THE EFFECT OF COMPRESSION SOCKS ON BALANCE SKILLS - RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

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Using compression materials to enhance physical performance is rapidly becoming the hottest topic in today's sports and exercise, which is why sportswear companies are starting to create modified versions of compression garments that are being used for medicinal purposes. In addition to improved injury prevention (Bernhardt & Anderson 2005; Cameron et al. 2008), decreased amount of lactate in the bloodstream (Kraemer et al. 1998: Bringard et al. 2006; Sperlich et al. 2013) and enhanced performance in high-intensity exercises, studies have suggested that compression garments may improve the kinesthetic sense (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014). The purpose of this study is to evaluate the effect of compression socks on motor learning, specifically balance and agility after an 8-week training program.

The participants were a group of 49 males and females between the ages of 18-75. They were non-athletic adults who were matched by experience with physical activity and sport as well as their age. A preliminary survey was done to ensure that the subjects' medical conditions were good. The subjects were divided into two equal groups, of which the experimental group used compression socks (Zeropoint Oy) during an 8 week training period. The materials consisted of 20% Nylon, 20% Lycra and 60% Coolmax. The socks that were used were the *Intense Compression Socks,* which had a compressive effect of 20-30mmHg. The socks were designed to have a graduated compression that was tighter around the ankle while decreasing the compression closer to the knee. The other test product was a *running compression* sock from Pro Touch that was made from 98% Polyamide and 2% Elastane, which did not have the same medically compressive effect.

Both of the groups participated in the same 8-week training program. The baseline measurements determined how the two groups were divided. The groups had to be at a similar level of balance. The balance was measured by a force plate: one legged stance with eyes both open and closed for 30 seconds. The number of people in the both test and control groups were 15-20. The program consisted 8 weeks/2 one hour sessions per week. The progression was measured by pre- and post-training tests.

The experimental group had a significant reduction (p= ,009) in peak balance displacement during a fast anterior perturbation, which means that the subjects were able to retain better balance during a fast perturbation. The experimental group also had a significant reduction (p= ,031) in peak balance displacement during a slow anterior perturbation, where the center of pressure displacement was decreased. The evidence showing the effects of a balance training period paired with the use of compression materials improved the participants' balance slightly, but not statistically significantly. It was, however, concluded that combining compression socks with a balance exercise program may yield to better results than without compression socks.

Keywords: compression, garment, proprioception, kinesthesia, balance, force, plate, motor skill, intervention

TIIVISTELMÄ

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Urheilusuoritusta parantavat kompressiomateriaalit ovat nopeasti nousseet polttavaksi puheenaiheeksi nykyurheilussa sekä -liikunnassa, minkä takia monet urheiluvaatemerkit ovat alkaneet kehittää omia versioitaan kompressiovaatteista, joita on alun perin käytetty lääketieteellisessä käytössä. Pienentyneen loukkaantumisriskin (Bernhardt & Anderson 2005; Cameron et al. 2008) alentuneen veren laktaattipitoisuuden (Kraemer et al. 1998: Bringard et al. 2006; Sperlich et al. 2013) ja korkean intensiteetin suorituskyvyn paranemisen lisäksi tutkimukset ovat osoittaneet kompressiomateriaalien edesauttaneen kehon kinesteettisen aistin toimintaa (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014). Tutkimuksen tarkoitus on selvittää kompressiosukkien vaikutusta motoriseen oppimiseen, etenkin tasapainoon sekä ketteryyteen 8 viikon harjoitusjakson aikana.

