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UTILIZATION OF WEARABLE TECHNOLOGY IN INDIVIDUAL SPORTS

Bachelor's Thesis
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1. INTRODUCTION

Wearable technologies' market is growing and it is forecasted that in 2020 the market value will be from 34 billion dollars up to 62 billion dollars (Lamkin, 2016; Goasduff, 2016). The one thing for sure is that the market will keep growing in the future and that the technologies will advance. "Wearable electronics are devices that can be worn or mated with human skin to continuously monitor an individual's activities without interrupting or limiting user's motions" (Brooks et al., 2016, 509). Most of the wearable technologies are nowadays related to sports and fitness but it is assumed that wearable technologies will change the field of healthcare as well (Finpro, 2015). The "quantified self" movement, which means individuals interested in self-tracking their bodies, might be the one reason wearable technology market keeps growing rapidly (Page, 2015).

As the field is relatively new, there is a lot of development going on and it should be studied as well. Many of the new innovations are only researched and tested in the laboratories or among elite athletes, and those are not available in the consumer market yet, which could be changing in the next few years. This paper aims to present an overview on wearable technologies' use in individual sports, both in consumer and elite level. The paper aims to answer questions such as how wearable technologies can be utilized in individual sports and whether the advanced technologies could be used in consumer markets as well. Wearable technology is researched as well in team sports but this thesis is limited in devices that help individuals doing their sport. In addition, the study addresses what motivates the users to keep using their wearable devices. The research method used is literature review and besides that some use cases obtained via Internet and own interviews are presented. The literature review concentrates on articles that are not more than five years old as the field keeps developing quickly.

Research of already existing consumer wearables reveal that the biggest consumer interest in both US and Europe is still on wristband wearable sensor devices (Anzaldo, 2015). According to Page (2015, 2) wearable devices are used in elite sports for "performance enhancement, training optimisation, injury prevention, stress factor estimations and determining experience level". Actually, preventing injuries could be the biggest benefit that wearable technology can provide, at least when measuring the costs. Wearable technology has been studied in preventing soft-tissue injuries, detecting concussions and measuring the amount and range of specific movements to prevent overuse injuries. Soft-tissue injuries happen in all levels of sport and concussions are typical for contact sports, so these injury preventing technologies would certainly be appreciated in consumer markets as well.

Studies related to technique analysis have also been conducted in many sports. Wearable sensors can provide more accurate data regarding the technique and it can be provided even in real time. Measuring biovital signs from human sweat with wearable devices provides a lot of possibilities also other than just following the amount of lactic acid. Deeper understanding of human bodies could be achieved when these biovitals can be measured constantly instead of occasional blood tests.

As can be inferred from the above, there are a lot of possibilities regarding the use of wearable technology. Preventing injuries, training optimisation and increasing performance are probably in the interests of everyone doing sports, not only for elite athletes. Goasduff (2016) mentions also smart coaching in Gartner's report for the trends of 2017 and 2018 regarding wearables. Drawing conclusions on data might be challenging for ordinary fitness consumers and thus smart coaching is a trend for the fitness consumers who don't have their own coaches like elite athletes do. Studies also emphasize that designing the user experience is the most crucial part of development when producing devices to consumer markets.

Baca and Schwartz (2016) divide wearable technologies into three categories: commercial ones that are available in consumer markets, advanced ones that are mostly used for scientific purposes and the experimental ones that are in their developing phase. This literature review concentrates mostly on the advanced and scientific technologies that have been researched during the past few years. It is also discussed whether these technologies could fit into the consumer markets in the future.

In the literature review the possibilities with wearable technologies are first addressed in injury prevention in chapter 2. Possibilities with wearable technology related to training analyses are then addressed in chapter 3. After that the user experience of wearable technology is being discussed and some use cases from internet and interviews are introduced in chapter 4. Use cases concentrate more on the commercial wearables as the persons interviewed are national level athletes or fitness consumers and don't yet have the access to the advanced technologies. Finally some critics towards wearables will be covered in the chapter 5.

2. Wearables in injury prevention

Preventing injuries is important both to the elite athletes and regular consumers dealing with sports and several inventions using wearable technology aim to prevent and decrease injuries or help in detecting them in the early phase. For the elite athletes, injuries may lead to missing the whole season, which can mean losing sponsor deals and possible prize money. For sport consumers, injuries can cause for example sick leaves from work, which leads to monetary losses both for the society and the individual. Curing the injury in hospital care or with the help of physical therapists can be really expensive, especially when one doesn’t have a proper insurance. Injuries can also cause mental problems especially for elite athletes, whose whole career is dependent on their bodies and its functioning, and when injuries happen they won’t be able to practise their profession. Injuries also harm the physical progress especially on young athletes, who develop quickly and might fall behind from their age group’s results.

