickness absences and illness-related early retirement in occupational health care in Finland (Reho et al. 2020).

The additional interesting factor why developing tools, methods and doing research related to this group of Finnish citizens is that for the group of some 150 000 university

students in Finland (Tilastokeskus 2020a) the most common service provider is Finnish Student Health Service, FSHS (YTHS 2020a). When comparing for instance to occupational health in Finland, the number of potential patients is manifold with over 2 million occupational health customers. However, in occupational health the services can be provided by four different types of service providers, including multiple different private practices which communicate and share information only a little (Martimo & Mäkitalo 2014). This makes implementing and developing commonly shared tools much easier in the university student health and FSHS in comparison to occupational health. In addition, university students have similarities with each other by sharing similar age groups and education levels.

## 1.2 Research gap and research questions

Use of wearable technology for health and well-being purposes is an emerging area of research, but it is still quite in its infancy. There are some preliminary holistic studies of using wearable devices in Finnish health and well-being with certain groups. Utilization of wearable technology was studied in Finnish occupational health care by interviews and questionnaires with health care professionals in occupational health (Rauttola et al 2019). The age range in occupational health consist of employees from 15-years to 74-years (Tilastokeskus 2020b). Use of wearable devices, with focus to physical activity trackers, was also studied among Finnish adolescents with study group ages being from 11-years to 15-years (Ng et al. 2017). However, there is a gap in research among university students and for that reason research focused on wearable health and well-being technology use among them. To limit the scope of the research, this research focused specifically on university students in Turku area in Finland. The first research questions are following:

- How common it is to use and at what frequency do university students in Turku use wearable devices for health and well-being purposes?
- What type of health and well-being wearable devices do the university students in Turku use and what indicators do the devices monitor?

Wearable technology is a studied area from the perspective of adoption of the technology by the users. Research reveals both positive and negative factors that impact the intention to use wearable devices. Studies show that users tend to stop using the wearable devices after a while (Piwek et al. 2016). In order to reap the benefits from wearable devices, users need to be motivated to use them. Additionally, to provide insight for development and design of wearable devices, it is important to understand the factors the users value in the devices they use and on the other hand why do they not want to use them. The next research questions are following:

- What features do the university students in Turku value in wearable devices?
- What are the reasons for the university students in Turku not to use wearable devices?

Only limited amount of clinically proven benefits exist related to use of wearable devices and the focus is mostly around physical activity and obesity (Piwek et al. 2016; Shuger et al 2014). The technology has come a long way and it can measure and impact other areas as well such as sleep and mental recovery. In addition to the benefits, wearable devices might have drawbacks or challenges such as experienced stress related to use of information of technology (Schukat et al. 2016). In order to understand how to reap the health and well-being benefits and avoid potential drawbacks or challenges, information is needed about the experiences from the users. The next research questions are following:

- Does use of wearable devices result to perceived health and well-being benefits among the university students in Turku and what type of benefits do they experience?
- Does use of wearable devices result to perceived health and well-being drawbacks or challenges among the university students in Turku and what type drawbacks or challenges do they experience?

Finally, it was discussed that implementing wearable devices for health care purposes is not enough to reap the potential benefits of the technology, but large engagement strategies should be put in place in the organizations in order to achieve the benefits of the technology and create change in user's health behavior (Patel et al. 2015). To start analyzing if some strategies can be put in place among the university students, it needs to be found out first if the university students use the devices independently or together with FSHS. Similarly, as the use of wearable devices was studied in the area of occupational health from perspective of health care professionals (Rauttola et al 2019), it is valuable to understand if wearable devices are used in cooperation with the university students and FSHS health care professionals. The final research question is the following:

- Have the university students in Turku used wearable devices in cooperation with health care professionals such as FSHS and how have they done it?

## 1.3 Structure of the research

The first chapter in the research familiarizes the reader with the background of wearable technology and emerging university student health issues. The research gap is identified, the research questions presented with justifications, and the study population is determined.

The second chapter includes an extensive literature review to wearable technologies in health care and well-being purposes. The chapter starts with the definition of wearable devices and technology with a look to different aspects of the technology. Then literature about the different use cases, benefits, and drawbacks or challenges is investigated. As last in the second chapter, the research related factors that either positively or negatively impact the intention to use the wearable devices is reviewed.

The third chapter in the research presents the state of the university student health care in Finland. The overview of how the health care works for the university students and the regulation behind is discussed. Then the main health issues that the students experience are reviewed and the current methods for utilization of information technology in student health care, such as e-visits, are discussed.

The fourth chapter includes the presentation of the research methodology for this research. First the timeline for different key research phases of the research is shown starting from literature review and ending to the conclusions. Then the structure and questions of the survey, which was the choice of the collection for empiric data, are presented including the reasoning behind the survey questions and selection of responses. Last in the chapter the survey distribution methods are presented, and the validity and ethics of the research methodology are discussed.

The fifth chapter displays the results of the survey. The results are split to four pieces. They start with background information of the survey respondents which is followed by section for use of wearable devices and the device types. Then the results for the experienced benefits, and drawbacks or challenges are shown. Last, the results for student wearable user's collaboration with student health organization are shown.

The sixth chapter contains then the discussion about the results of the survey and the research questions are answered. The limitations are identified, recommended future study is stated, and the research conclusions are drawn.

# 2 WEARABLE DEVICES IN HEALTH AND WELL-BEING

## 2.1 Definition and features of wearable devices

Wright and Keith (2010) define that the term wearable technology refers to items which can easily be worn and taken off. They highlight that the goal of the technology is to incorporate functional portable computer and electronics seamlessly into people's daily lives. Jhajharia et al. (2014) provide six different features which wearable devices have. First, they should be wearable for extended time periods. Second, the devices should be smart with advanced circuitry and connections. Third, they should provide constant access to information services and should interact with the user any given time. Fourth, the device should sense the internal state of the user and provide best possible feedback. Fifth, they should take minimum amounts of user attention and should guarantee privacy. Sixth, the device should provide automation or computation and the data to be presented with an interface consistent to user preferences.

The sensors, which do the recording of data in wearable devices, can be divided into three categories. First, there are activity monitors that monitor movement using, for instance, accelometers and gyroscopes. Then there are physiological monitors which have a long-term contact with the body. With these device sensors, biosignals such as heart rate, breathing rate and blood pressure can be measured. Finally, there are devices with environmental monitoring. These sensors can for instance be used to detect progression of some illnesses based on the analysis from breath samples. (Rodgers et al. 2015.)

Wearable devices can record multiple types of signals, that can be used for health and well-being monitoring. The technology in the devices is capable of recording number of biosignals such as electrocardiogram (ECG), blood pressure, body and/or skin temperature, respiration rate, oxygen saturation, heart rate, perspiration or skin conductivity, heart sounds, blood glucose, electromyogram (EMG), electroencephalography (EEG) and body movements (Pantelopoulos & Bourbakis 2009). Potential to measure and test body fluid biomarkers such as glucose and chloride from saliva, sweat, tears, volatile biomarkers such as acetone and ammonia from breath, skin perspiration, and digestive system using wearable non-invasive sensors was researched (Tricoli et al. 2017). The devices can be used to monitor social interactions of the user which can be measured using Bluetooth proximity to other devices, and sleep quality and snoring which could be recorded with device microphone (Piwek et al. 2016).

Many features typical for wearable devices create possibilities for health care applications. The devices are consistent, there exists a constant interaction between the user and the device, and they are not easily lost as they are embedded to users' body. The devices are unrestrictive, they create no distraction, and they allow the user to multi-task with the

devices recording data without the user needing actively to guide the device. The technology is mobile, and the user can take it wherever he / she goes. The devices are communicative and can be used as communication mediums. Finally, the devices are attentive, and provide prompts and reminders if needed. (Jhajharia et al. 2014.)

The size of the wearable health and fitness device market and number of devices depend on the definition of the device. The numbers vary whether on focusing on wearable health devices, fitness trackers, smart watches or some other type of device with health or well-being supporting features. The projected market size for wearable health care sector devices in 2020 and 2021 was 9 billion and 17 billion US dollars, respectively (Statista 2016). When focusing to shipments of fitness trackers alone, the number of unit shipments was projected to be 85 million units on 2020 and 94 million units on 2021 (Statista 2017). In comparison, for smart watches, which most of incorporate health and well-being features, number of shipped units globally was projected to be 100 million US dollars in 2020 and 109 million US dollars in 2021 (Statista 2019b). Regardless the focus area of wearable health or well-being devices, the device amounts grew intensely during the past years and this trend is expected to continue when moving forward in the 2020s.

In Finland wearable devices in health care and well-being can be divided to well-being technology devices and medical devices. In order to sell devices under the category of a medical device, they need to be provided with CE tag which identifies that the device has been verified to comply with EU Medical Device Regulation. The tag for medical device means that the device is meant to be used at, for instance, diagnosing or monitoring diseases, disabilities or injuries, to study anatomical or physiological functions, or to regulate fertility. Many of the wearable devices such as fitness bands and smart watches in the market for health and well-being, are not certified as medical devices. One of the reasons for this is that getting medical device certificate would increase the costs for manufactures. For that reason, many of the devices are sold and marketed as well-being devices. Additionally, wearable devices can be divided to consumer devices and professional devices based on the way they are used and designed to be used. (Rauttola et al. 2019.)

Number of features should be considered when designing the devices to improve the adoption of wearable technology. First, the devices should be wearable and comfortable in which case it is important to think about the size and weight of the device as users are not willing to use heavy and bulky devices. Skin irritation should be minimized as users might use the device 24 hours of the day wearing the device on their body. Tightness and pressure should be considered as tighter devices are not comfortable to use. Second, the devices should have immunity to artifacts, such as body hair, which might interfere with the recording of the data and thus impact the reliability of the results. Third important feature to consider is sampling frequency which means, for instance, frequency of recording heart rate. With different health care applications there is a need for varying frequency. There should not be only one default frequency for everything. Fourth feature is

the personalization of the information which the device produces. The system should provide an option to configure the way the info is shown. Fifth feature is seamless data integration to other devices in order to combine the data with other applications as well. Final important feature of the devices is user identification. It should be as easy as possible to log into the device. (Jovanov 2015.) The factors impacting the intention to use wearable device are reviewed in more detail in chapter 2.4.

## 2.2 Use of wearable devices in health and well-being

Wearable devices can be used for several purposes in health and well-being. Examples of the uses are shown in Table 1. Wearable devices can be used for treatment of Parkinson's disease, stroke management, and head and neck injuries (Rodgers et al. 2015). In addition to Parkinson's disease wearable devices can have potential uses in other motor neuron diseases as well (Bonato et al. 2003). The devices can be used in management of respiratory health diseases by providing feedback about oxygen saturation, pulmonary ventilation, which is calculated from respiratory rate and volume of air inhaled and exhaled with each breath, physical activity, and air quality (Aliverti 2017). The technology might have potential benefits in improvement of cardiovascular health with community-based approach (Yingling et al. 2014). Other possible uses of wearable devices are early age detection for autism spectrum disorders, disaster and battlefield medical care, elderly care monitoring in home or nursing homes, behavioral therapy for conditions such as drug addiction requiring long term monitoring, anxiety and other mental health monitoring to complement clinical visits, and diabetes to monitor indicators of extreme levels of insulin and sugar (Fletcher et al. 2010). Wearable devices can be utilized in aiding surgical recovery and preventing sudden infant death syndrome with babies using smart shirts (Park & Jayaraman 2003).

Though wearable devices are planned and studied for multiple health and well-being cases, there is only a little clinical randomized and controlled study proving actual health and well-being benefits of wearable devices. Physical tracking and motivation are one of the exceptions. Tracking physical activity with a pedometer, which tracks steps taken, was clinically proven to increase physical activity among older people. (Piwek et al. 2016.) Similarly, related to physical activity tracking, use of wearable devices was shown useful in fighting obesity which is a risk factor for many chronic conditions such as diabetes and hypertension (Shuger et al 2014).

One key element of wearable devices for health and well-being tracking is that the devices can be used outside clinically supervised environments throughout the whole day in most of the normal life environments of the users. It is very difficult and expensive to record and produce data in the clinical environments in similar manner than wearable

devices can potentially offer. The requirement for wearable devices to be used outside clinical environments is that the recorded data is reliable. If, for instance, heart rate trackers give false data, specifically for already sick customers, it could potentially lead to wrong or even dangerous incorrect diagnoses. In his study Jovanov (2015) researched how well one of the most common wearable devices, a smart watch, could record activities and produce data during a four-month period. His results were that the watch could record 88.88 percent of the study period. In another study, which investigated whether fitness trackers and smart watches could accurately track heart rate and steps, it was shown that the devices are relatively accurate (El-Amrawy et al. 2015). This means that there is at least potential in tracking steps and heart rate, one of the most common features in fitness and health related wearable devices. Additionally, number of consumer off-the-shelf health and well-being wearables were studied and found useful on tracking emotion, stress, and sleep though they did not yet match medical-level devices in sensor and signal quality (Saganowski et al 2020). To improve the data reliability and sensor quality there could be better alternatives instead for commonly used fitness band and smart watches worn on wrists. Smart textiles, such as shirts with sensors, might even be better at recording data and suitable for health care applications (Pantelopoulos & Bourbakis 2008). Smart textiles might be potentially beneficial development focus area for wearable researchers and manufacturers to improve the quality of consumer devices for health and well-being use cases.

Wearable devices can assist on supporting healthy lifestyle and well-being in number of ways. Ananthanarayan and Siek (2012) studied wearables that address the problem of motivating physical activity by raising self-awareness. According to their study, self-awareness was raised by self-monitoring, social influence and fun interaction methods. Self-monitoring was achieved through real-time sensors coupled with digital journals that helped users in goal setting. Social influence was achieved by forming social groups who supported the use of device and sharing the results in the group. Finally, fun interaction meant making the healthy activity fun and, for instance, gamifying it.