Tutkimukseen osallistui 49 miestä ja naista, joiden iät vaihtelivat 18–75 välillä. He eivät olleet liikunnallisesti aktiivisia aikuisia. Ryhmät olivat jaettu liikunnallisen historiansa sekä ikänsä mukaan. Osanottajille oli annettu kyselylomake ennen tutkimusta, jotta saatiin varmistettua heidän olevan fyysisesti terveitä tutkimukseen osallistumiseen. Osallistujat jaettiin kahteen ryhmään, joista koeryhmä käytti lääketieteellisessä käytössä olevia kompressiosukkia (Zeropoint Oy) 8 viikon harjoittelujakson aikana. Testisukan materiaali koostui 20% Nylonista, 20% Lycrasta and 60% Coolmaxista. Tutkimuksessa käytetyt sukat olivat *Intense Compression Socks* -sarjaa 20-30mmHg:n puristusteholla. Sukat olivat suunniteltu asteittain lisääntyvällä puristuksella, mikä oli tiukimmillaan nilkan kohdalla ja löysempi lähellä polvea. Toinen testissä käytetty sukka oli Pro Touchin *running compression* -sukka, joka oli valmistettu 98%

Polyamidista ja 2% Elastaanista. Kyseisillä sukilla ei ollut samanlaista asteittain löystyvää puristusominaisuutta.

Kontrolliryhmällä oli sama harjoitteluohjelma, mutta he eivät käyttäneet lääketieteellisessä käytössä olevia kompressiosukkia. Molemmilla ryhmillä oli sama 8 viikon harjoitteluohjelma. Koe ja kontrolliryhmä jaettiin alkumittauksen perusteella. Tavoitteena oli muodostaa kaksi ryhmää, jotka olivat tasapainotaidoiltaan samalla tasolla. Tasapainotaitoa mitattiin tasapainolaudalla: yhden jalan seisonta silmien ollessa kiinni sekä silmien ollessa auki 30s. Osallistujien määrä oli 15–20 yhtä ryhmää kohden. Harjoitteluohjelma koostui 8 viikon harjoittelusta. Harjoituskertoja oli kaksi kertaa viikossa. Kehitystä seurattiin alku- ja loppumittauksilla.

Koeryhmällä tapahtui merkittävä vähennys (p= ,009) tasapainon menetyksen suurimmassa arvossa nopean anteriorisen häiriön aikana, mikä tarkoittaa sitä, että osallistujat kykenivät ylläpitämään tasapainonsa paremmin nopean häiriön aikana. Koeryhmällä oli myös merkittävä vähennys (p= ,031) tasapainon menetyksen suurimmassa arvossa hitaan anteriorisen häiriön aikana, jossa painopisteen muutos oli vähentynyt. Tutkimus osoitti kompressiomateriaalien käytön yhdessä tasapainoharjoitusohjelman kanssa parantaneen osallistujien tasapainotaitoja hieman, muttei tilastollisesti merkittävästi. Sen sijaan tutkimus antoi viitteitä siitä, että tasapainoharjoitusohjelman aikana käytetyt kompressiosukat saivat aikaan parempia tuloksia verrattuna sukkiin, jotka eivät olleet lääketieteellisessä käytössä.

Avainsanat: kompressio, sukka, proprioseptiikka, kinestesia, tasapaino, tasapainolauta, motorinen taito, interventio

TABLE OF CONTENTS

1 INTRODUCTION

Using compression materials to enhance physical performance is rapidly becoming the hottest topic in today's sports and exercise, which is why sportswear companies are starting to create modified versions of compression garments that are being used for medicinal purposes. These garments include different sleeves, pants and shirts that are supposed to increase neuromuscular activity and blood flow in the muscles. There are some positive results when compression materials are used for rehabilitation purposes (Pearce et al. 2009). However, their use for exercise purposes has not always been conclusive. There are clear signs that compression materials work better in certain movements, such as repetitive jumps and running at high speed (Kraemer et al. 1998; Doan et al. 2003; Bottaro et al. 2011), whereas in some cases they might actually hinder the limbs natural movement (Birmingham et al. 2000; Cameron et al. 2008). The force of the compression also changes the results in different movements, which means that a certain balance must be found between the exercise and the compressive garment (Bottaro et al. 2011).