2.1. Upper limb injuries

In the US 25% of upper extremity injuries in 2014 were shoulder injuries in adults, and over 116 000 high school athletes sustain a shoulder injury yearly. Rafeldt et al. (2016) introduce a body-worn inertial-measurement units (IMU) device, which measures movements that happen overhead in ballistic sports such as baseball throw and volleyball serve. Research shows that spikes during training in the amount of overhead movements increase also the risk of injuries. Especially the amount of movements in training has been difficult to measure and thereby difficult to control to prevent overuse. (Rafeldt et al., 2016)

Wearable inertial-magnetic measurement units (IMMUs) have also been researched in swimming. Cortesi et al. (2015) used the technique to analyse three-dimensional joint kinematics of the upper limbs during simulated swimming. The placement of sensors and the simulated swimming can be seen in the figure 1. Rafeldt et al. (2016) were able to measure acceleration, rotation rates and magnetic field direction with the help of the sensors to track what kind of movement was performed while Cortesi et al. (2015) were able to track also the range of motion in the upper limbs. The main difference between IMU and IMMU is that IMU is only able to measure an amount of a specific movement performed while IMMU is able to measure also the range of the movement.

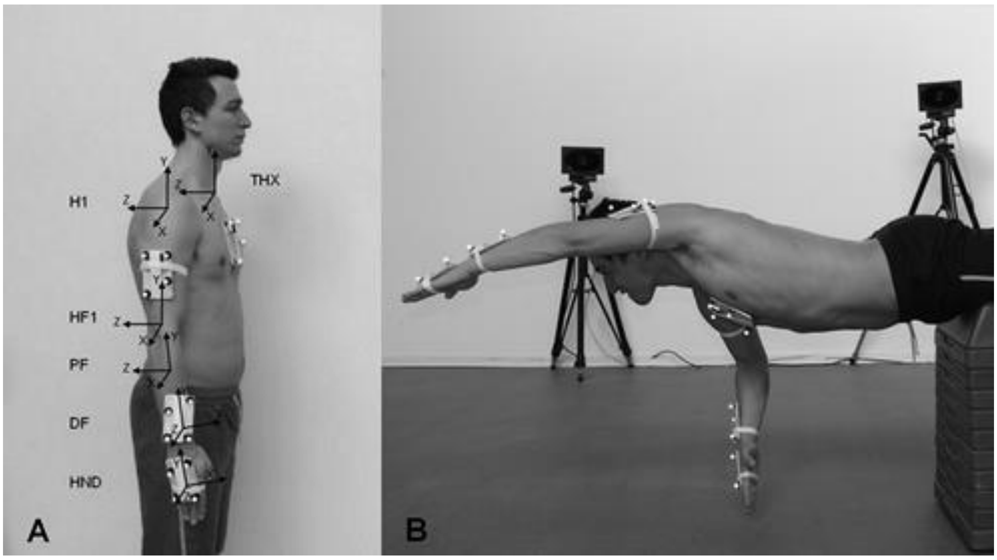

Figure 1. The placement of sensors (A) and dry-land simulation of front-crawl swimming (B) (Cortesi et al., 2015).

Cortesi et al. (2015) aimed to analyse the technique in swimming and thereby prevent injuries as Rafeldt et al. (2016) only concentrated on overuse injury prevention by tracking the amount of specific movements that have been discovered to cause injuries. Swimming is cyclic movement and the joint angular velocities in the movements are much slower than in ballistic movements such as throwing, so the IMMUs are especially suitable to measure swimming (Cortesi et al., 2015). Therefore, the different velocities in movements researched explain somewhat in part the difference in the results' accuracy.

Recent studies have shown that IMU sensors are able to track the right movements with 86% accuracy, with slightly undercounting the repetitions (Rafeldt et al., 2016). Compared to, for example, step counters, IMU sensors measure three-dimensional movements and are thereby much more complex. Taking the complexity into account, the accuracy of 86% is good for the sensors and the algorithm (Rafeldt et al., 2016). Also in the research performed by Cortesi et al. (2015) the accuracy of the results was good, though depending on the swimming style. With swimming styles including faster motion velocities, such as front crawl, also the results differed from the standard (Cortesi et al., 2015).

These kinds of wearable devices could work as well in the consumer market as in the elite sports. Avoiding too many repetitions or using a wrong technique might be even more crucial to unexperienced consumers than to the elite athletes, as their bodies might not have adopted the right movements of the sports. On the other hand, injuries related to overusing are more typical to elite athletes, who aim to maximize their training amount. The problem with the consumer markets might be the accuracy, while Rafeldt et al. (2016) describe that the accuracy could be improved by a sample with a consistent level of competition participation status. A sample group where the participants have similar experience would decrease the variety in task biomechanics and velocity (Rafeldt et al., 2016). In the consumer markets the user group might be too diverse for the wearable device to be accurate. If the accuracy problem could be overcome, this wearable device would suit well for the consumer markets to avoid injuries also on the other fields than sports, where overuse causes a risk of injury.

2.2. Leg injuries

Wearable inertial-measurement unit (IMU) sensors have also been researched to measure the movements in lower limbs. Bahr et al. (2017) researched the sensors in volleyball to track the amount and the height of the jumps. The research using IMUs conducted by Rafeldt et al. (2016), concentrating on overhead motions and Bahr et al. (2017), concentrating on jumps, aimed to track the amount of movements that may cause injuries when the amount of those grows too much. In the research the amount of jumps were tracked both in trainings and in matches (Bahr et al., 2017). In the match the IMU system counted more jumps than visual review as it detects smaller motions as jumps. In practice, the system was able to track almost 97% of the jumps and didn't take any non-jumping activities as jumps. The accuracy reached in the research performed by Bahr et al. (2017) was slightly better than in the research of Rafeldt et al. (2016) though both of these studies using IMUs reached a relatively good level of accuracy.