Health benefits can occur from monitoring with wearable devices in two ways. First way is wellness and disease management in which an individual actively participates in the management process. For instance, the user might be tracking blood glucose levels actively and storing them into database to receive feedback from the process. This model requires the user to actively participate in the monitoring the health. The second main way is independent living and remote monitoring in which the user of the wearable device is not the one actively following their data but rather a caregiver who is, for instance a health care professional, tracks the data and gives potential recommended actions if needed. (Korhonen et al. 2003.) Especially the latter model is interesting in cases in which the patients themselves would not actively seek to change their behavior even though

there are clear signals they are needed to do so. One good example would be management of chronic stress to which an individual might not be active to react.

| Health and well-being use | Description of the wearable device use |
|---|---|
| Diabetes (Fletcher et al. 2010) | Use of skin attached sensors to monitor blood glucose and insulin levels to notify user when the levels change |
| Mental health issues (Fletcher et al. 2010; Piwek et al. 2016) | Use sensors to track physical activity and social interactions to identify potential early-phase mental health cases |
| Motor neuron diseases (Bonato et al. 2003; Rodgers et al. 2015) | Use sensors to track body movement patterns that are common for motor neuron diseases for early identification and support on-time medication |
| Physical activity (Piwek et al. 2016) | Use devices to track the distance traveled and apply gamification and other motivation methods to increase the distance daily |
| Respiratory diseases (Aliverti 2017) | Use multiple sensors to track signals, such as oxygen saturation and pulmonary ventilation, to identify respiratory diseases such as asthma |
| Sleep (Aliverti 2017) | Track amount and quality of sleep with devices that can be worn in the body during the night |
| Surgical recovery (Park & Jayaraman 2003) | Aid recovery from surgeries wearing smart clothing on the area of the body in which the surgery was done to give feedback about healing and infections |
| Weight management (Shuger et al 2014) | Support weight loss by tracking supporting activities such as physical activity |

**Table 1: Examples of health and well-being uses for wearable devices**

## 2.3 Drawbacks or challenges from using wearable devices

Using wearable device might not be enough for the user to change his / her behavior related to improving his / her state of health and well-being. Wartella et al. (2016) conducted a survey for the teens in the United States in which it was found that from all teens, who responded to the survey, 7 percent used wearable digital health device and from that group of 7 percent only 17 percent had changed their behavior based on the feedback from the device. According to the results of the survey the number is only half in comparison to the 34 percent of teens who had changed their behavior after searching health related information online.

One potential reason why the users do not change their behavior when using the device might be lack of quality feedback the device should produce. Dave Evans (2014), Cisco's chief futurist, commented that current devices tell users what they are doing but, at least

not that well right now, how they are doing. For instance, a fitness wrist band tells you that your average heart rate during the workout was 150 beats per minute, but it does not necessarily tell you whether it is good or bad for you. The need for more accessible feedback was shown in other studies as well (Yingling et al. 2014). The manufacturers should invest in the data analytics capabilities of the devices so that the devices could produce better data and give recommended actions. Consumers are more interested in devices which have better big data analytics capabilities in comparison to devices with less capabilities. Thus, investments in that area lead to higher profits for the manufacturers of the devices (Wu et al. 2016). It is also a challenge for the device developers and the health care professionals to organize and interpret the data. Global standards are needed for managing and storing the data. Models are needed to define how the data that the devices record should be processed together with rest of the health data in order to produce valuable health data. (Redmond et al. 2014.) However, the flip side of better data analytics tools is the data privacy risks that using the devices might create.

Istepanian et al (2004) discuss the potential challenges for deployment of wearable devices which need to be resolved and handled. These challenges include technological, economic and social challenges. Technological challenges consist of user acceptance issues such as wearability and battery life of the device. This area also includes how to seamlessly and reliably record the data with the device sensors. Economic challenges include the price for the preventive care done with the device in comparison with the possible cost savings occurring from early detection of medical conditions and standardization protocols for development of the devices. Social challenges include how to handle possible liability issues occurring from lawsuits from using the devices, how the data privacy is being considered, and advantages of social networking of peers and interested parties. The coverage of health care and patient's participation is also one social challenge to be resolved.

Using wearable devices does not necessarily result in health benefits only but there can be drawbacks. Wearable devices can cause multitasking and users having less focus on the work they are currently doing (Norman 2013). Multitasking and constant interruptions during work through digital channels were shown to increase perceived stress and indirect effects on burnout, depression and anxiety (Reinecke et al. 2016). The devices can also result in unintended behaviors such as increased anxiousness in users about their health, or the devices might change users' behavior for worse (Schukat et al. 2016). Negative unintended behavior changes are presented in Table 2. Wearable devices can create privacy risks as the devices might produce, store and utilize health data in a way the user does not approve (Schukat et al. 2016). For instance, if insurance companies get hold of the user's health data, they might price and modify their products in ways which are not favorable for the user as the customer of the company. In addition to modification of user behavior and data privacy risks, wearable devices and their sensors will be exposed to

active and passive attacks due to the technology of the device's connections such as Bluetooth (Schukat et al. 2016). This means, for instance, that criminals could intrude a fitness tracker with GPS positioning service and thus track the users' life.

| Unintended behavior change | Description |
|---|---|
| Subjects change their behavior for the worse. | Users might decrease physical activity if the device is telling they are moving enough. |
| Subjects may become more anxious about their health. | Users might develop anxiety of the topic they are tracking. |
| Subjects may become addicted to the device. | Users may become addicted on self-monitoring beyond what is considered a healthy level of attention to oneself. |
| Subjects may adhere well to a program where adherence was expected to be poor | Users might be too active on health-related activities such as taking drugs than expected and intended by the clinical personnel. |
| Subjects may fortuitously self-diagnose a problem | Users might self-diagnose a disease for themselves though they would not have one (or in positive health behavior change diagnose disease before clinical personnel). |
| Subjects or carers trust the validity of the system too much | Users might trust the sensors of wearable device too much such as the device planned for fall detections sensor devices would always give trustworthy feedback in every fall. |

**Table 2: Unintended behavior changes from using wearable devices (Schukat et al. 2016).**

## 2.4 Wearable device adoption

### *2.4.1 Factors with positive impact on intention to use wearable devices*

To reap the benefits from the wearable devices requires that the users must be willing to use them. Historically larger groups of users have not been willing to adopt using the devices due to the wearibility, security and privacy risks and dislike the technological solution of the devices (Rutherford 2010). Studies have shown that 50 percent of wearable device users stop using the devices after one year (Piwek et al. 2016). According to models formatted based on technology acceptance model (TAM) users are more willing to use wearable devices if the factors that have positive impact on the intention to use the device, often referred as perceived benefits, outweigh the factors with negative impact to use the device which is instead often referred as perceived risks (Li et al. 2016; Nasir & Yurder 2015).

Based on the studied research the factors with positive impact to user's intention to use wearable devices have been set to three categories in this paper. The categories with their factors are described in Figure 1 on the left side of the figure. First category of the factors that have positive impact on the intention to use wearables is perceived benefits from the use of the device. This category consists of perceived informativeness, performance expectancy, perceived usefulness, self-efficacy, perceived vulnerability and perceived severity. Perceived informativeness means that the user needs to feel that the device provides relevant health information (Li et al. 2016; Wieneke et al. 2016). Perceived expectancy refers to the value how much using the device brings effectiveness on performing certain activities such as losing weight (Gao et al. 2015). Perceived usefulness refers generally to users' view how the devices are useful for them (Kim & Shin 2015; Wieneke et al. 2016). Self-efficacy refers to users' capacities to self-monitor and self-manage their physical conditions (Gao et al. 2015; Wieneke et al. 2016). Finally, perceived vulnerability and severity refers to users who more likely using wearable device used if they experience high risk and level of severity of the health condition they might get. (Gao et al. 2015).

The second category of the factors consists of the usability of the wearable devices and the technology which is built in them. The factors in this category are functional congruence, personal innovativeness, hedonic motivations, effort expectancy, perceived ease of use and perceived legislative protection. Functional congruence refers to perceived comfortability and durability of the device (Gao et al. 2015; Li et al. 2016). Personal innovativeness means that the users are more willing to adopt new, state of the art technology (Li et al. 2016). The similar behavior can be seen in recent years as new smart phones have entered the markets. Some people feel need to have the phones immediately. Hedonic motivations refer to enjoyment of using the technology (Gao et al. 2015). Effort expectancy and perceived ease of use refer to users view how easy it is to use the device and the technology (Gao et al. 2015; Kim & Shin 2015). Finally, perceived legislative protection refers to user believing that they are protected from misuse of the data in legislative basis (Li et al. 2016).

The third category consists of the social factors of using wearable devices. This category consists of perceived prestige, social influence, social belonging and social acceptance. Perceived prestige means that the users are more willing to adopt technology if the community where the user acts in, has positive approach to the devices, then the users have bigger chance to adopt using wearable devices (Li et al. 2016). Social influence similarly refers to the level of how socially acceptable and recommended it is to use the wearable devices (Gao et al. 2016). Finally, social belonging and acceptance refer to the value for the user sharing the data in a social group (Wieneke et al. 2016). Related to sharing data in social groups, one way in which social aspects play part in the adoption of wearable device is gamification (Yingling 2014).

The different factors in perceived benefits do not always necessarily act independently. Kim and Shin (2015) investigated the impacts of perceived usefulness, perceived ease of use and cost of smart watches related to the users' intention to use the devices. They discovered that though the users might find the device useful and providing relevant information, the device needs to be easy to use so that it will be used.

### *2.4.2 Factors with negative impact on intention to use wearable devices*

Factors that impact negatively on intention to use wearable devices have been described in Figure 1 in the right side of the figure. Perceived privacy risk is the most notable factor that has negative impact on the user's intention to use wearable devices. With privacy risk it is meant that the user is afraid the data recorded by the wearable device, might end up in the wrong hands. The devices constantly create data throughout the whole day and the data often includes sensitive health data from the user such as daily activity or heart rate. The users however do not necessarily know where the data is being sent to and who uses it (Li et al. 2016; Gao et al. 2015; Wieneke et al. 2016). Though it has been shown that perceived privacy risk has impact on user's intention to use the devices, the device users do not necessarily utilize rationalized decisions making. When weighing the benefits and potential privacy risks, the risks tend to be ignored by the users (Wieneke et al. 2016).

Other perceived risks exist as well in addition to the privacy risk that have negative impact on the intention to use wearable devices. The user might stress perceived performance risk which means that buying the product may not deliver the expected benefits. The user might be faced with financial risk when financial losses might occur for him / her regarding bad purchase decision. The correlation of cost was shown with the intention to use the devices though it was shown to be somewhat small (Kim & Shin 2015). Then there is time risk which occurs from consumer using time to make the device purchase. The user might experience also psychological risk which means negative impact on the peace of mind for the consumer from bad purchase decision. Next there is social risk which means losing reputation in a social group if the device purchase decision looks foolish. Related to social factors, it is important to notice that positive social aspects play also part in the factors with positive impact on the intention to use wearable devices. Then there is physical risk which can occur if the device causes threat to the consumers physical life. (Nasir & Yurder 2015.) The extreme cases might be rare in common devices, such as smart watches, but in medical devices, such as measuring blood glucose, with people with diabetes, errors in the functions of the device might be fatal. Devices might result to physical risk also in smaller scale by causing irritation of skin, for instance.

### *2.4.3 Relation of wearable device type to the factors impacting the intention to use*

Depending on the device type, there exist differences in the adoption of the wearable devices. According to the study by Gao et al. (2015) there are differences in the factors impacting intention to use wearable devices between fitness and medical wearable devices. According to the study fitness wearable device users pay more attention to hedonic motivation, functional congruence, social influence, perceived privacy risk, and perceived vulnerability. Medical wearable users pay more attention on perceived expectancy, effort expectancy, self-efficacy, and perceived severity. This could be interpreted so that if a manufacturer is targeting to create a wearable device purely meant for some health care use cases, then from the privacy point of view it is more important for these devices to be easy to use and provide good feedback rather than be fully privacy proof.