This Master’s thesis focuses solely on the effects of compression materials in learning new skills. There has been little research regarding this field, which makes it an interesting new aspect in compression materials. Although measuring skill learning has not been a focus in many of the studies, there are signs of improved proprioception when compressive garments are used (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014). This, on the other hand is a vital factor in learning new skills.

At first the thesis will be focusing on the definition of motor learning in movements and its three stages and examine how learning occurs neurologically. After this I will explain what compression materials are and what they do before, during and after exercising. However, the main focus of the thesis is on the effects of compression materials on the proprioception of the limb. The aim is to find a connection between learning new skills and using compressive garments.

2 LITERATURE REVIEW

This section of the thesis concentrates on the definitions of motor learning, skill learning and how they affect the human body. Thus, it is important to enlighten the concept of motor skill learning and its three phases: cognitive phase, associative phase and the automatic (Huisman & Nissinen 2005; Eloranta 2007; Jaakkola 2013) or autonomous phase (Gallahue & Ozmun 2002; Magill 2007, 265), and what they stand for. Additionally, this section gives preliminary insight to the neurological changes happening during these three stages. The thesis will go deeper into this matter on section three.

2.1.1 What is motor learning?

Learning motor skills is defined as a series of events within the body that is caused by repetition of the same performance (Doyon 2005; Magill 2007, 265) and leads to permanent and consistent changes in an individual's potential to execute movements (Gallahue & Ozmun 2002, pp.14; Eloranta 2007; Jaakkola 2013). It is a somewhat sustainable change in the information, skills, readiness and execution, that are based on the experiences of the individual (Huisman & Nissinen 2005). Motor learning is constructive by nature, which means that new skills are being developed from earlier skills (Eloranta 2007). The information is actively processed and structured by the brain, which means that the person is never solely receiving the information. (Huisman & Nissinen 2005.) Learning is often internal, which makes it difficult to measure (Jaakkola 2013). However the changes in execution are not always caused by learning. Often individuals face changes in environments that require instinctive alteration of one's behavior. (Huisman & Nissinen 2005.)

This efficacy is enhanced, because humans command their muscle contractions to reflect the perceived position of their limbs (Robbins et al. 1995). The progress in learning skills can be seen as better consistency, versatility and efficiency. This, on the other hand, leads to a better performance. (Jaakkola 2013.)

2.1.2 Three stages of learning motor skills

Gallahue and Ozmun (2002, 14) describe motor skills as a "*common underlying process of control in movement*". As mentioned earlier, every performance is observed, reflected and evaluated through previous performances (Eloranta 2007). Learning motor skills can be divided into three different phases: cognitive phase, associative phase (Gallahue & Ozmun 2002, 313; Eloranta 2007; Magill 2007, 265) and the automatic phase (Eloranta 2007; Jaakkola 2013). This is also known as the Fitts and Posner model (Magill 2007, 265). However, others have described the last stage as the autonomous stage (Gallahue & Ozmun 2002, 313-315; Magill 2007, 265). This three-stage process is affected by the mechanical interaction between the person and the environment (Doyon 2005; Kim et al. 2013). Through these stages it is possible to monitor the individual's progress (Jaakkola 2013).

The *cognitive phase* of learning is the early stage of learning a skill (Huisman & Nissinen 2005; Eloranta 2007). In this stage of learning skills, the individual tries to understand the nature of the activity he or she is trying to learn (Magill 2007, 265; Jaakkola 2013) and form a conscious mental plan for the movement (Gallahue & Ozmun 2002, 313). To form this plan the person might ask himself why, where, what or how to do the performance (Gallahue & Ozmun 2002, 313; Magill 2007, 265). At this stage, the information of the new skill is being gathered through listening (Huisman & Nissinen 2002, Magill 2007, 265), watching, feeling and observing it closely (Huisman & Nissinen 2005). It also requires the individual to visualize and form a schema of the movement. In the first stages of learning the concentration is focused on the intrinsic aspects of the movement, which leads to controlling the movement consciously. This causes the execution to be inefficient, since the person also focuses on external information. (Jaakkola 2013.) In addition to this, the characteristics of the cognitive stage include a large amount of errors and lack of consistency (Magill 2007, 265).