Tracking the amount of jumps in volleyball may prevent the players from overuse injuries such as jumper's knee and it enables also researching the effect of fatigue in jumps in the matches (Bahr et al., 2016). Another typical injury in sports is a tear or rupture in the anterior cruciate ligament (ACL) in knee. Especially in sports where there are lots of cuts and pivots, such as football, basketball and American football, injuries in ACL are quite typical (Craker et al., 2017). In the Ohio State University, basketball players are monitored with the help of technology, including wearables, to find out reasons for injuries (Mertz, 2013). Players perform movements typical to their sports and those are monitored with help of reflective markers in bodies, high-speed cameras and also the floor is embedded with force plates. With data gathered for over 20 years, the researchers have been able to discover some issues that increase the probability for ACL injuries (Mertz, 2013). If a player is discovered to have higher probability for injury, he or she is instructed to perform movements correctly. Also adding strength to the weak areas has been proved to be successful as it is possible to reduce risk for ACL injury by up to 65% (Mertz, 2013).

Injuries are often caused by poor balance between muscles and sometimes also overusing specific muscles or body parts. ACL injuries are caused by knee abduction which is caused by muscle recruitment and weakness in hip and knee area (Mertz, 2013). As many ballgames, that are typical to cause ACL injuries, are a popular hobby around the world, it would be useful to have wearable technology that could prevent injuries. Many amateurs play those ball sports just for fun and may not have any idea of their muscle balance, for example. If the data gathered by The Ohio State University could be combined with wearable technology and an application to analyse one's risk to ACL injuries, probably many injuries could be prevented. The application could instruct people who belong to the risk group to exercise right muscles to gain better muscle balance and prevent an injury in ACL. Overuse injuries, such as jumper's knee in volleyball, are usually more typical to the competitive athletes who aim to maximize their training amount. Though, there are lot of people who suffer with overuse injuries in different sports so wearable technology using IMUs could be useful to many competitive athletes.

2.3. Soft-tissue injuries

Among athletes soft-tissue injuries such as sprains, strains and contusions are the most common type of injuries. Poor conditioning, overtraining and dehydration are reasons that typically cause soft-tissue injuries. By measuring the biovitals from the body it could be possible to prevent those type of injuries. Wearable technology to measure those biovitals from sweat instead of blood or saliva is being developed (Heikenfeld, 2016).

With sensors placed straight to the skin it would be possible to measure several things from sweat; electrolytes, metabolites, small molecules and proteins. With help of this information the stage of fatigue could be followed closely in a training by following the amount of lactic acid in the athlete's body. If an athlete is training in a too tired stage, the risk of injury grows notably. (Craker et al., 2017) Lactic acid is though only one parameter of the tens of others which could be followed by this wearable technology.

Nevertheless, making sensors that can sense electrochemical sweat analytes is difficult. The sensors must be prepared from a scratch and they can't yet be purchased anywhere. In addition, making portable versions of all the parts needed is challenging. These problems are being solved by placing the sensors straight to the skin where they can quickly and precisely measure sweat and its analytes continuously. Despite their tiny size they can precisely measure a single type of ion or a molecule from the sweat. Also, having more than one sensor increases the credibility and usability of the results. Monitoring the results is enabled with Bluetooth in the sensor devices. (Heikenfeld, 2016)

Measuring lactate thresholds with wearable technology has been researched also in cycling. The method investigated by Borges et al. (2016) used technology that was based to near infrared LED technology to predict the lactate threshold from blood. The device can be seen in use in figure 2. Also with this system the blood samples could be avoided and the lactate threshold could be monitored continuously. As the research was done in cycling, where soft-tissue injuries are not so typical, the information was used to monitor cyclists' performance and physiology (Borges et al., 2016). Though, if the same methodology could be broadened to other sports too, it could also be useful in preventing soft-tissue injuries by monitoring the levels of fatigue. The wearable lactate threshold sensor reached acceptable levels of agreement, i.e. traditional LT values had the typical error of estimate lower than 15% when compared to wearable lactate thresholds, when compared to traditional methods (Borges et al., 2016).

These kind of technologies are a leap forward among the wearable devices, as they use completely new technology. Most of the wearable devices that are currently in use are based on accelerometers and they detect movement. The sensors placed straight to the skin could be used also for other purposes than sports as they can measure so versatile things from the sweat, such as cortisol which is marker of stress (Heikenfeld, 2016). When this technology will become more developed and available in the consumer markets also, there will most definitely be a demand for it. Anzaldo (2015) names a couple of new techniques, such as woven technology and printed electronic ink that could be used for these purposes as well in the future. These technologies would be useful to anyone doing sports who want to track what is going on in their bodies. With help of the technology some of the soft-tissue injuries could be avoided in all levels of sports and a better understanding of body activity could be reached.