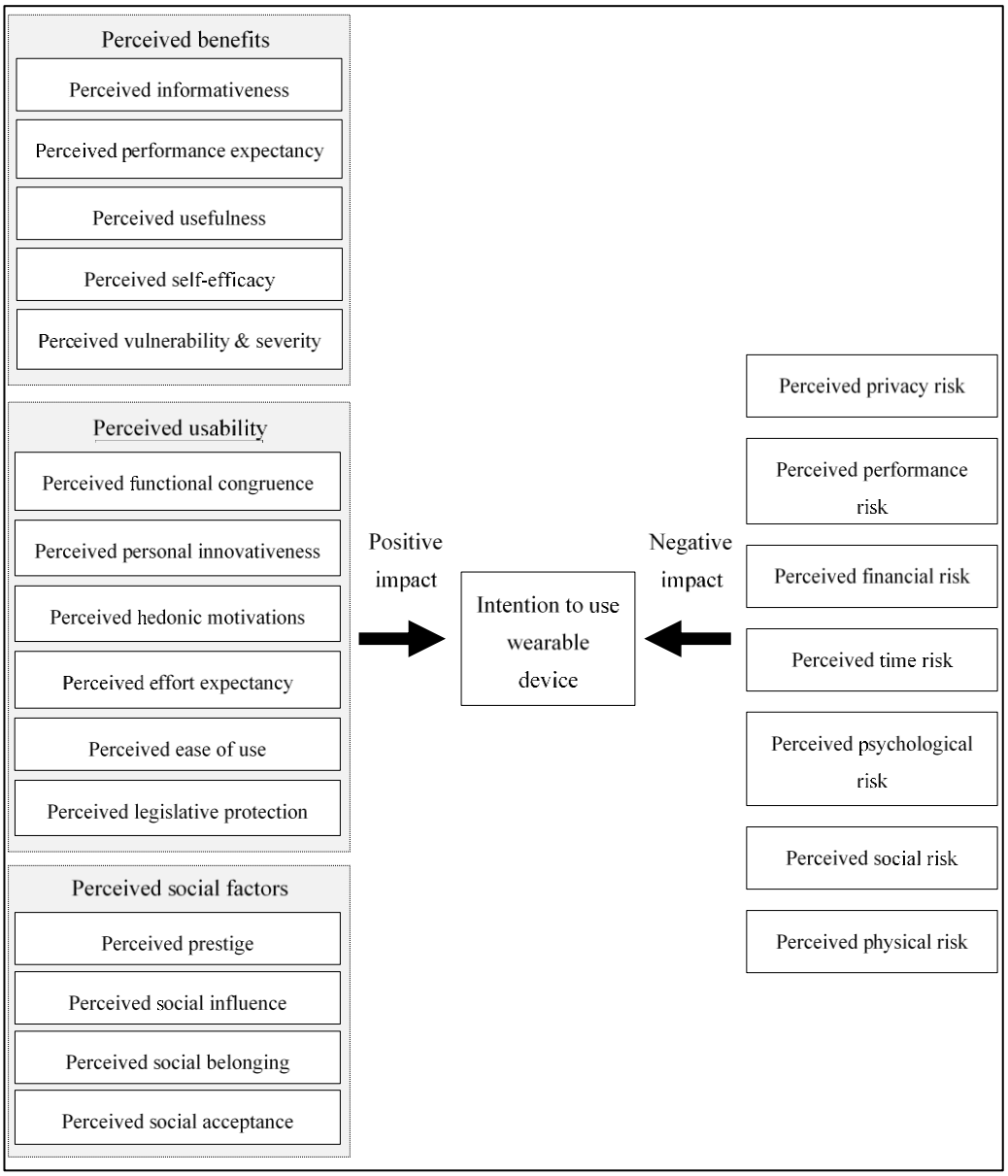


**Figure 1: Factors impacting on intention to use wearable devices**

# 3 UNIVERSITY STUDENT HEALTH AND WELL-BEING IN FINLAND

## 3.1 Overview of university student health care in Finland

In the universities in Finland study some 150 000 active students (Tilastokeskus 2020a). Most of the students are entitled to use the services of the Finnish Student Health Service (FSHS) which currently operates local services in 18 towns and cities across Finland. The services of FSHS include, for instance, monitoring and promotion of students' health, welfare and fitness, provision of health and medical care services, and mental health and substance abuse services. Additionally, the other group of higher degree students in Finland, the students in the universities of applied sciences whose amount is some 140 000, will be allowed to use the services of FSHS starting from 1.1.2021. This will be enabled by a new national legislation, Health Care Act Section 17 (2), which enters into effect on 1.1.2021. This change doubles the number of customers for FSHS. The funding of FSHS undergoes also some changes. In 2020 the funding was based on the health care fee from the university students, funding from Social Insurance Institution of Finland (SII) and on financial aid from the university cities. With the new legislation, 23 percent of the funding will be based on the fees collected from students by SII and rest 77 percent of the funding is based on the governmental funding. (YTHS 2020a.)

Student health care is stipulated in the Health Care Act 1326/2010 in Finland. The legislation defines as goals of the student health care to advance the health, well-being and studying ability of students. The tasks for student health care are to organize of health and nursing services for students including following four different aspects. First, tasks include advancing the safety and healthiness of student community and tracking the progress between every three years. Second, they include advancing and tracking the health, well-being and studying abilities of students which involves two fixed-term health checks for students in high-school and professional schools, and health checks for all students based on individual need. Third task is to organize health and nursing services for all students involving mental health and substance abuse work, advancing sexual health, and dental health. Fourth task for student health care is early identification of the need for special support or examinations and, if necessary, steering towards additional examinations. In addition, outside primary care, which is organized under student care, students are entitled to care of long-term illnesses and special health care according to other acts and decrees. For instance, in mental health care, the responsibility of health care moves to special psychiatric health care in cases in which the situation of the patient is not going for the better. (Tuovila et al. 2020.)

The principles of student health care are defined to be student originating, early intervention and multiarea cooperation. Student originating means that the services need to be arranged so that the special features of students are being considered. Also, the different needs of adult students in comparison to younger students, need to be considered in the services. Early intervention means detection and intervention of health risks or problems for students, student community and student environment. Multiarea cooperation means prerequisite for successful achievement of student health care goals by cooperation between health and nursing care services, student institutions and student organizations. (Tuovila et al. 2020.)

Several different professionals operate in student health care. Main contact points for students are student health care nurses whose main responsibilities include, for instance, health checks and assessment for need of care. Then there are also physicians whose responsibilities include health checks and health care visits. Third, in some departments works nurses who are specialized on mental health and substance abuse work. Their responsibility is mainly to examine potential mental health issues and handle short period therapeutic interventions. In addition to physicians and nurses, there are health care psychologists who take care of psychological assessments and planned short term treatment periods. Student health care involves also three types of dental health professionals. Dental nurses are responsible for assessment need of care and take part in prevention of dental diseases. Dental hygienists manage dental health checks and take part in prevention of diseases. Finally, dental physicians perform dental examinations, and early as well as remedial treatment. (Tuovila et al. 2020.)

One of the most important features of student health care is to promote the students' studying ability. The studying ability is formed of student's own resources such as physical and mental health, the study environment such as the study communities, the study skills such as the study technique, and teaching activities such as tutoring. The different factors of studying ability do not act in vacuum but constantly and dynamically impact on each other. (Tuovila et al. 2020.) The concept and goals of promoting study ability are much consistent with the goals of promoting work ability in workplaces in occupational health (Ilmarinen 2009). Poor management of study ability for that reason reflects to poor work ability when the students move into working life. One of the key activities related to student health care is communication towards students to advocate their health and well-being. The aims of that communication are, for instance, increase the skills of self-care for the students and support changes in lifestyles. Digital channels have grown importance in recent years for this communication towards students. It is important that the information is up-to-date and reliable. (Tuovila et al. 2020.)

Student health care has some specific tasks to prevent professional diseases. Multiple professions include environments and tasks in which employees are exposed to harmful effects regarding health. Students of those professions are also exposed to the same risks

when studying that profession. For instance, noise, dust, vibration to the hands and body, skin diseases and chemicals from constructions sites are among the matters that student may be exposed during their studies. It is the responsibility of student health care to arrange health checks and prevent health issues that might be caused by previous health risks in work and studies. (Tuovila et al. 2020.) The previously mentioned health risks have been shown to cause most of the occupational health related diseases in work life (Yränheikki & Savolainen 2000). Thus, taking preventive actions already during studies and changing the mindset and behavior of students is valuable in the long-term.

## 3.2 Health issues among university students

### *3.2.1 National health survey for university students*

Since year 2000 FSHS has executed holistic health status survey for the university students including students both from academic universities and universities of applied sciences focusing to under 35-year-old students who study for either bachelor's or master's degree. The latest survey was conducted in 2016. The average age of the respondents was 24 years. Based on the results of the survey, 72 percent of students had a long-term or more frequently recurring disease, injury or problem diagnosed by health care professional for which they had received care during the year. The most common issues experienced by the students were tiredness, sleep problems, back issues, skin problems, symptoms of flu, flatulence, and psychological symptoms. One-third of the male respondents reported they experienced some symptom each or almost every day and half of the female respondents reported that they experience some symptom daily or almost daily. Over one-fourth of the students who responded to the survey, was obese. When measured in BMI scale 36 percent of men and 26 percent of women were obese. 40 percent of the student exercised physical fitness only once a week or not at all. (Kunttu et al 2016.)

### *3.2.2 Tiredness and sleep problems*

Based on the results from survey for the university students, 38.5 percent of the student experienced tiredness or powerlessness on weekly basis or more frequently. 27 percent of the students also reported that they experience sleep problems such as problems falling in sleep or waking up during sleep on weekly basis or more frequently. (Kunttu et al 2016.) Sleep deprivation is one of the causes resulting from sleep problems. It can be partial, short or long-term and impact to multiple health issues and cognitive performance.

In addition to cognitive performance, sleep deprivation has impact on the mood of the person. (Pilcher & Huffcutt 1996.) Cognitive performance and human functioning are important for students to effectively learn and apply new information.

Students are exposed to both mental and physical stress during the day. Use of brain during the day will lead to energy depletion as similarly exercising will lead to energy depletion in muscles. Sleep plays a crucial role in restoring those energy levels. When person sleeps, energy levels in brain and in muscles will restore. Also, anabolic processes such as secretion of growth hormone and testosterone, are enhanced and catabolic processes such as secretion of cortisol which plays role in stress, are suppressed. In long run reduced or poor-quality sleep can lead to metabolic diseases, depression, burnout, and mortality. (Åkerstedt et al 2009; Halson 2008.) Thus, considering students health, it is one of the single most important things for the students to get enough and good quality sleep in order to stay healthy and proceed in their studies.

### *3.2.3 Psychological and mental health problems*

Psychological and mental health problems are more common each day among university students. Since 2000 the number of students who report they experience mental health problems tripled. The number of students who reported their mental well-being as moderate or worse was 34 percent of the respondents to the survey. 18.1 and 18.4 percent of the students reported they experience symptoms of depression and anxiety, respectively, on a weekly basis of more frequently. Additionally, 24.2 percent of the students reported they experience tenseness or nervousness weekly or more frequently. Total 44.2 percent of students said they experience psychological symptoms in weekly or more frequent basis. (Kunttu et al 2016.) Mental health issues are complex disorders that have not usually only one cause behind them. Factors that can expose students to mental health issues are, for instance, chronic stress (Chiba et al. 2012), pain (Max et al. 2006) and attitude toward negative and positive events in life (Fresco et al. 2006).

Mental health issues are a problem that transfer from student life to working life also. They are among the main reasons for work disability that causes, for instance, early retirement and increased amount of sickness absences. They increase health related costs through increased visits to health care professionals by patients suffering from mental health problems. (Reho et al. 2020). That is why it is crucial to enable early detection and intervention for people suffering from mental health issues already when they are students and might start to develop symptoms. Early detection is important also for that reason that students themselves might not recognize the symptoms for mental health issues or for issues exposing them to mental health disorders. For instance, in a study in which

stress was studied utilizing students heart rate variability, the students examined were not always able to recognize that they had stress (Metsärinne et al. 2018).

New tools to support the early detection would be needed. It could also be the case that though mental health issues are being reported in health surveys, the students with symptoms might not actively seek help from student health services. When stress symptoms and the related occupational health care visits were studied in occupational health care in Finland, psychological stress was not associated to visits to health care nurses and severe symptoms of stress were not associated to visits to health care physician (Kimanen et al. 2011). Not only there is need for early detection tools, but also for tools that monitor the students' health by either prompting health professional or the student or both to take action.

### *3.2.4 Musculoskeletal problems*

Students are troubled by musculoskeletal problems in similar way to other groups of citizens as well. 32.5 percent of the survey participants reported they experience upper back or neck area issues weekly or more frequently. 16 percent of the respondents said they experience symptoms of back pain weekly or more frequently. The number of survey participants who experienced pain in limbs and joints was 10.5 percent with the same frequency. (Kunttu et al 2016.) Similarly, as with students, in occupational health musculoskeletal issues are together with mental health issues main causes for sickness absences and retirement caused by work disability (Reho et al. 2020).

Back pain is caused often by multiple different factors which also tend to interact with each other. Causes for back pain are, for instance, stooping, sitting and heavy lifting. Back pain could be prevented by, for instance, improving work ergonomics, having safety training and planning for prevention programs for the people. (Troup 1984.) For university students especially sitting and working in unergonomic positions is causing risk for back pain. It is important to have solutions that remind students about risks and motivate to positive changes in their studying environment and ergonomics.

### *3.2.5 Obesity and lack of physical activity*

Obesity increases the risk of multiple other diseases in people. The student survey revealed that 29.5 percent of the students are obese measured in BMI scale. The responses in the survey also revealed that 39.6 percent of the students did physical exercise only once or less than once a week. The physical exercise was defined in the survey as activity

of at least 30 minutes at a time so that it caused at least light sweat and out of breath. (Kunttu et al 2016.)

Obesity related disorders include type 2 diabetes, hypertension and dyslipidemia. The main reasons for student obesity are amount and quality of food that students consume, and lack of physical exercise and other activity. Genetics play also important role in that one person gains weight easier than the other. (Sparkling 2007.) In addition to directly health related issues, obesity might have some indirect effects as well concerning students. Research shows that obesity is associated with declined levels of school performance (Taras & Potts-Datema 2005).

Lack of physical activity is proved to result in multiple health disorders and significant avoidable health care costs (Colditz 1999). It can lead to, for instance, poor metabolic health, obesity, musculoskeletal disorders and poor quality of sleep (Tammelin 2009). There are multiple different recommendations of physical exercise, how much to do it in a week and what kind of exercise would be beneficial to do. There are also different recommendations for light exercise and for heavy exercise. One common recommendation in Finland for adult citizens comes from UKK-institute which acts as the center for health promotion research. The institute recommends having moderate exercise at least 2 hours and 30 minutes in a week or heavy exercise of 1 hour and 15 minutes (UKK-institute 2020). It is important to find new tools to motivate students to exercise and in order to prevent health issues on escalating because of ignorance for this part of health.

## 3.3 Utilization of technology in university student health and well-being

Finnish student health care saw some steps towards health care digitalization and utilization of health care tools as FSHS launched its self-service portal in 2016 for students to interact more actively with FSHS through digital channels (YTHS 2020b). With launching the portal FSHS was targeting to have from 50 to 80 percent of the student contacts through digital channels. This would save time for health care professionals to focus on cases needing more acute response and the focus area would be moved from treating diseases to preventing diseases. (HMV Public Partner 2015.) In the survey for health of university students 2016, over half of the students who responded the survey said they had a mobile app related to health or well-being and utilization of digital channels had replaced face to face visits in FSHS locations.