In the cognitive stage the nerves create a loose bond of nerves, which give the person an overall view of the task at hand. It gives the person an idea of what the task is about, and raises the interest to pursuit an answer to the obstacle (Eloranta 2007; Jaakkola 2013). After executing the same movement multiple times, the nerves start forming tighter and more intricate bonds, which make it easier to perform (Eloranta 2007). This stage provides the person with a lot of positive experiences through quick progress, which can be seen as high practice motivation (Jaakkola 2013).

The *associative phase* of learning physical skills is when the already learned skill is getting more accurate (Eloranta 2007), which is a result of practicing the skill for an unspecified amount of time (Magill 2007, 265). Gallahue and Ozmun (2002, 313) along with Magill (2007, 265) describe it as a point where the learner is able to perform the task by understanding environmental cues and the requirements of the movement. During this phase, the sensorimotor feedback is being compared and combined with older experiences of the same execution (Huisman & Nissinen 2005). This means that the person is already aware of what needs to be done to accomplish the task, which leads to actually learning the skill (Eloranta 2007). This leads to more accurate and efficient movements, because the person is not using unwanted muscles during the motion. This is caused by a faster nerve mechanism that provides the impulse to the muscles. (Jaakkola 2013.) As a result, the person makes fewer mistakes while performing, since the basic mechanisms of the skill have already been learned (Magill 2007, 265). Due to the fact that the task starts to seem easier, it motivates the person to practice more, which speeds up the learning process (Eloranta 2007; Jaakkola 2013). Repeating the same task also brings more consistency to the execution and they start to resemble each other more (Eloranta 2007; Magill 2007, 265; Jaakkola 2013). Neurologically this phase requires a more widespread and thick mesh of nerves. (Eloranta 2007; Jaakkola 2013).

When the performance is guided by the subconscious part of the brain, the person has reached the *automatic phase* (Eloranta 2007) or *autonomous stage* (Gallahue & Ozmun 2002, 313-315; Magill 2007, 265) of learning the skill. It means that external and cognitive guidance is no longer needed (Huisman & Nissinen 2005) and the performance of the task becomes habitual with very little effort (Gallahue & Ozmun 2002, 313; Magill 2007, 265). In this stage of learning, the processing of the gathered information has simplified and become faster because of the way nerve schemas consist of a bigger and a more accurate mesh. (Eloranta 2007; Jaakkola 2013.) This, on the other hand, gives room for the brain to try and adapt the skill into new situations (Stillman 2002; Eloranta 2007; Magill 2007, 265-266; Jaakkola 2013). Additionally, each movement starts to resemble each other more (Jaakkola 2013). In short, automatic motor skills are accurate, consistent and fast relfex-like movement skills that are performed automatically (Eloranta 2007; Jaakkola 2013). They are also highly efficient, which is a result of an improved coordination between muscles, because the body is not using unwanted muscles to perform the movement. These factors give room for the person to concentrate on the environment, rather than the actual performance. (Jaakkola 2013.)

2.2 BALANCE

Balance refers to the ability to maintain postural stability while moving around the horizontal or vertical axis or staying still. Static balance can be described as the ability to maintain posture while sitting or standing in one place, whereas dynamic balance refers to the ability to sustain postural control during movements. (Kalaja 2012.) According to Haywood and Getchell (2009), stability and balance do not mean exactly the same. Balance is connected to the person's or object's ability to maintain equilibrium, whereas stability refers to the ability to resist movement. (Haywood & Getchell 2009, 38.) A good static balance does not correlate to a good dynamic balance. If a person's dynamic balance skills are challenged further, the body adapts to it by activating the muscles in the knees and hip. Therefore, the neural control needed to maintain balance in a dynamic condition is far greater. (Piirainen 2014.) Even though an increase in stability correlates to better balance, maintaining balance does not always lead to better stability. It also hinders movement, which may not be purposeful for athletes' dynamic movement. (Haywood & Getchell 2009, 38.)