Figure 2. Wearable lactate threshold sensor (a), WLT combined in compression calf sleeve (b) (Borges et al., 2016).

2.4. Concussions

Concussions are quite typical in team sports that have contact with other players, for example in American football, rugby and ice hockey. A concussion is not dangerous if it is treated in a right way, but noticing it might be the most challenging part of the treatment as the symptoms of a concussion may happen much later than the impact itself. Also the symptoms vary a lot depending on the person. Especially in matches the players may disregard some of the less severe symptoms caused by a concussion to be able to play the match to the end. With wearable technology in helmets it is possible to find out which hits cause a danger of the concussion and which do not. Both of the research presented in this chapter done are related to American football, as the probability of concussion is approximately 75% higher in American football than in any other sport (Ramasamy & Varadan, 2016).

"Concussion is a transient disturbance of brain function induced by biomechanical forces from a direct or indirect blow to the head" (Bonin et al., 2015, 1257). An impact to the head causes strains to the neural tissue and the severity of strains depends on the impact severity and the impact direction. If the strain magnitude is high enough it may cause also transient changes to neuronal function. With helmet design it is possible to minimize the effect of impacts to the head and with wearable technology attached to the helmet or elsewhere to the head it is possible to measure the impact forces by measuring linear and angular acceleration. (Bonin et al., 2015)

Bonin et al. (2015) researched two commercially available wearable sensors, helmet system HITS and X2 mouthguard which are both based on accelerometers. The head impacts were tested with a horizontal linear impactor and a total of 896 impacts from 12 different sites were tested with the sensors. Both systems detected 95% of the hits between 3.6 and 11 m/s that were tested. Ramasamy & Varadan (2016) researched a helmet that was equipped with 3D accelerometer and nanosensors for EEG signal acquisition to detect concussions in real-time. Both the system level functionality and individual functionality were proved to be acceptable and the system gave better possibilities to interpret concussions in real time.

Neither of the systems studied by Bonin et al., (2015) were able to accurately estimate the direction or the magnitude of the impacts. Despite the limitations the wearable sensors had in the study, they provide important information on the head impacts in contact sports. With help of the error data from the research it is possible to examine player safety and among others helmet design even closer. (Bonin et al., 2015) The research performed by Bonin et al. (2015) was a lot more diverse regarding the accuracy of accelerometers as they proved the accuracy from 12 different sites while Ramasamy & Varadan (2016) only did three simulated conditions. That may explain the more critical results that Bonin et al. (2015) got from the accuracy.

Considering player safety, it is important to be able to track all the impacts that may cause concussions. Concussions typically happen in team sports but the effect they cause affects training in individual level. Recovering from a concussion depends a lot on the injury severity but also on the age of the player, as brains develop until the age of 25. Thereby the younger players are detected to require a longer recovery. (Ramasamy & Varadan, 2016) After a detected concussion at least the professional series such as NHL and NFL have protocols that an individual athlete has to follow to be able to return to the game field. As these kinds of protocols don’t exist in amateur-lever series, discovering the concussions in those cases is more critical so that they could be taken care of. Also, in amateur-level teams there aren’t doctors and physical therapists to take care of and to monitor the players, so wearable technology has also thereby an important role. It could help amateur-level players to track and take care of concussions in an early phase even though the accuracy in the wearable sensors researched wasn't yet the best possible.

It has become clear that wearable technologies have enormous potential in preventing injuries in many different sports. Even though the studies presented are conducted in specific sports, many technologies could be broadened to many other sports as well. Preventing injuries is related to pretty diverse things in training. Overuse injuries are one example that can be prevented in many ways: controlling the amount of certain movements in one training, concentrating on right technique in certain movements and controlling the amount of certain movements in a longer period of time. Wearable technology that helps analysing the technique and training amount will be presented in the next chapter. As it seems, training analysis and injury prevention are pretty much related to each other.

3. Wearables in training analysis

The ability to analyse the previous trainings is crucial especially for elite athletes. Also for recreational athletes with goals the easiest way to help the progress forward is to analyse both the technique and the training amount. To ease that analysis, wearable technology has been developed to record technique, biovital signs and training amount, for example. These technologies make even real-time analysis possible in trainings.

3.1. Technique analysis

Technique analysis is especially in elite sports quite crucial as the right technique not only prevents injuries but also enhances performance. In competitions the margin that separates the competitors can be really small, and there even a small change in technique can make the difference. Analysing the technique has though been quite challenging especially in quick movements when human eye is limited. Analysis has also required experienced coaches to be able to detect quick changes and varieties in technique. Video has been quite much used tool in technique analysis but it requires watching several times and in longer performances it is also time consuming. With quick movements the problems with human eye still exist even though it is possible to slow down the videos. With the help of the wearable technology the analysis can be done almost in real time and in a reliable way where there is no risk of humane mistakes. Wearable technology in technique analyses has been examined in several sports.