One of the most common ways of use of health care technology among students is through mobile health and fitness applications. Purely on Apple App Store, there were over 45 000 mobile health applications in 2020 which is not even including the number of fitness or well-being applications (Statista 2020). The options for students to select and

utilize mobile actions for health care and fitness tracking are therefore extensive. The use of mobile health care applications for health improvement is studied area in various cases with university students outside Finland also. Gowin et al. (2015) studied the use of mobile health and fitness apps for weight loss. Their findings were that students felt that using smartphone applications to meet their goals of developing exercise routine or improving their eating habits was helpful. Their findings included also recommendation to focus on ease of use with the applications and include gamification as one of the features of the applications. The use of mobile health applications among university students was shown to result in improved eating behavior, feelings of being healthier, having better health monitoring and having more motivation to practice exercise when comparing health behaviors between health applications users and non-users (Sarcona et al. 2017). Studies among university students revealed direct factors, such as experiences of use of the applications, and indirect factors such as applications summaries, evaluations and experiences from previous users, that impact the selection of mobile health application (Choi & Stvilia 2014). Finally, research showed beneficial effects of mindfulness application use to ease stress and improve self-compassion and mindfulness (Huberty et al. 2019). Multiple studies focused as well on the factors impacting adoption, intention to use, and user perceptions about mobile health and fitness apps (Yuan et al. 2015; Haluza & Wernhart 2019; Warnick et al. 2019; Kinney 2017; Peng et al. 2016).

In addition to digital visits and mobile health and fitness applications there is still one dominant digital health and well-being channel among university students. In a study among French university students almost 95 percent of the students reported they had searched for web-based health information within a year. Most of the searches focused on nutrition, pain and illnesses, and mental health issues. In comparison about only half of the students reported they used mobile applications for health, physical activity or well-being. (Montagni et al. 2018.) Similarly, 83 percent of the students in Finland in year 2018 reported that they had searched information related to diseases, nutrition, or health within last three months (Tilastokeskus 2018).

# 4 RESEARCH METHODOLOGY

## 4.1 Research process

The overall topic for this research was formulated to be wearable devices and their impacts to health and well-being based on the authors interest to smart watches and their health impacts. The initiating question concerned if smart watches, and other wearable devices had positive or negative impact on the user's health.

When the overall topic was decided, the work continued with extensive literature review on wearable devices in health and well-being. The research questions were formulated, and study populations selected based on two findings made during the literature review. First, there exists only a little research on clinically proven benefits of wearable devices. Some studies about perceived benefits and perceived challenges are done. Additionally, case studies are done related to potential use cases for using wearable devices in treating and monitoring different types of health issues. For this reason, it was decided that the research should try to answer to questions whether the users felt the devices had positive or negative impacts on health and well-being. Additional interest was on the kinds of health and well-being benefits, drawbacks or challenges use of the devices might provide.

The second thing that was found out from the research was that, as the technology allows multiple different uses for health and well-being, there a was need to limit the research to certain study population. For instance, uses, motivation towards intention to use, and device design factors can be different for different groups such as for elderly and for adolescents. Finland was selected to be the target location area due to it being most convenient as the research was conducted in Finland. There also exist multiple health care sectors from private sector to public one in Finland. Initial idea was to study occupational health but as there exists recent holistic study on the use of wearable technology in occupational health (Rauttola et al. 2019,) another group needed to be selected. A review on wearable device use in Finnish health and well-being was made and it was found out that higher degree students, including both university and university of applied science students, and student health care was neglected area of study in the field of wearables in health care and well-being. Additionally, as higher degree students form somewhat homogenous group considering, for instance, their age and educational background, the possibility to generalize results makes the group interesting to study. Finally, higher degree students in Finland in the universities and universities of applied sciences in Turku was initially set as the target group due to authors existing relationships to the Turku area universities which helped the data collection. However, during the data collection phase, the initial study population of all higher degree students in Turku area was dismissed due

to inability to collect empiric data from the students of the universities of applied sciences who are part of all higher degree students in Turku. Thus, the study population was reformulated to consist of the university students in Turku, which included students in the University of Turku and Åbo Akademi University. Next as the research study population was identified and set to be university students in Turku, an extensive literature review was conducted related to university student health and well-being with focus on emerging health trends and information technology use. The research questions were supplemented from the findings related to university student health and well-being literature review.

When the research questions were formulated based on the literature reviews on wearable devices in health and well-being and use of wearable devices in Finnish health and well-being, the next step was to select the method to collect the empiric data for the research. As the amount of literature related to clinically proven benefits and use of wearable devices was limited, no hypotheses, that would be tested in the research, were created based on the literature review. It was decided to study the phenomenon among Turku university students more generally. The research population consisted of the 20 000 students in the University of Turku (Turun Yliopisto 2020) and 5 500 students in Åbo Akademi (Åbo Akademi 2020) making the total population size 25 500. There existed few potential formats how the actual data could be collected such as interviews, surveys by mail or in web or by following the study group on-site. The data collection method was selected to be web-based survey. Having the survey in internet allowed to distribute the survey to as many students as possible in time- and cost-effective manner, and to process the both quantitative and qualitative data in effective manner. Additionally, as this research was being written, the in-person meetings were limited due to covid-19 pandemic. Due to the size of the population it was decided that a sample representing the population was collected with a survey instead of trying to collect the answers from the whole population.

It was chosen that the survey was conducted with a mixed methods research approach. Mixed methods have been described as the third methodology after quantitative and qualitative focused research methods (Tashakkori & Teddlie 1998). In mixed methods the data was able to be collected concurrently or sequentially pending on the priority the quantitative data has been given in comparison to the qualitative data (Creswell et al. 2003). Creswell and Clark (2007) identify four main types for mixed method research, which are triangulation designs, embedded designs, explanatory designs, and exploratory designs. First, they present triangulation design which involves collecting data same time for both quantitative and qualitative questions. They describe the two methodologies in triangulation used to offset shortcomings in each other. According to them, the integration of results from these two methodologies allows to study towards complex phenomena. Second, they define embedded designs which feature the second data taking supplementary role for the other. They state that the criteria of the study are that the secondary data

is not meaningful without the primary data. They give example that in embedded designs quantitative questions could be supplemented with open ended questions to better understand the nature of the answers. Third, they offer explanatory designs which is characterized by initial quantitative phase followed by qualitive section which explain the results from the previous. Finally, as fourth they suggest method of exploratory designs that involves as first step a qualitative section which is then validated by quantitative phase. They state that the goal in this design is to first identify important factors around the research question and then to test to factors in larger sample.

The method that was selected for this study from mixed methods was explanatory design methods as it was found to be most suitable. The features of explanatory designs were reflected in the survey structure. The questions were built in the surveys in groups which started first with quantitative section, such as if user had experienced benefits from use of wearable devices with possibility to answer yes or no. The first question was then followed by additional question or questions which combined quantitative and qualitive features trying to explain and further understanding related to the first question. Examples include questions such as what kind of benefits the user had experienced with set of preselected answers formulated based on literature review and option to give answer using survey respondents' own words. In that way survey answers were not limited to the discovered factors from literature, but the survey in qualitive manner could provide new insights to the topic. The survey structure and questions are discussed in more detail in chapter 4.2. Use of mixed methods made sure that the topic around use of wearables in health care and well-being by university students was answered and discovered as extensive way as possible.

After the method to collect the empiric data was selected to be mixed methods approach explanatory designs and web-based survey, the survey questions were created, tested and finalized. The survey was distributed as online link to student associations in Turku universities and the respondents were given until September 30$^{th}$, 2020 to answer to the survey. More details about the survey distribution and validity are discussed in chapter 4.3. When the survey response time ended, the results of the survey were exported from the Webropol survey tool and processed with Microsoft Excel software. The results were then analyzed and written down, and the research questions were answered based on the results from the survey including reflections to literature. Additionally, other interesting and surprising findings from the research were discussed. Finally, conclusions of the research were made, limitations were identified, and future potential study cases were recommended at the end of the research. Also, 2 gift cards were drawn and sent to the winners' emails among the survey respondents who wanted to take part to the gift card draw.

## 4.2 Survey structure and questions

The survey questions were formatted based on the topics found in the literature review, and similar survey by Rauttola et al (2019) which was performed with occupational health care professionals was used as starting point for formulating the survey questions. The survey included multiselect questions which had pre-determined answer options. In addition, 7 of the questions included possibility to answer with open ended answers if the predetermined selections of possible answers were not suitable.

First group of questions consisted of background questions which were *age*, *the university or university of applied sciences the student studied in* and *start year for the studies*. The age information was used to confirm the age group of the students who responded as there can be students in universities from all ages starting from recently graduated 18-year-old high schoolers to over 65-year-old pensioners. Among Finnish adolescents aged 11-15 years old only 17 percent said they own wearable heart rate monitor or sport watch, one of the most common types of wearable devices (Ng et al 2017). In comparison in Finnish occupational health, 57 percent of workplaces reported that they use wearable devices in health care and well-being purposes (Rauttola et al. 2019). It is valuable information to discover at what age group use wearable technology will be more common.

The second group of questions was targeted to discover how common the use of wearable technology was among the university students and what kind of devices were being used. Also, if the survey respondent did not use wearable devices then the additional point was to discover why they did not use them. The aim for this question was to understand, if the reasons why students did not use the devices, reflected the theory for adoption of wearable devices, and the factors with negative impact on intention to use presented in chapter 2.4.3. The first question in this group was following: *Have you used wearable technology within last 12 months and how actively you use it?* User were able to select between answers *I have not used, I use yearly, I use monthly, I use weekly and I use daily*. If the respondent of the survey selected the first option, *I have not used*, then the following question was shown to the user and no other questions were shown to the person responding to survey: *Why have you not used the device(s)?* If the user selected some other option in the question, then following next questions were shown in this question group: *What is the monitored indicator which the device(s) collect data about?* and *What factors had impact in your selection of the device(s) in comparison to potential competitor device(s)?*

The third group of questions was shown to those survey respondents who reported they used wearable devices in the previous category of questions. The questions in this group aimed to discover whether users experienced and what kind of health and well-being benefits users experienced from use of the wearable devices. The questions were: *Have you experienced health and well-being benefits from use of the device(s)?* and *What kind of health and well-being benefits have you experienced from use of the device(s)?* The

response options to the kinds of health and well-being benefits were derived from literature discussed in chapters 2.4.1 regarding factors with positive impact on intention to use wearable devices and 2.2 regarding uses and benefits from wearable devices. Additionally, the presented health issues among the university students in chapter 3.2 were reflected in the selection of answers in order to discover if wearable technology could support the treatment or monitoring for these health care issues. Next aim was to discover whether the users experienced and what kind of drawbacks or challenges they had experienced from the use of wearable devices. The questions were following: *Have you experienced drawbacks or challenges from use of the device(s)?* and *What kind of drawback or challenges have you experienced from use of the device(s)?* The selection of answers was formulated based on literature reviewed in chapter 2.3 related to drawbacks or challenges of using wearable devices and 2.4.2 related to factors with negative impact on intention to use wearable devices.

The fourth group of questions aimed to discover whether the students used wearable devices and they shared the data produced by the devices with FSHS or some other student health organization. The questions were: *Have you used the device(s) in cooperation with health care professional (for instance FSHS or other student health) or shared the data the devices have produced with health care professionals?* and *How have you used the device(s) in cooperation with health care professional (for instance FSHS or other student health) or shared the data the devices have produced with health care professionals?* This is important point to understand as wearable devices could supplement many ways current health care monitoring treatment and allow unobtrusive personal health care monitoring in non-clinical environments (Bonato 2005; Pantelopoulos & Bourbakis 2009).

Final piece of the survey for all the respondents of the survey was to ask if they wanted to take part in the gift card draws among the respondents. The respondents were asked to confirm following; *I want to participate to the draw of the gift cards which will be done after the time period to answer the survey has ended*. If they decided to participate in the draw, they were asked to fill in their email-address for contact in case if they would win the draw.

## 4.3 Survey distribution and validity

The survey was distributed as open online link among Turku university students through student associations operating in the University of Turku and Åbo Akademi University. As mentioned before, the original plan of the research was to distribute the survey additionally to students of the universities of applied sciences in Turku but the contact persons in student associations did not either reply or declined to distribute the questionnaire.

Thus, the students in the universities of applied sciences were limited out from the research study population. The university student associations in Turku were contacted using Facebook and by email. From the 41 contacted student associations in the University of Turku 26 which means 63 percent accepted to distribute the survey to their members. From the 25 contacted student associations in Åbo Akademi University 5 which means 20 percent accepted to distribute the survey to their members. As the University of Turku is mainly a Finnish speaking university, Åbo Akademi a Swedish speaking university and both universities have also non-Finnish or Swedish speaking students, versions of the survey and its descriptions were made in Finnish, Swedish and English. In this way the questions and selection of answers were to be understood by the survey respondents as easy as possible and the misunderstandings were minimized from the survey language perspective.

The survey questions and structure were tested with the thesis supervisor from the University of Turku and with peer students including users and non-users of wearable devices from the University of Turku. This was done to ensure that the questions and response options were easy to understand and unambiguous, that the survey response flow worked well, and response time was sufficient. All questions related to personal data were limited out of the survey in order to comply with the health care and personal data related to data privacy and security regulations. In order to achieve higher response ratio and larger sample, two €50 gift cards were drawn after the survey response time ended on September 30$^{th}$, 2020 among survey respondents who wanted to take part in the draw. The gift cards were funded by the author of this research. The response selections, such as whether the person used wearable devices or not, did not impact on the results of the gift card draw. The collected emails to contact the draw winners were not used in the study in any other manner except for contacting the winners of the draw.

# 5 SURVEY RESULTS

## 5.1 Survey reliability and background info

Total number of survey respondents was 331 persons. Due to the format of survey distribution by student associations forwarding the survey, it could not be counted how many students received and saw the survey link. 81 percent of the respondents studied in the University of Turku and 19 percent studied in Åbo Akademi University. There was one respondent who studied in Turku University of Applied Sciences and one respondent who did not mention the university. As no contacts were made or survey distribution acceptance was received from student associations in the universities of applied sciences in Turku, no other answers were received from students in those organizations. Research focused for that reason on the university students in Turku instead of all higher degree students in Turku. The responses from the person who studied in the Turku University of Applied Sciences and from the person who did not state the university were removed from the results, resulting to sample size of 329 persons in the research. There studied about 20 000 students in the University of Turku (Turun Yliopisto 2020) and about 5 500 students in Åbo Akademi University (Åbo Akademi 2020) making the total research population amount some 25 500. The sample thus consisted of some 1.3 percent, 329/25 500, of all the university students in Turku. The ratio of responses in the sample reflected the numbers of students of the two universities in Turku in comparison to the study population. From total number of the university students in Turku, about 80 percent, 20 000/25 500, studied in the University of Turku, and 20 percent, 5 500/25 500, in Åbo Akademi University. Thus, the sample percentages 81 percent and 19 percent, are quite aligned with the population ratios of university student's distribution between the two organizations which were 80 and 20 percentages. As the focus on this research was to study the phenomenon of wearable devices in health and well-being in extensive manner utilizing both quantitative and qualitive elements, the statistical significance of the research was not calculated.