Chavarro-Hernandez et al. (2016) have researched an electronic system to monitor biovital signs in weightlifting. This system measures the sEMG signal of the biceps and elbow's joint angles. The system was able to detect muscle activation signals and measure the joint angles in real time and with good accuracy. (Chavarro-Hernandez et al., 2016) Having an electrical system for technique analysis in weightlifting is especially important as many sports use weightlifting exercises in strength trainings. Also, the system developed by Chavarro-Hernandez et al. (2016) was designed to be a low-cost model which may contribute a lot to the distribution of the system. It can be used to give real-time feedback to the athletes in training and to analyse weightlifting techniques more carefully. System is worn by a volunteer in the research in figure 3. All the parts in the arm are for acquiring data and the processing unit is attached to the chest.

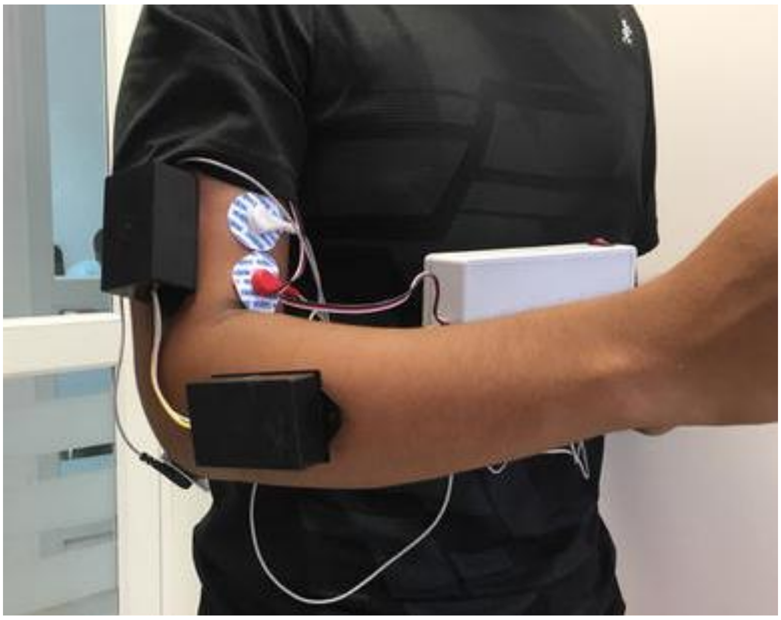

Figure 3. Electronic system for biosignal monitoring in use (Chavarro-Hernandez et al., 2016).

Another wearable technology to analyse the technique of the upper limbs is researched by Cortesi et al. (2015) in swimming. The system used wearable inertial-magnetic measurement units (IMMUs) to track the joint angles in upper limbs. The research was done in laboratory and the swimmers only simulated their technique in the laboratory because the research was much easier to control in the laboratory and in dry-land. (Cortesi et al., 2016) The system used in swimming is perhaps not as advanced or ready to be adopted as the system used in weightlifting. Also the reached accuracy of joint angles was better in the weightlifting research than in the swimming research. The movements and joint angles in swimming are much broader than in weightlifting which may affect the accuracy that can be reached with sensors.

Both swimming and weightlifting are holistic sports where the whole body is used to create the movement. Anyhow, only upper limbs' movement were researched in both cases. Buurke et al. (2016) have been researching running mechanics with the help of the IMMUs during the marathon. Also in this research the joint angles were researched, but differing from two previous cases, the joint angles were ankle, knee and hip. The duration is also much longer than in the previous ones, as the joint angles were measured during the whole marathon. The research was done outside the laboratory setting to find out the actual influence of fatigue in running mechanics in real environment. Both swimming and running mechanics were researched with IMMUs but the results of swimming mechanics were based on simulated swimming and might thereby not be as reliable as the running mechanics which were researched in a real environment.

The research performed by Buurke et al. (2016) was the first one to study 3D kinematic changes in running mechanics outside of the laboratory and for such a long way. It proves that the wearable technology using IMMUs is actually new and still developing. The research performed by Cortesi et al. (2016) was performed in dry-land to reach better accuracy and control over the study. For the same reasons the study was performed in a laboratory-setting. Chavarro-Hernandez et al. (2016) studied biovital signs in weightlifting and the study was also conducted outside the laboratory as the system aimed to be wireless and portable. These studies show that the development of the wearable devices to help in technique analyses is constantly developing. In swimming the water as one element may cause some challenges to the technology but in sports that take place in dry-land it has been possible to analyse the technique outside the laboratory.

For the sport consumers outside the elite sports technique analysing might be as important. When there is no element of competition and gaining competitive advantage by the right technique, having the right technique can be emphasized by avoiding injuries. Both of the sports researched outside the laboratory, running and weightlifting, are also popular sports among the sport consumers. Achieving the right technique is crucial in both as both can cause injuries when done wrong. Many people train these sports without coaches and thereby a wearable system that analyses technique could be really useful. Of course, in elite sports the coaches interpret the results from the sensors, but a system could be developed to give feedback on the technique based on the sensor results. A research group in University of Utah has been researching sensors to be placed into shoe insoles to give feedback on gait (Mertz, 2013). The same technology could be expanded in learning new sports or improving the technique, where an application would compare the data collected from sensors to the data created by professionals and give feedback based to the comparison (Mertz, 2013).

3.2. Analysis related to amount

Some of the wearable technology is designed to gather information from training. Both elite and recreational athletes typically use training diaries to follow their training amount and the improvements related to speed, power or endurance, for example. As a training diary is a subjective tool for describing training load and training information, Connor et al. (2015) researched the accuracy of training diaries with help of a wearable camera device, SenseCam, and an accelerometer. The research showed that there were differences between training diary and objective methods in training intensity, training duration and travel time for training the session (Connor et al., 2015). Comparing subjective training diary and objective camera and accelerometer can be confusing for athletes as individuals may have different perceptions of training intensity, for example. On the other hand these objective measures can be a good way of making sure that the training is in the target level and that the information in the training diary is correct.

Jain (2015) provides a smart gym framework that is based on the idea of smart cities. A smart gym system could track the movements and repetitions done in the gym and the weights that were used. Based on the vital signs, machine feedback and the workout history the system could recommend a personalized workout plan for every workout. The system would require a fitness device and smart gym equipment that are able to communicate with the system. (Jain, 2015) This kind of system could again record data that has previously been written in training diaries. Analysing gym trainings could be easier with the data that the system objectively provides rather than subjective training diary.

Having a training diary is more typical for athletes who have goals to achieve and coaches that help analysing the training diaries. They are not elite athletes only, but having a training diary is probably rarer among the fitness consumers. Thereby these inventions may not be as useful for the sport consumers as for competitive athletes. Though, smart gym system could help anyone to keep improving their results in the gym even without a coach because the system could take many aspects into account when developing a workout plan. The smart gym framework is probably actually more suitable for consumer markets as the elite level athletes typically have a ready plan for their gym workouts made by their coaches. It could still help also them to track the movements and weight used without a subjective training diary.

4. User experiences of wearables

To be the next big breakthrough in technology or sports industry, wearable technology companies will have to pay even more attention on the users and the user experience. Poor user experience or unnecessary features may cause consumers to reject wearable devices. That is why it is important to invest in the user experience as much as the technological aspects of the products. The user's opinions and needs can be found from research but also straight via consumers themselves. First some theoretical background will be presented and then it is compared to the use cases conducted via interviews from fitness consumers and Finnish athletes.

4.1. Designing user experience

Wearable technologies used nowadays are still mostly sport watches with heart-rate monitors and GPSs. Therefore, also most of the user research is still focused to the more traditional technologies as the new innovations are just rising. Nylander & Tholander (2015) have researched the use of sport watches and users' relation to their wearable technology and sport itself. They interviewed ten athletes, both recreational and elite, who use wearable technology in endurance sports. The research found out that people used the technology only to complement the subjective feeling they get from the training.

Biocca & Shin (2017) have researched the user experience and the forms of health feedback in the quantified self movement. As the quantified self movement concentrates on tracking different signals from human bodies, the research was not similarly about users' relation to the technology but about how the user interface should be in quantified self. Biocca & Shin (2017) found out in the research, that health feedback is most efficient when it is displayed in comparative form and in text. Comparative feedback motivated the users to perform preventive health measures better than the non-comparative. Also the feedback in text was found more motivating than feedback in images in the research.

Nylander & Tholander (2015) emphasize in their research, that for many, even for elite level athletes the lived-sense of being an athlete is more important than the objective measures gained from technology. Even though the athletes used the technology to help them to set and achieve goals, gather data and analyse training, they did not feel they are doing sports for the matter of technology but it was only a helping tool. (Nylander & Tholander, 2015) As all the participants in the research were quite active in doing sports, also the use of wearable technology was quite natural part of doing their sports. Thereby the research could also concentrate on users' relations. Biocca & Shin (2017) emphasize the poor user experience in quantified self. Difficult interface and usability are the main reasons that affect the consumers' acceptance of the technology. By their research, Biocca & Shin (2017) have been trying to influence on the quantified self technology development. By a user-centered point of view it is possible to develop technology that motivates consumers to use it.

Jäntti (2017) has also written about wearable technology design and how it influences the users' motivation to use the technology. Also she emphasizes the importance of user experience and the design aspects for wearables to make a breakthrough in consumer markets. To the elite athletes the design or the user interface of the wearable technology may not be as important as the pure data that wearables are able to offer. For consumers willing to have healthier life habits or adding motion into their days those things can be crucial regarding the motivation to use the technology. Jäntti (2017) emphasizes also the meaningful feedback from the wearables, which Biocca & Shin (2017) have researched; the feedback that motivates is comparable and in text format.

Jäntti (2017) mentions also that the social sharing aspect in the feedback could motivate if the comparison is done with a group that has similar level of activity. On the other hand, Nylander and Tholander (2015) found out in their research that social sharing and comparing the data from their sport watches played a really minor role to the interview participants. This may be explained as Jäntti (2017) concentrates on really novice consumers whose goal might be just to add some exercise to their lives. They need all the possible pushing to keep motivated and to get started with their exercising. Participants interviewed in the research by Nylander & Tholander (2015) were recreational or elite athletes who already had regular exercising habits and many of the participants had some precise goals in their sports. For those people the comparing of the sports data is not motivating as they are trying to reach their own goals.