The age groups of survey respondents are shown in Table 3 in which the groups have been divided by the university of the student. The largest age group among the respondents was 20-24-year-old with 65 percent of the responses. The second largest group was 25-29-year-old with 19 percent of responses with under 20-year-old following with 13 percent as third largest group. The fourth biggest group was over 35-year-old with 2 percent of the responses and smallest group was 30-34-year-old with 1 percent of all responses. The results mean that most of the respondents were under 30-year-old.

| | University of Turku students | | Åbo Akademi University students | | Total | |
|---|---|---|---|---|---|---|
| | n | Percent | n | Percent | n | Percent |
| under 20 years | 34 | 13 % | 8 | 13 % | 42 | 13 % |
| 20-24 years | 172 | 65 % | 43 | 68 % | 215 | 65 % |
| 25-29 years | 53 | 20 % | 10 | 16 % | 63 | 19 % |
| 30-34 years | 2 | 1 % | 1 | 2 % | 3 | 1 % |
| over 35 years | 5 | 2 % | 1 | 2 % | 6 | 2 % |
| Total | 266 | 100 % | 63 | 100 % | 329 | 100 % |

**Table 3: Age groups per university**

As last background information start year for the studies was requested from the respondents. The results are shown in Table 4. The response activity correlated with the start year of the studies as students who frequently started their studies were more active on responding the survey. The largest start year group for the respondents was 2020 with 23 percent of the respondents. It was followed by 2019 with 20 percent, 2018 with 17 percent, 2017 and 2016 with 11 percent, 2015 with 10 percent, 2014 and 2013 with 3 percent, and 2012 or before with 2 percent of the respondents. No gender, field of study information or other socioeconomical information were collected for this study, so it is not known in this research, for instance, what was the percentage of male and female among the respondents and what topics did the survey respondents study in the universities. Overall distribution of survey responses in different age groups shown in Table 3 and in different start years for studies shown in Table 4 is quite similar between the University of Turku and Åbo Akademi University which improves the reliability of the survey results.

| | University of Turku students | | Åbo Akademi University students | | Total | |
|---|---|---|---|---|---|---|
| | n | Percent | n | Percent | n | Percent |
| 2012 or before | 5 | 2 % | 0 | 0 % | 5 | 2 % |
| 2013 | 8 | 3 % | 3 | 5 % | 11 | 3 % |
| 2014 | 7 | 3 % | 2 | 3 % | 9 | 3 % |
| 2015 | 26 | 10 % | 8 | 13 % | 34 | 10 % |
| 2016 | 29 | 11 % | 8 | 13 % | 37 | 11 % |
| 2017 | 28 | 11 % | 7 | 11 % | 35 | 11 % |
| 2018 | 46 | 17 % | 11 | 17 % | 57 | 17 % |
| 2019 | 53 | 20 % | 11 | 17 % | 64 | 19 % |
| 2020 | 64 | 24 % | 13 | 21 % | 77 | 23 % |
| Total | 266 | 100 % | 63 | 100 % | 329 | 100 % |

**Table 4: Start year for studies per university**

## 5.2 Use of wearable devices and device types

In Figure 2 it is shown whether the survey respondents used wearable devices within last 12 months and if they did, how actively they used it. 40 percent of the respondents stated they did not use wearable devices and 60 percent used devices within last 12 months. 38 percent of the respondents reported they used the device daily, 11 percent weekly, 6 percent used monthly and 5 percent yearly.

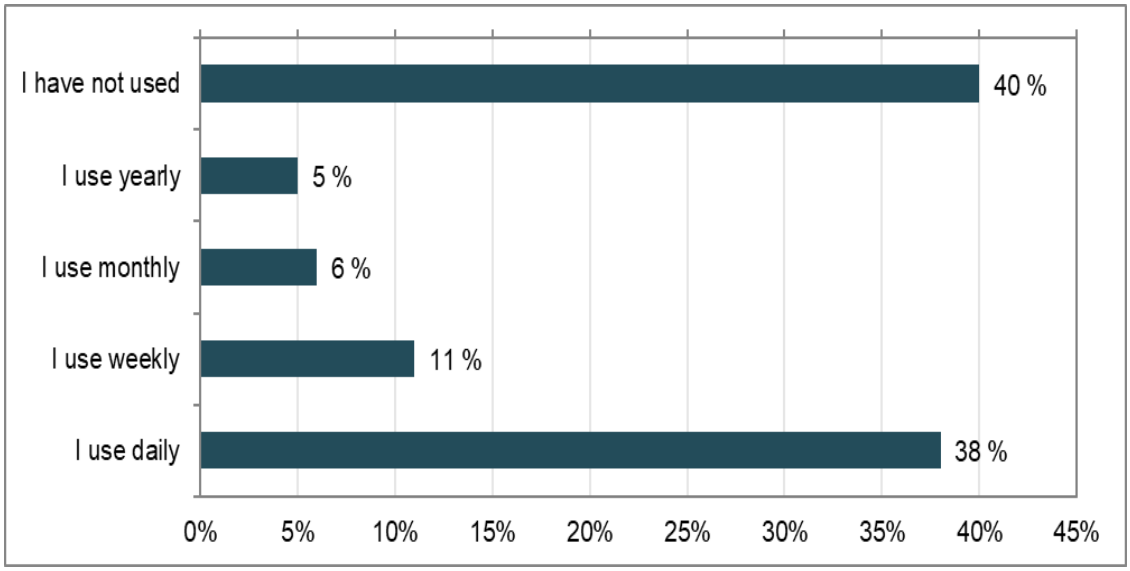


**Figure 2: Have you used wearable technology within last 12 months and how actively you use it?**

Those people who responded that they used wearable devices at least yearly in the previous question, were requested to name the device type that they used. The results are shown in Figure 3. The most common device type was activity tracker, movement tracker or pedometer. 62 percent of the respondents who used wearable devices said they had this feature in their device. Second most common type was smart watch which was reported by 56 percent of wearable users. It was followed by heart rate monitor device type with 38 percent users stating they used this type of device. Next, 12 percent of wearable users said they used smart headphones which was the fourth largest type group. The fifth largest type group was shared by general category of wearable sensors or probe in which the specific device type was not stated, and by smart jewelry to which 4 percent of wearable users stated they used either of the mentioned device types. Few respondents stated they used blood glucose meters, skin implants or sensors, hearing aids or smart belts. In the category of other, in which respondents were able to tell about other types of devices they used, following types of devices were reported; "*insulin pump", "sport watch"* and *"smart shoes"*. The only categories with no responses were electrodes and associated collectors, smart glasses, and smart clothing (with exception shoes being mentioned once in the other category).

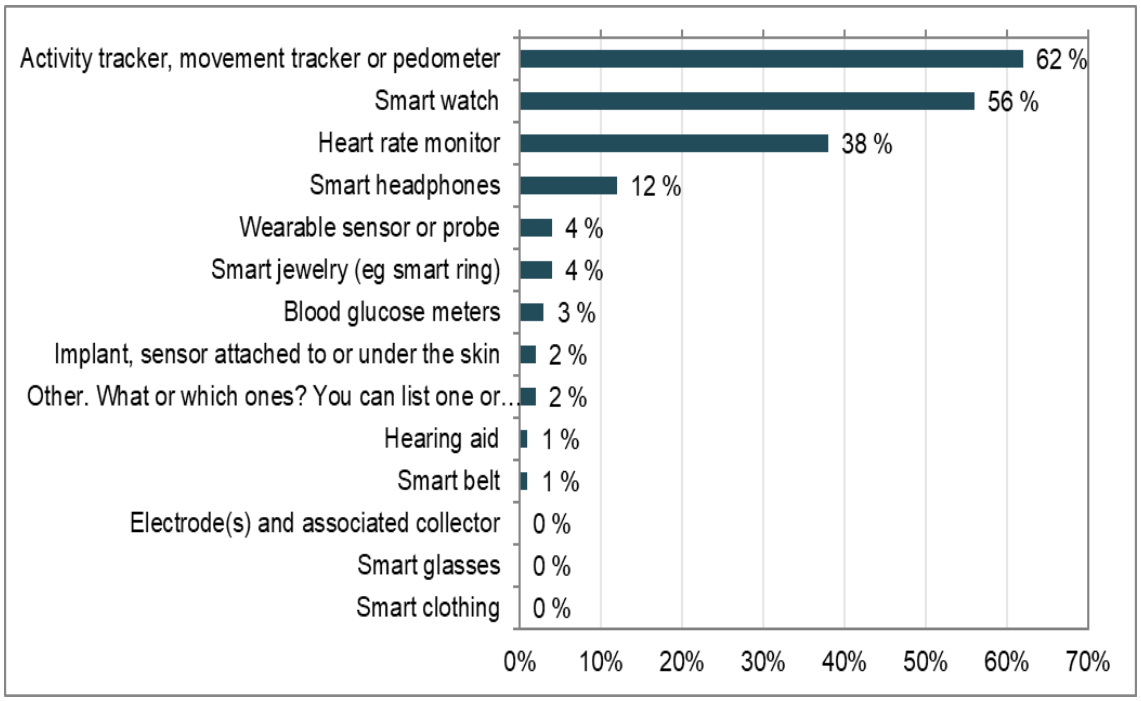


**Figure 3: What kind of device(s) have you used?**

For those users who used wearable devices the survey continued with request to identify what were the indicators the devices monitored. The results are shown in Figure 4. 89 and 88 percent of the users stated their devices monitored heart rate and heart rate variability, and body movement and exercising, respectively. The results correlate with the most common device types used in the Figure 4 with activity trackers, smart watchers and heart monitors being in the top 3 most common device types. Next three most common monitored indicators were amount of sleep, location and quality of sleep reported by 67, 65 and 60 percent of wearable users. Monitored indicators that made to the top 10 included also altitude and its variation, physical recovery, breathing, stress, and muscle activity and function. Indicators, that less than 10 percent of respondents reported their devices monitored, included heart function, mental recovery, body position and ergonomics, blood sugar, brain function, blood pressure, and environmental sounds. None of the users reported that their wearable monitored environmental chemicals. Additionally, no responses in the other category were given.

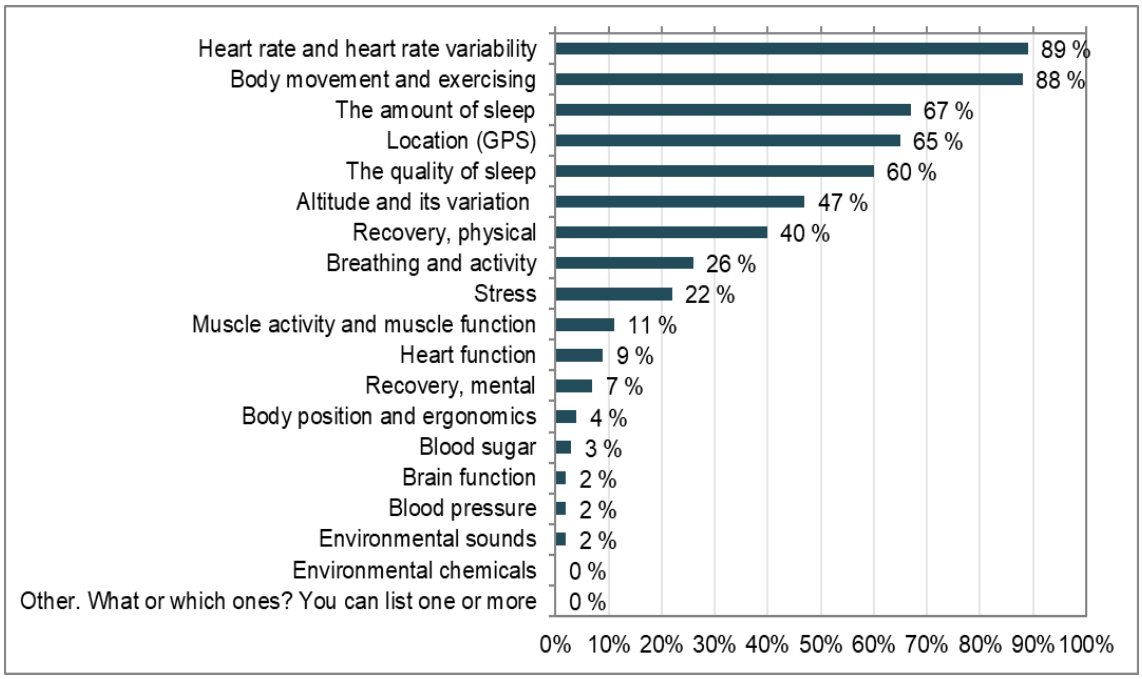


**Figure 4: What is the monitored indicator which the device(s) collect data about?**

Finally, the users of wearable devices were asked why they chose the devices they used in comparison to the competing devices. The results are shown in in Figure 5. The number one reason was the price of the device which was selected by 69 percent of wearable users. Almost equally important reason was the device appearance which was selected by 67 percent of the respondents. 59 percent stated as reason of choice the device features related to health and well-being, and 58 percent the usability and comfort of use of the device. As next most common reason almost half, 48 percent, of the respondents said the ratings from other users impacted the selection of the device. 30 percent of the wearable users stated their selection was impacted by the device data handling and display of data in external application. 16 percent stated that social factors such as a friend having a similar device, impacted on the device selection. Only 9 percent stated that the device data privacy and security features had impact on the choice of the device. Also, multiple open answers were given in the other category in which 11 percent of wearable users stated to arguments that impacted the device selection. Multiple users mentioned *"gift"* being the reason for having the device, so they did not do the selection of the product themselves. Users also mentioned "*domesticity*" as one important reason for device selection. Other mentioned reasons included *"water resistance", "compatibility with other devices", "battery life", "versatile features"*. One of the respondents mentioned that the product *"ethics"* impacted the selection and one respondent stated that *"selection was made by health care units product availability"* which might be more common case with medical devices.