As can be seen already from this material, different user groups of wearable technology need also different feedback. Jäntti (2017) hopes the feedback to become as personal and accurate as possible to really motivate the consumer. Also Gartner mentions smart coaching to be one of the wearable trends the next years (Goasduff, 2016). By that they mean the ability of machine intelligence to analyse the gathered biometric data and to provide real-time advice and feedback. Clearly the meaningful feedback is a property that will be required from wearable technology to motivate consumers to use it. Jäntti (2017) names the user motivation for a longer period of time as the biggest challenge wearable technology companies has to overcome. Though, the feedback property is probably most valuable for those consumers who do not have too high goals with their exercising. More exercise-oriented people may use the wearable technology only for completing their own feelings and for getting more accurate data from their training.

4.2. Use cases

Like said earlier, most of the wearables' use is nowadays still focused on the wrist-worn wearables. Use cases are gathered from the internet and by interviewing Finnish athletes and fitness consumers about their wearable devices. Fifteen Finnish national level track and field athletes were asked in April 2017 whether they use any wearable technology and only three of them said that they are using. The number tells about the low use rate of wearable technology even in competitive sports. The interviewees who had a device were asked about their experiences of their wearables and whether they felt it useful and were still using it. Most of the use cases are related to activity detectors worn in the wrist.

Seven women, who were not especially active in sports, tested different Polar activity trackers for four weeks organized by Anna-magazine (Haikarainen, 2016). All of them said that the devices were a good motivator in adding motion in everyday life because they counted steps and activity and set goals for those. Many of the women also started more active training in the test period and used the data to analyse their trainings and the diversity of trainings done in one week, for example. Some of them also tracked the quality of the sleep with help of the tracker and the daily calorie consumption was followed by some. All of the women found the device pretty useful and motivating, the only downside mentioned was the lack of GPS. (Haikarainen, 2016) Some factors that might have influenced the positive feedback were that the women got the devices for free and that for the most of these were the first activity trackers they tested. Test period was also relatively short, so the motivation for using these activity devices for a longer time was not properly tested. For this shorter period, the usability and diversity of the functions available satisfied the test group extremely well.

Two Finnish national level athletes find their activity trackers / sport watches useful in their sports and use those actively. Noora, a hurdle runner, uses Fitbit activity tracker that has also lots of other features such as GPS, heart rate measuring from the wrist and synchronization with phone app (Toivo, 2016). Athlete A, a shot putter, uses Polar activity tracker that measures heart rate from wrist and can be synchronized with phone app as well (Athlete A, 6.4.17, an interview). Both of them use the device in their training to find out the heart rate, intensity and also calorie consumption. Athlete A found it especially useful that there were separate programs for different sports such as strength or running.

Both of the athletes also use the app to analyse and follow the training amounts and activity but they did not use it for measuring sleep. Athlete A found the device disturbing while sleeping because it had a light in it and neither Noora uses it for sleep tracking. The easiness of use is thanked by both of the athletes, as no additional device for heart rate tracking was needed. However, both of them also criticize the accuracy of heart beat in high-intensity training. Both Fitbit and Polar activity tracker seem to lose the heart beat when there is a lot of motion or the heart beats goes higher because measuring from wrist is still more inaccurate than from the chest. In general both of the athletes find their trackers pretty useful and the only downside mentioned is the inaccuracy in heart beat tracking.

The interviews showed that the quality of the tracker played some role in the user activity. Consumer A, fitness consumer, did use her Cielo device for a little time but then found it unnecessary (Consumer A, 6.4.17, an interview). Athlete B, CrossFit athlete, also had a Garmin activity tracker with basic features such as steps count and calories burned and she did not find it really useful to use either (Athlete B, 6.4.17, an interview). Both Athlete B and Consumer A used the tracker to track sleeping quality, Athlete B mostly for that. Athlete B complained that the device did not record any other sports than steps taken, so the device was not very useful in crossfit, for example. Consumer A used her device regularly for a little time but then got tired of it. None of these devices measured heart rate, for example. It seems that these devices did not motivate the users to keep using them, as both Athlete B and Consumer A exercised regularly so the device did not motivate them to add activity and did not provide enough information of their trainings to keep it interesting.

One more special use case is Athlete C, Finnish national level discus thrower, who has type 1 diabetes. He was offered a chance to try an under-skin device that can measure blood sugar levels continuously for two weeks (Athlete C, 6.4.17, an interview). One device lasts under the skin for two weeks and the patient can change it by himself. He found the device really useful as he could follow the blood sugar variation constantly during trainings and competitions. As the device is relatively new it is also pretty expensive. Athlete C said that if the price of the new device would be reasonable, he would definitely prefer using that instead of the old methods of measuring blood sugar because it is much more useful to combine with sports. These kind of devices belong more to the field of health care but they can have an impact in the other fields as well. This device is a perfect example of new technology being developed which still has to be developed more to meet the criteria of consumer markets.