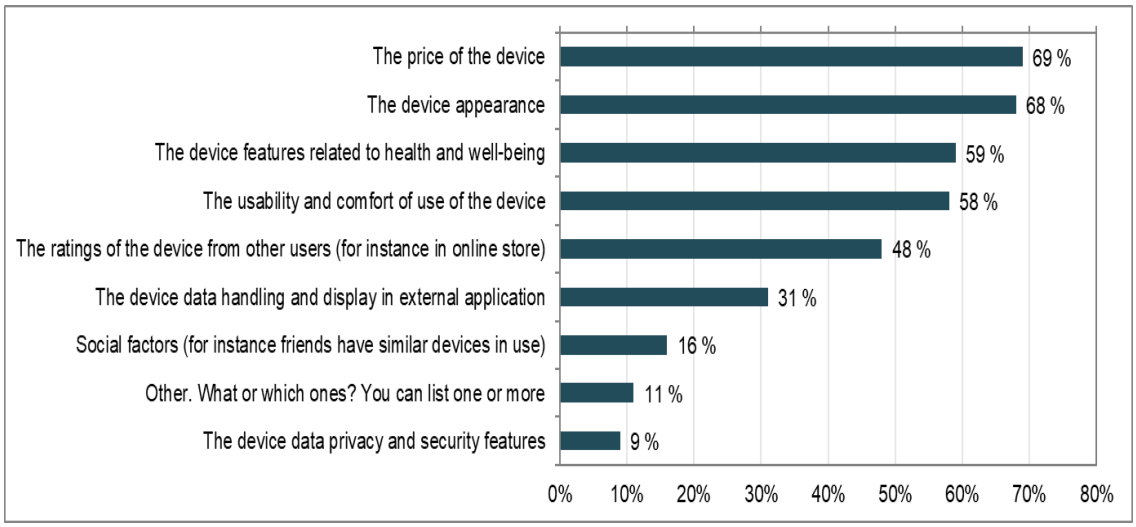


**Figure 5: What factors had impact in your selection of the device(s) in comparison to potential competitor device(s)?**

Those survey respondents who responded that they did not use wearable devices, were requested to give information why they did not use them. The results are shown in Figure 6. The most common reason was that the respondents were interested in acquiring the device but prioritized some other purchases above wearable device. It was mentioned as a reason by 55 percent of the non-users. The second most common reason selected by 38 percent of the non-users was that the respondents did not believe the devices being useful for them. The third most common reason stated by 32 percent of respondents, bit overlapping with the first one, was that the respondents were interested in using the device but did not have the funds for purchase. The fourth reason, selected by 12 percent of respondents, for not using wearable devices, was that the respondents did not want to use devices due to the threat of data privacy and/or security problems. The fifth and sixth most common reasons, reported by 10 and 5 percent of the respondents, were related to the features of the wearable devices. First, 10 percent of non-users said they are not interested to use the device due to the appearance of the device. Then, 5 percent responded that they are not interested to use the device due to poor usability of the device. Additionally, 8 percent of the non-users gave reasons in their own words for not using the devices in the other category. Most common type of open answer was that the users did not have need for the devices. Examples included answers such as *"I do not have the need for the device"*, *"I have not experienced need for the device"*, and *"I am not just interested in the device but not for the predetermined reasons"*. The second type of open answer was the stress that the device could cause. The answers included *"the device might be on the way, and taking care of the device would be additional worry to life"*, *"I do not want to live in symbiosis with the device but keep some kind of feeling of freedom"*, and *"the less devices I have more stress free life I have"*. The third category of answers was that the users did not even consider on the purchase of the device with answers such as *"I have not considered purchase decision enough"*, and *"I have not thought about the matter that*

*much and I aim for reasonable spending"*. Some additional reasons for not using wearables were *"I am afraid of the device radiating"*, and *"I am against for tracking and monitoring of everything, which easily leads to operating in performance mode"*.

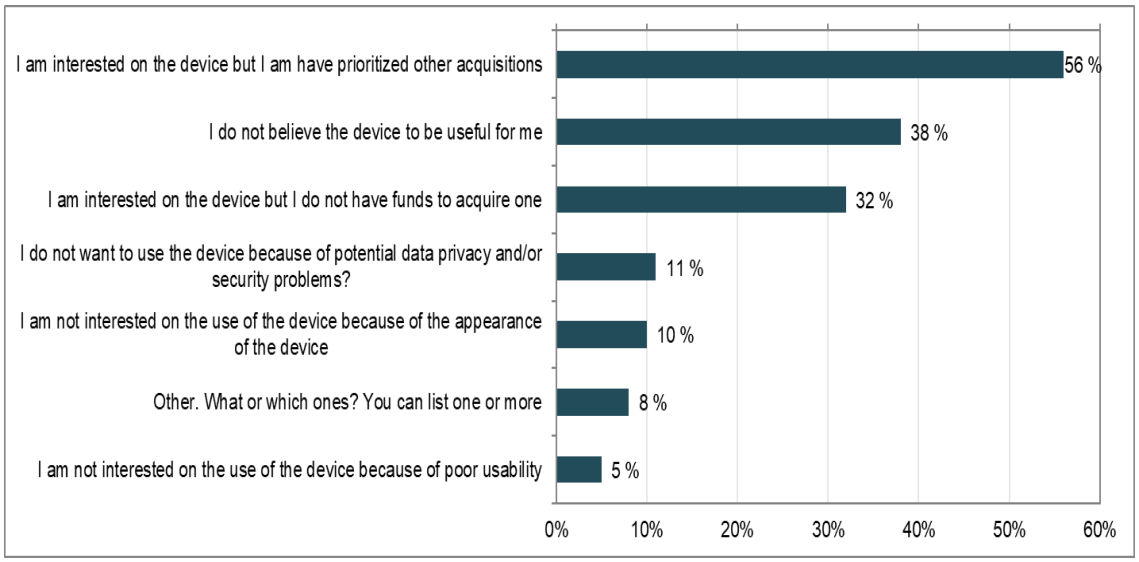


**Figure 6: Why have you not used the device(s)?**

## 5.3 Benefits, drawbacks or challenges of wearable devices

The remaining questions and data concerns only those 60 percent of the survey respondents who reported they used wearable devices withing last 12 months. The respondents were asked if they experienced health and well-being benefits from use of the wearable devices. 96 percent of the respondents answered they experienced benefits and 4 percent stated they did not. The 96 percent of the users were asked to name what kind of health and well-being benefits they experienced. The results are shown in Figure 7. The first two most common benefits were related to increased amounts of physical activity. First, the most usual experienced benefit selected by 73 percent of the wearable users was that the device supported the users to increase daily activity. It was followed by device supporting users to increase amount of fitness exercise responded by 61 percent of the users. Reported by 52 percent of the users, the third most common benefit which the users experienced, was the device giving users additional information about their health and well-being. Over 20 percent of the respondents stated that the benefits they experienced included also the device supporting improvement of sleep, support of physical and mental recovery and support of weight management. Some users also mentioned they gained benefits related to medical conditions, such as the device helping to monitor and/or treat a disease which was reported by 5 percent of users. Devices also helped hearing with one percent of the users. Few users experienced benefits also related to support in stress

management, support in healthier diet, support in focusing, increase of social activities, and support in substance use management. In the category of other in which the users were able to give answers in their own words, all answers were related to the wearable device giving information about the sports performance. Examples of the answers were *"the device has helped me to do workouts in the correct workouts zones and maximizes the workout benefits"*, *"the device has increased my overall knowledge about the exercise"*, *"the device functions as a timer for my exercise"*, and *"the device gives me feedback about the quality of the exercise"*.

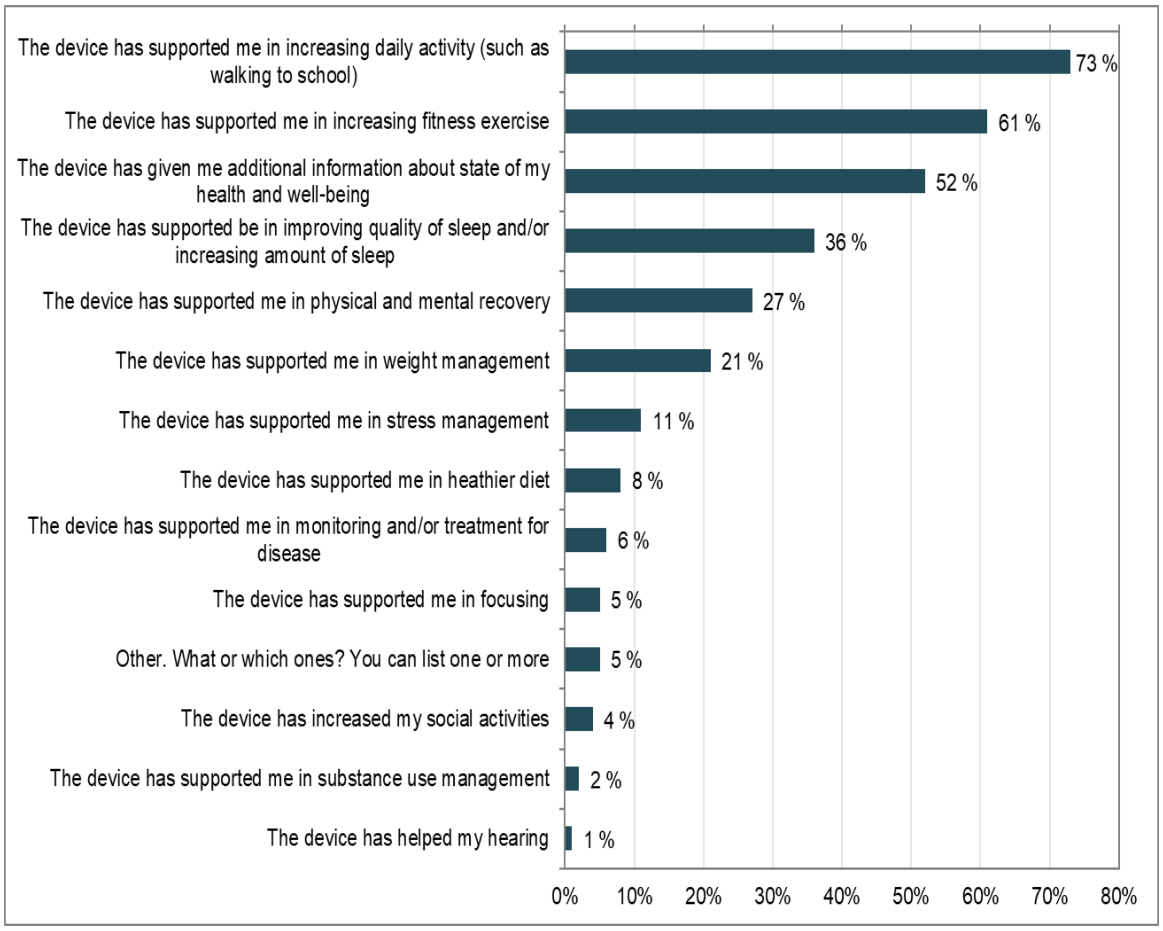


**Figure 7: What kind of health and well-being benefits have you experienced from use of the device(s)?**

Respondents were next asked to tell if they experienced drawbacks or challenges from use of the devices. 34 percent of the respondents stated they experienced drawbacks or challenges and 66 percent stated they did not. The 34 percent of those who experienced drawbacks or challenges were asked to name them. Figure 8 shows the results for this question. Unlike in other questions, none of the options in the answers were reported by over 50 percent of the respondents. Additionally, the other category where the users were able to give answers in their own words, was selected by 20 percent of the respondents. The most common drawback or challenge was that the device did not measure accurately

signals the users body produced which was reported by 42 percent of respondents who experienced drawbacks or challenges. Next most common drawback or challenge was that the device caused stress which was reported by 35 percent of the respondents. 26 percent of the respondents reported that the device felt uncomfortable and 22 percent reported that the device caused addiction. 12 percent of the respondents reported that use of the device resulted in over exercising. Drawbacks or challenges reported by less than 10 percent of the respondents included that the users did not receive value for money, the data privacy and security concerned the user, the data and the recommendations produced by the devices were useless, user did not like the appearance of the device, or the usability of the device was not good. Among the answers given by the users in their own words in the other category there was one single highlighted category which was that the devices caused rash or other skin problems. The examples of answers were *"the wristband has causes rash"*, *"the smartwatch allergizes my skin a bit and I need to have pauses from using the device"*, and *"I get skin rash from the plastic of the device"*. The next common type of answers given in own words was related to charging and battery of the device. Answers included *"charging is problematic in a device that is worn 24 hours in a day"*, and *"the device battery life is so weak that I need to charge it often. When the device was being charged, I often forgot it and did not wear it in the morning"*. Additionally, users gave answers of other types of drawbacks or challenges which were *"focusing overly to the steps, calories burned, hear rate and other signals the device measures and displays has psychological impact. That is why I have decided only to use it during direct exercise"*, *"the features of the devices do not function properly and the number of different sport categories is low"*, and *"concentration to other device is worsened (when using the device)"*.