To summarize the use cases, it seems that also the activity trackers have to have enough meaningful features and feedback that consumers or athletes from any level keep using them. Both competitive athletes and consumers needing some motivation boost were pleased with their devices when they had enough functions, possibility to analysis and they were motivating to exercise even more. More simple devices did not provide data precise enough to be used in analysis or did not motivate to move more. Contrary to the research results it seems that also the technical aspects played a significant role in use motivation with wearable devices.

5. Critics on wearables

Wearable technology is able to offer many positive things and useful information but also critics on wearables have been stated. Halson et al. (2016) criticise the wearable technology industry of selling technologies that are not rigorously and independently tested to determine the accuracy of the technologies. Baca & Schwartz (2016) note as well that the data validation processes have been undertaken in research projects and only for some high-quality consumer wearables as the processes are time consuming and expensive. They also criticize the accuracy of activity trackers that are based on acceleration data. Trackers can detect movements that are not actual activity and count them to daily activity. Also misplacements can cause accuracy errors in activity trackers. (Baca & Schwartz, 2016) It may be true that the technology companies are not testing their wearables carefully enough. However, even on this study there has been a couple of studies that confirm the accuracy of commercially available devices. Those researches do not however remove the fact that the producing companies should have confirmed the accuracy of their devices themselves. As some shortages on accuracy were found, it means that the companies have not done their work properly.

Halson et al., (2016) criticise the companies that produce technology to measure sleep and recovery to not publish their algorithms. Also very few devices are compared to the golden standard of polysomnography, which usually refers to a multi-parametric sleep study supervised by medical staff (Halson et al., 2016). They also question whether it is important for athletes to have data of their sleeping from every night and if striving for perfect sleeping every night causes stress which may complicate the sleeping. These notices are important to consider and it may depend on individual athlete whether the amount of data available really helps or causes more stress. Sometimes gaining the competitive advantage in elite sports depends on really small things, such as monitoring sleep, and to gain that advantage many athletes are ready to try diverse things.

Some ethical questions of wearable technology are also involved. Baca & Schwartz (2016) question whether the data collected by the devices is safe from third parties in the cloud where it is stored. The data safety is actually one of the biggest concerns regarding wearable technology. The devices are able to collect very diverse data on their users and that data could be used for many purposes, for example insurance companies could use the data for defining the injury payments. Choo et al. (2017) researched an Android Wear wearable device and found out it stores a large amount of sensitive data such as sound recordings, smart phone notifications and biomedical data. The data privacy may not be one of the companies' biggest concerns when developing new wearable devices as they are striving for better usability and smaller size of the devices. Choo et al. (2017) found out in their research that device encryption that is typical for smartphones, was not possible for smart watches even though they have personal data in them as well.

Halson et al. (2016) claim that the marketing of wearable devices is based on pseudoscience and social psychology even though it should contain facts and evidence-based statements. They state that the marketing of the wearable devices and the general information overload is confusing the athletes and coaches. Marketing in general is not based only on facts but it appeals to feelings, so why would the marketing of wearable technology make an exception? It is true that nowadays it is possible to measure all kinds of data and every athlete should find the essential data measures for themselves as measuring every possible biovital sign might only cause too much stress on athletes. Nevertheless, elite athletes typically consider their choices based on the effect they have on their sports, so they may not be the group that suffers most of the information overload or marketing efforts.

6. Summary and conclusions

Even though wearable technology has limited consumer selection in the market still, there is huge market potential in wearables. At least for elite athletes the wearable technology can provide competitive advantage by preventing injuries, analysing technique more carefully and in real-time and also following the fatigue and recovery more closely. For elite athletes the pure data provided by wearables is probably the most important feature in the devices but for the consumer markets the user experience is as important. Many fitness consumers train without coaches so they may need help analysing the data provided by the devices. If that problem can be overcome, for example by smart coaching, these advanced technologies have a huge market potential in the consumer market as well. For everyone dealing with sports avoiding injuries and having the right technique are goals that are taken for granted and by wearable technology that could be made easier also for consumers without coaches.

Wearable devices that are meant to motivate people to exercise more have to be designed carefully. The feedback has to be personal, meaningful and motivating so that people will keep on using their devices. Data privacy has to be carefully taken into account when designing any kind of wearable devices and the technology should be carefully tested before entering the market. If these matters are taken into account when planning, designing and producing wearable technology, they have all the possibilities to be the next big breakthrough in the field of sports.

To conclude, for elite athletes wearable technology provides already a possibility to gain competitive advantage. With some changes in the devices and the design these advanced technologies could be brought also into consumer markets where they could benefit recreational athletes in achieving their goals. However, the interviews and studies reveal that using wearable devices is not very common yet and it is mostly limited to wrist-worn devices. It can be assumed that wearable technologies will be developed in the near future and both elite and recreational devices will advance. In consumer market the user experience and design seem to be more important than technology advances, at least for now.

Research questions were related to the use of wearable technology in sports now and in the future. This paper managed to present an overview of technologies that are now being used or researched in the field, but the future use remains a bit unclear. Some of the advanced technologies might come to consumer markets but the advanced technologies of the future remain naturally unclear. Suggestions for future research are finding out requirements to turning advanced technologies suitable for consumer market and studying the data privacy even more closely

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