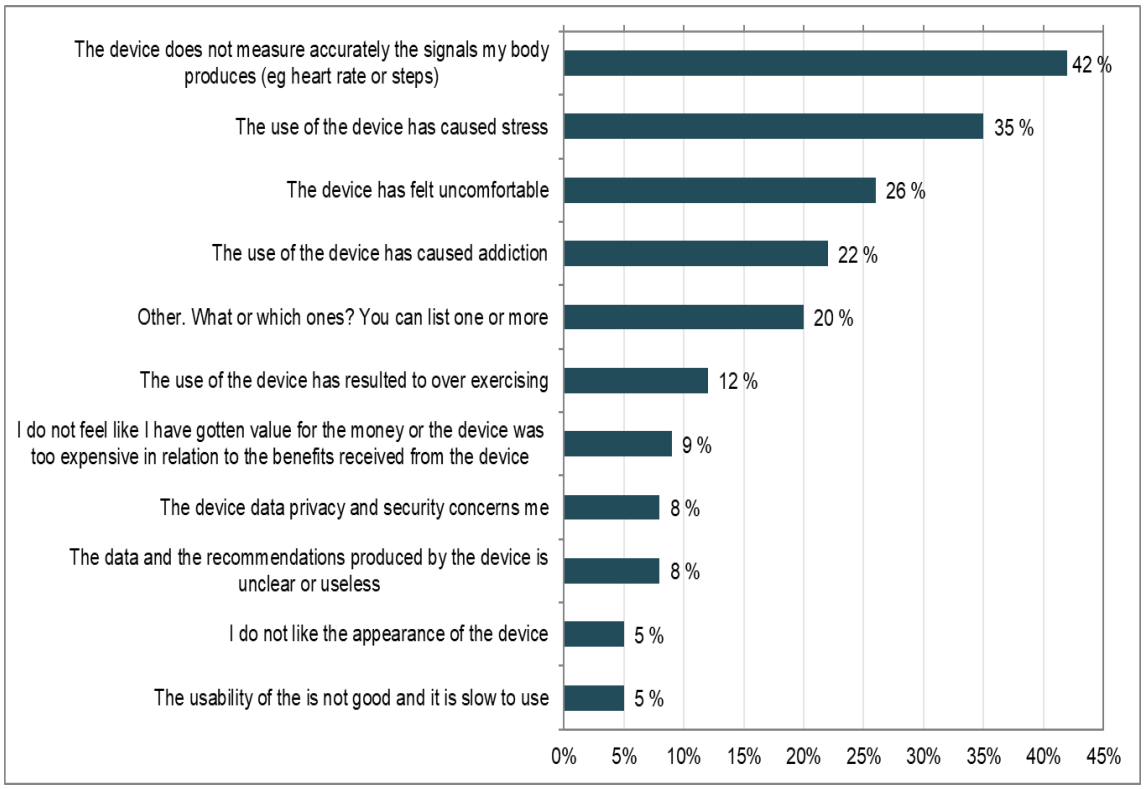


**Figure 8: What kind of drawbacks or challenges have you experienced from use of the device(s)?**

## 5.4 Collaboration with health organization

In the last section of the survey users of wearable devices were asked if they used the devices or shared the data the device produced with health care professionals such as FSHS. 94 percent of the respondents stated they did not, and 6 percent stated yes, they did. Those 6 percent of the users who used the devices or shared the data the devices produced, were then asked how they did it. Figure 10 shows the results for different forms of cooperation or data sharing. Most usual identified way was the use of the device and sharing of the data in a self-imposed way with health care professional which was reported by 50 percent of the respondents. These types of people started to use wearable devices without the recommendation of health care professional. The next most common way was for the user to use the device independently in self-care based on the recommendation of health care professional which was reported by 33 percent of respondents. Only 25 percent of the respondents used the device and shared the data in cooperation with health care professionals. For these people the initiative to use the device came from health care professional. Finally, 17 percent of the respondents used ways which did not fit preselected options, but they used the option to give answers in their own words in the other category. The open answers included *"I use the device and share the data with a*

*coach"*, and *"I could tell about my worries about my sleep quality by sharing data from my smart watch"*. The last answer could be included as part of the most usual ways of using the device and sharing the data in self-imposed way.

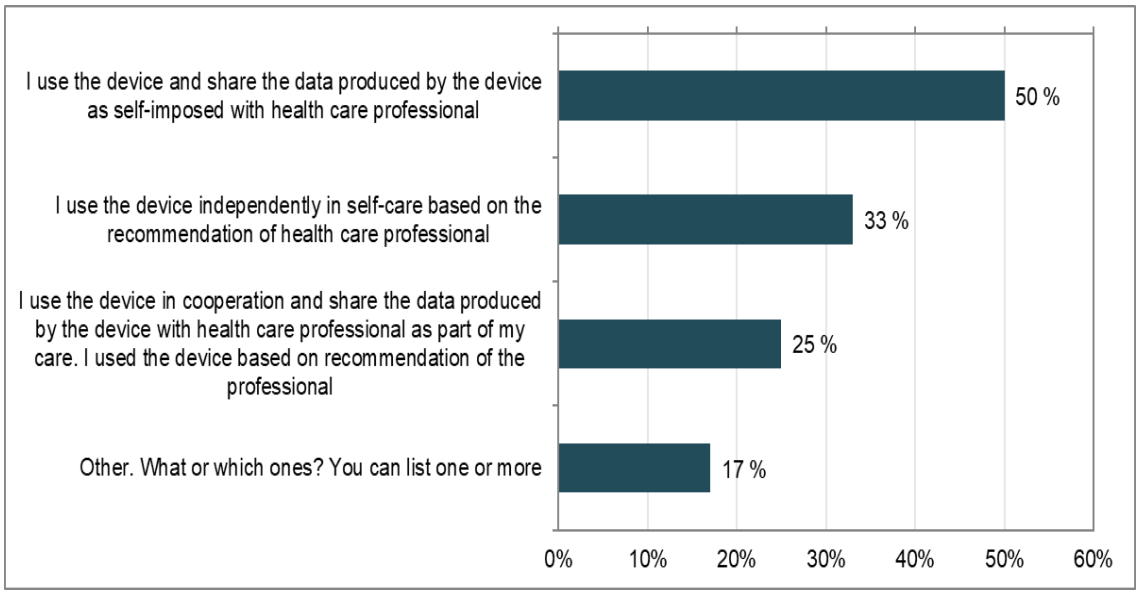


**Figure 9: How have you used the device(s) in cooperation with health care professional (for instance FSHS or other student health) or shared the data the devices have produced with health care professionals?**

# 6 DISCUSSION AND CONCLUSIONS

## 6.1 Discussion of the results

The first research questions studied how common the use of wearable devices was among the university students in Turku, and what type of devices were used. The questions were following:

- How common it is to use and at what frequency do university students in Turku use wearable devices for health and well-being purposes?
- What type of health and well-being wearable devices do the university students in Turku use and what indicators do the devices monitor?

Based on the survey results, 60 percent of the university students used wearable devices and 40 percent did not within last 12 months when answering to the survey. The results are somewhat high if comparing the number to, for instance, use of sport or heart rate wearable devices among group of Finnish adolescents. Among the group of adolescents only 17 percent reported they own a wearable device (Ng et al 2017). Additionally, devices are relatively expensive for students who usually rely in Finland for income on government social support for students. The results suggest students are willing to invest in wearable devices and prioritize the purchase. The students who use the wearable devices, use them frequently. The results of the survey indicated that almost half, 49 percent, of the survey respondents, used wearable devices on a weekly basis or more frequently. Overall, the results indicate that the use of wearable devices is common already among university students. Based on how common the use of devices is, they could potentially be used more effectively in health and well-being.

The device types which were most common among the student wearable users were activity trackers, smart watches and heart rate monitors which were reported by 62, 56 and 38 percent of the survey respondents, respectively. The results are expected as smart watches and activity trackers with heart rate monitoring are among the most common and sold wearable devices (Statista 2019c). Smart watches include often both features, activity tracking and heart rate monitoring, in addition to their other features. As smart watches and activity trackers are easy to use in daily basis, the device types are one of the most important explanatory factors on the frequency of the use of wearable devices on daily basis. Interesting finding in this section of the survey results was that smart jewelry, such as smart rings, had a quite low number of users. Though smart jewelry, such as the Oura ring, gets quite much attention in the media in the wearable's world, they are quite rare devices at least among the university students in Turku. Additionally, the lack of use of smart clothing is an interesting finding as smart clothing and textiles have been considered

to have the most potential for accurate recording of data. There does not seem to be smart clothing in the market open for large audiences yet.

The indicators that the devices monitored were aligned with the device types. Almost 90 percent of the survey respondents stated that their devices monitored heart rate, and body movement and exercise. Increase in exercise and physical activity is one of the few clinically proven health benefits related to wearable device use (Piwek et al. 2016). It is thus a valuable finding that the devices monitor indicators with proven benefits. Sleep tracking was one of the indicators the survey respondents stated their devices monitored. Amount of sleep was reported to be monitored by 67 percent of wearable users and quality of sleep by 60 percent of users. Sleep problems and tiredness are widely spread health issues among university students (Kunttu et al. 2016). In long the run reduced or poor-quality sleep can lead to metabolic diseases, depression, burnout, and mortality (Åkerstedt et al 2009; Halson 2008). The research provides valuable finding that with support of wearable devices, users can monitor their amount and quality of sleep, and take corrective actions to improve it. Overall, these results indicate number of potential sources for data, such as heart rate, exercise, and sleep, that could be utilized in monitoring and in treatment in health and well-being cases with larger groups of students. The data could be utilized by treating health care personnel as one of the data sources among other data sources such as patient interviews and blood tests when monitoring or treating a health disorder together with the patient. On the other hand, the results also indicate cases which are not ready to be monitored with wearable devices yet among students, such as environmental chemicals and body ergonomics, but existing other monitoring methods should be preferred in care.

Next research questions were related to the adoption of wearable devices among university students in Turku. The questions were following:

- What features do the university students in Turku value in wearable devices?
- What are the reasons for the university students in Turku not to use wearable devices?

The questions were researched through indirect and direct questions to the university students. First, users of wearable devices were requested to identify why they chose the device they used over the competitor. The number one factor was the price of the device which was reported by 69 percent of the respondents followed by the device appearance reported by 68 percent of the respondents. The price is important especially for students due to most likely lower income in comparison to full-time working peer adults. Appearance may be highlighted due to the prevalence of smart watches, activity trackers and other wearables which are usually worn on user's wrist visible to other people as well. The next most important factors were the features the devices offered related to health and well-being, and usability and comfort of the device. These were reported by 59 and

58 percent of the respondents. The perceived benefits and usability of the device, or functional congruence, were also factors identified in the literature about adoption of wearable devices to impact the intention to use the devices positively. Unexpectedly the data privacy and data security features were the least important factors when selecting the device over competing device. Data privacy and security risk, the perceived privacy risks, were stated in literature to have one of the biggest negative impacts to intention to use wearable device. It would make sense users want to prioritize high the privacy and security features when making the device purchase. However, it seems that when making the device purchase in real life, the data privacy and security does not matter that much. It can be argued that the users do not utilize rationalized decision-making regarding data privacy and security features.

The non-users were asked reasons why they did not use wearable devices. The two of the reasons were related to the funds of the non-users as 56 percent of the non-users were interested but prioritized other acquisitions and 32 percent of non-users stated they did not have funds for the device purchase. These are somewhat expected practical reasons due to limited income that students have as they are not working full-time. The wealth status was not confirmed from the users in this research, so this cannot be confirmed in the scope of this research. Financial risk was also in the literature among the factors that impacted negatively on user's intention to use wearable devices (Nasir & Yurder 2015). Next, 11 percent of non-users reported potential data privacy and security risks as reasons for not purchasing and using device. The numbers related to data privacy and security seem again low in comparison to the importance of privacy and security in literature. Few users also stated in open comments that they did not want to use the device because it would cause additional stress. Stress and anxiety were identified in the literature also being one of the potential unintended behavior changes with negative health and well-being impacts (Schukat et al. 2016).

The next research question concerned the benefits, drawbacks or challenges users who used wearable devices experienced. The questions included:

- Does use of wearable devices result to perceived health and well-being benefits among the university students in Turku and what type of benefits do they experience?
- Does use of wearable devices result to perceived health and well-being drawbacks or challenges among the university students in Turku and what type drawbacks or challenges do they experience?

Most of the users of wearable devices experienced health and well-being benefits from the use of the devices as 96 percent stated they experienced benefits and only 4 percent stated they did not. The number of users with perceived benefits is high, and the results indicate the devices could provide health and well-being benefits to also users who do not

yet use wearable devices. Use of the devices could provide benefits to other students in Finland as well and perhaps even to larger masses and other groups of citizens. The users who experienced benefits, were then requested to name the kinds of benefits they experienced. The number one benefit reported by 73 percent, was device supporting the user in increasing daily activity. Additionally, 61 percent reported that the device supported them in increasing fitness exercise. As obesity and lack of physical activity were among the top health issues for university students (Kunttu et al. 2016), utilization of wearable devices brings valuable new tools to increase physical activity with direct impacts to students' weight management. Physical activity is also important factor related to the other health issues students experience such as poor metabolic health, obesity, musculoskeletal disorders and poor quality of sleep (Tammelin 2009). It makes utilization of wearable devices to increase physical activity even more valuable.

52 percent of the students who experienced benefits reported that the device gave them more information about the users' state of health and well-being. As the students' main source of health-related information is still going to be searches online, it is valuable to have additional ways of tracking your health which is not based only the subjective assessment of health using information found in internet searches. Additionally, students might be prompted to act if they notice that some part of their health and well-being, such as physical activity, seems low compared to nationally recommended activity amounts. 36 percent of the students stated that the device supported them improving their sleep quality and amount of sleep. Though over 60 percent of the wearable users reported that their devices tracked amount of or quality of sleep, the results indicate that these features help improving sleep in students only partially. It could be that the device makes student aware of the sleep patterns, but the device does not include effective features to motivate student to take actions improving sleep. Still, the wearable devices bring a beneficial new tool, maybe first of its kind, for students to get feedback about their sleep, in order to improve poor sleep, which is one of the most common health issues among university students. Finally, 27 percent of the students stated that the wearable device supported their mental and physical recovery. Mental health issues are the health trend with most increase in student health in recent years. 44 percent of university students in Finland experience psychological symptoms in weekly or more frequent basis (Kunttu et al. 2016). Thus, tools are needed to support improving the state of mental well-being in students and prevent mental health disorders from escalating to more serious problems.

The users of wearable devices were next requested to identify if they experienced drawbacks or challenges related to use of wearable devices. The results were more mixed than with experienced benefits as 34 percent of the users said they experienced drawbacks or challenges and 66 percent stated they did not. From the 34 percent of users, 42 percent stated that the device did not accurately measure the signals from body. It seems that though some wearables are capable of relatively accurately track some signals, such as

smart watches and fitness trackers record heart rate and steps (El-Amrawy et al. 2015), there is still improvement in areas of other device types and measurement of signals such as sleep. The other potential reason for users highlighting this challenge, is that users expect even higher accuracy of tracking than the technology is yet able to provide, and manufacturers are promising to users. 35 percent of the respondents who experienced drawbacks or challenges named devices causing stress as one of them. Additional stress is important factor to consider when thinking if wearable devices could be utilized more commonly in health and well-being. Already mental health issues, including stress, were one of the emerging health care issues among university students. It is needed to consider is it wise to bring new objects to their lives that result in increased stress. As mentioned before, stress and anxiety were identified in the literature as well, as one of the negative outcomes of using wearable devices (Schukat et al. 2016).

26 percent of the students reported that the device felt uncomfortable and multiple students stated in open comments that the device caused skin rash or irritation. In literature the usability was identified as one of the group of factors with positive impact on intention to use wearable devices, and the physical risk as one of the factors with negative impact on intention to use wearable devices. One of the key features and benefits wearable devices have is that they record signals from users in non-invasive manner throughout the day. Therefore, it is important that the devices feel as comfortable as possible. As the devices are usually in contact with the users' skin, the device designers should focus on materials and designs as comfortable as possible. Finally, interestingly only 8 percent of the students reported that the data privacy and security worried them. As discussed before with reason for the users not using wearable devices, the results related to data privacy and security are surprisingly low in comparison to the findings of the importance of the matter in literature. In literature the data privacy and security threats and risks, named as perceived privacy risks, were named as the greatest single negative factors impacting user's intention to use wearable devices (Li et al. 2016; Gao et al. 2015; Wieneke et al. 2016). It could be that the users trust in the technology that much that they are just not afraid for the data privacy and security risk that much. It could be also that in this case neither, users do not apply rationalized decision making and not account data privacy and security risks that high in comparison to other drawbacks or challenges occurring from use of the devices.

The final research questions aimed to discover if the users of wearable devices used the devices in cooperation with health care professionals. The question was following:

- Have the university students in Turku used wearable devices in cooperation with health care professionals such as FSHS and how have they done it?

Only 6 percent of the survey respondents who used wearable devices stated that they used the devices in cooperation or shared the data with health care professionals and 94

percent did not. Results are expected as many of the users of wearable devices most likely use them to monitor and improve their health without having a health disorder for which they should seek help from health care professional. In these types of cases there would not be any initiation to share the data. Among the users who shared the data or did cooperation with health care professional, the most common way was to share the data that in self-imposed way which was reported by 50 percent of the users. 33 percent of the respondents used the device based on recommendation from health care professional and only 25 percent used the wearables as part of their health care treatment and monitoring done together with the health care professional. The results indicate overall that use of wearable devices is not yet implemented as part of regular health care activities at FSHS or other health organizations students use except of few rare cases. It can be deduced from the results that wearable devices offer great potential for FSHS, which acts as a provider for university student health, for monitoring and treating health disorders together with the patients. Student health care is also cooperation between different stakeholders impacting student lives, such as the university organization and student associations. There is room for the different stakeholders to work together on finding new ways of utilizing wearable devices more effectively in order to improve student's health and well-being and manage studying ability of the students.

## 6.2 Limitations and future study

There are several limitations for this research. The sample size of the study was 329 persons. In comparison to the study population, Turku university students with 25 500 students, sample is only 1.3 percent of population so results might change with larger sample. The results concern only university students in Turku and cannot be generalized for all university students or other students in Finland. In addition of age, study start year and the university the student studied in, there was no other background information collected from the student respondents related to possibly important correlating factors, such as wealth and income, for the students' use of wearable devices. The empirical data collected in this research cannot for that reason be used to analyze other cases for correlation than with the mentioned collected background information. Additionally, the aim of this research was to study the phenomenon of use of wearable devices generally and extensively, and not to try to discover correlations and causality within different variables in the research material.

Related to the benefits, drawbacks or challenges discussed in this research, all results were related to the subjective, perceived experiences from the survey respondents. The results cannot be used as arguments for clinically researched impacts related to the use of wearable devices. For instance, 73 percent of the respondents who reported they

experienced benefits related to use of wearable devices, reported that the device supported them increasing daily activity. However, it is not in the scope of this research to study whether the daily activity increased and what was the actual role of the device in comparison to other factors. Additionally, the selection of predetermined answers in the survey questions was formed as result from intensive literature review but there could be some answer categories that were missed in this research, that the survey respondents were not able to identify in the open comments neither.

Two main future study cases were identified related to this study and derived from the study limitations. First, the use of wearable devices should be studied in larger study among all university students in Finland. The groups of other higher degree students, the students in the universities of applied sciences, should also be included as they start receiving health care services from FSHS starting from 1.1.2021. This would provide valuable understanding about the use of wearable devices and their utilization related to health and well-being more generally in Finland among the mentioned groups. The second future study area is to study the benefits, drawbacks or challenges of different types of wearable devices in clinical and controlled settings. The results indicate that there are many perceived ones, but it should be studied what are impactful to students and other groups health and well-being.

## 6.3 Conclusions

This research focused on study the use of wearable devices for health and well-being purposes among university students in Turku. The results of this research provide new information about the state of utilization of wearable devices and insights how they could be used as part of student health care and managing student well-being. Utilization of wearable devices is increasing as more devices enter the markets each year. The devices provide different types of features that can be utilized for use cases in health and well-being. Among the university students in Turku over half of the students reported they used wearable devices. The most common devices types that the students used were wrist worn type of devices such as activity trackers and smart watches. The most usual indicators that the devices monitored were heart rate, exercise and sleep.

The results of the research indicate wearable devices are useful supporting university students' health and well-being. Almost all students who used wearable devices reported they experienced benefits related to health and well-being from use of the devices as only one-third stated they experienced drawbacks or challenges. The most common benefits were support in increasing daily activity and exercise, giving information about students' overall health, and support in improving students sleep. The most common experienced drawbacks or challenges were the device signal accuracy, the use of the device causing

stress and the device feeling uncomfortable or causing skin rash. Among the experienced drawbacks or challenges, only small part of students experienced the potential data privacy and security threats as potential issues. This is an interesting finding as data privacy and security risks, the perceived privacy risks, were identified as one of the main reasons in the literature impacting negatively users' intention to use wearable devices. Similarly, among the survey respondents who did not use wearable devices, only few respondents named potential data privacy and security problems as a reason for not using the device.

Finally, based on the research survey results, only a fraction of wearable devices users used the devices or shared the device data with health care professionals. The most common way to do this was for students to share the device data with health care professional in self-imposed manner. The results indicate that use of wearable devices in student health care for monitoring health and treating disorders by health care professionals, is still rare. Based on the survey results and use cases in literature, wearable devices provide tools with great potential to support both students and student health care professionals in improving students' health, well-being and studying ability.

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# APPENDICES

## Survey questions

TURUN YLIOPISTO

### Use of wearable technology for health care and well-being purposes among Turku higher degree students

Welcome to respond to the survey.

Your participation to the survey is important. The goal of the survey is to find out use of **wearable technology for health care and well-being among university and university of applied science students in Turku**. The survey will investigate how common the use of wearable technology is among students, the benefits and challenges the technology might have related to ways of life and health.

**Wearable technology** refers to wearable devices meant for self-measuring which are targeted to find out the behavior or physiological state of a person using one or more physiological signals such as physical activity, sleep or stress. Wearable technology consist of electronics that can be worn in a body as external probe/sensor or as part of material used in clothing which continiously measures the activity of a person without restraining persons movement. Examples of wearable technology are **activity bands, smart watches and smart rings**. Also medical devices such as **hearing aids** and **blood sugar sensors that are attached to skin** are included as part of the technology.

The survey does not include questions related to personal data . The collected information is not reported or committed to external parties so that they could be idenfied to concern single person. Responding to the survey takes about **5 minutes**. **Two pieces of 50 eur** Gogift gift cards will be drawn among respondents of the survey. In questions related to the survey you can contact Joonas Raina by email in address jojara@utu.fi. The last day to respond to the survey is **30th of September 2020**

## Background info

**1. Age**

- ◯ under 20 years
- ◯ 20-24 years
- ◯ 25-29 years
- ◯ 30-34 years
- ◯ under 35 years

**2. University or university of applied sciences**

- ◯ Diaconia University of Applied Sciences
- ◯ Humak University of Applied Sciences
- ◯ Turku University of Applied Sciences
- ◯ University of Turku
- ◯ Novia University of Applied Sciences
- ◯ Åbo Akademi University

**3. Start year for studies**

- ◯ 2012 or before
- ◯ 2013
- ◯ 2014
- ◯ 2015
- ◯ 2016
- ◯ 2017
- ◯ 2018
- ◯ 2019
- ◯ 2020

## Use of wearable technology

**4. Have you used wearable technology within last 12 months and how actively you use it?**

- ○ I have not used
- ○ I use yearly
- ○ I use monthly
- ○ I use weekly
- ○ I use daily

**5. What kind of device(s) have you used?**

- ☐ Activity tracker, movement tracker or pedometer
- ☐ Implant, sensor attached to or under the skin
- ☐ Electrode(s) and associated collector
- ☐ Hearing aid
- ☐ Wearable sensor or probe
- ☐ Heart rate monitor
- ☐ Blood glucose meters
- ☐ Smart watch
- ☐ Smart jewelry (eg smart ring)
- ☐ Smart headphones
- ☐ Smart glasses
- ☐ Smart clothing
- ☐ Smart belt
- ☐ Other. What or which ones? You can list one or more

**6. What is the monitored indicator which the device(s) collect data about?**

- [ ] Brain function
- [ ] Breating and activity
- [ ] Body position and ergonomics
- [ ] Body movement and exercising
- [ ] Altitude and its variation
- [ ] Muscle activity and muscle function
- [ ] Recovery, physical
- [ ] Recovery, mental
- [ ] Location (GPS)
- [ ] Stress
- [ ] Heart rate and heart rate variability
- [ ] Heart function
- [ ] Blood pressure
- [ ] Blood sugar
- [ ] The amount of sleep
- [ ] The quality of sleep
- [ ] Environmental chemicals
- [ ] Environmental sounds
- [ ] Other. What or which ones? You can list one or more

**7. What factors had impact in your selection of the device(s) in comparison to potential competitor device(s)?**

- [ ] The ratings of the device from other users (for instance in online store)
- [ ] The price of the device
- [ ] The usability and comfort of use of the device
- [ ] The device data handling and display in external application
- [ ] The device features related to health and well-being
- [ ] The device data privacy and security features
- [ ] The device appearance
- [ ] Social factors (for instance friends have similar devices in use)
- [ ] Other. What or which ones? You can list one or more

TURUN YLIOPISTO

## Use of wearable technology for health care and well-being purposes among Turku higher degree students

### The experienced benefits and challenges of wearable technology

**8. Have you experienced health and well-being benefits from use of the device(s)?**

- ◯ Yes
- ◯ No

**9. What kind of health and well-being benefits have you experienced from use of the device(s)?**

- ☐ The device has helped my hearing
- ☐ The device has increased my social activities
- ☐ The device has supported me in physical and mental recovery
- ☐ The device has supported me in increasing daily activity (such as walking to school)
- ☐ The device has supported me in focusing
- ☐ The device has supported me in increasing fitness exercise
- ☐ The device has supported me in weight management
- ☐ The device has supported me in substance use management
- ☐ The decvice has supported me in monitoring and/or treatment for disease
- ☐ The device has supported me in stress management
- ☐ The device has supported me in heathier diet
- ☐ The device has supported be in improving quality of sleep and/or increasing amount of sleep
- ☐ The device has given me additional information about state of my health and well-being
- ☐ Other. What or which ones? You can list one or more

**10. Have you experienced drawbacks or challenges from use of the device(s)?**

- ◯ Yes
- ◯ No

**11. What kind of drawback or challenges have you experienced from use of the device(s)?**

- ☐ I do not feel like I have gotten value for the money or the device was too expensive in relation to the benefits received from the device
- ☐ I do not like the appearance of the device
- ☐ The device does not measure accurately the signals my body produces (eg heart rate or steps)
- ☐ The device has felt uncomfortable
- ☐ The usability of the is not good and it is slow to use
- ☐ The use of the device has caused addiction
- ☐ The use of the device has caused stress
- ☐ The use of the device has resulted to over exercising
- ☐ The device data privacy and security concerns me
- ☐ The data and the recommendations produced by the device is unclear or useless
- ☐ Other. What or which ones? You can list one or more

**12. Have you used the device(s) in cooperation with health care professional (for instance FSHS or other student health) or shared the data the devices have produced with health care professionals?**

- ◯ Yes
- ◯ No

**13. How have you used the device(s) in cooperation with health care professional (for instance FSHS or other student health) or shared the data the devices have produced with health care professionals?**

- ☐ I use the device independently in self-care based on the recommendation of health care professional
- ☐ I use the device in cooperation and share the data produced by the device with health care professional as part of my care. I used the device based on recommendation of the professional
- ☐ I use the device and share the data produced by the device as self-imposed with health care professional
- ☐ Other. What or which ones? You can list one or more

**14. Why have you not used the device(s)?**

- [ ] I do not want to use the device because of potential data privacy and/or security problems?
- [ ] I am not interested on the use of the device because of poor usability
- [ ] I am not interested on the use of the device because of the appearance of the device
- [ ] I do not believe the device to be useful for me
- [ ] I am interested on the device but I do not have funds to acquire one
- [ ] I am interested on the device but I am have prioritized other acquisitions
- [ ] Other. What or which ones? You can list one or more

**15. I want to participate to the draw of the gift cards which will be done after the time period to answer the survey has ended**

- ( ) Yes, my email address for contact is
- ( ) No