Balance is a result of several perceptual systems working together, which help maintain postural control and balance (Abrahamová & Hlavačka 2008; Enoka 2008, 401; Haywood & Getchell 2009, 227; Gaerlan et al. 2012; Piirainen 2014; Woo et al. 2014). The somatosensory system, which consists of both tactile and proprioceptive systems, provides the most information (70%) for postural control in a stable well-lit environment (Woo et al. 2014). Visual receptors help the body understand how it works in relation to the environment, whereas the proprioceptive feedback gives information on how the limbs and body parts positioned relative to each other. (Enoka 2008, 401; Haywood & Getchell 2009, 227; Hijmans et al. 2009.) The kinesthetic input from the vestibular system helps control the position and movement of the head (Enoka 2008, 401; Haywood & Getchell 2009, 227). Even the auditory system provides information that can be used to help maintain balance (Haywood & Getchell 2009, 227). Therefore, balance is a combination of many different factors, such as visual, vestibular and somatosensory systems (Gallahue & Ozmun 2002, 387; Enoka 2008, 401; Gaerlan et al. 2012), adaptive systems, postural muscle response synergies (Ozmun 2002, 386; Piirainen 2014), joint range of motion, body morphology and muscle strength (Gallahue & Ozmun 2002, 386).

Maintaining adequate muscle strength (Ozmun 2002, 387; Piirainen et al. 2013) especially in the lower limbs helps sustain balance in everyday life as well as during slips that may cause falling (Gallahue & Ozmun 2002, 387). It has been proven that people in all age groups are able to gain more muscle strength through exercise. (Gallahue & Ozmun 2002, 387.) It has been previously suggested, that reflex amplitude decreases with age. This may also cause a decrease in muscle spindle sensitivity and/or a decrease in nerve conduction speed. The changes can cause the reflex size to be decreased. (Piirainen et al. 2013.)

Different sensory pathways (visual, vestibular and somatosensory inputs) have a vital role in balance control (Gallahue & Ozmun 2002, 387; Enoka 2008, 401; Gaerlan et al. 2012; Piirainen 2014). Visual system provides information of the environment, whereas the vestibular system senses the changes in orientation and motion of the head. The somatosensory system consists of cutaneous sensors and proprioceptors (joint receptors, muscle spindles and Golgi tendon organs). (Hijmans et al. 2009; Gaerlan et al. 2012; Piirainen 2014). These receptors help provide information of joint positions and muscle length, which are essential for maintaining good dynamic balance (Hijmans et al. 2009; Gaerlan et al. 2012; Piirainen 2014; Woo et al. 2014). The tactile stimulation inputs from cutaneous mechanoreceptors provide the central nervous system with information about pressure distribution and body position (Gaerlan et al. 2012; Woo et al. 2014). If these systems work accurately and transmit the information gained from the outside world, it should help maintain balance control virtually unaffected through the whole lifespan of the individual. (Gallahue & Ozmun 2002, 387; Enoka 2008, 401; Gaerlan et al. 2012). However, since older adults receive less information through visual and vestibular systems, the ability to maintain balance and regain it after a disturbance in balance is reduced significantly. (Gallahue & Ozmun 2002, 387; Abrahamová & Hlavačka 2008; Enoka 2008, 401.) On the other hand, proprioception is frequently used to maintain balance when visual or vestibular feedback is reduced or hindered (Gaerlan et al. 2012).

Joint range of motion may also have an essential role in maintaining postural control and balance. Even though the range of motion and joint flexibility decrease with age, they can still be improved with exercise. Through appropriate training the gap in flexibility between young and older adults can be reduced significantly. (Gallahue & Ozmun 2002, 386-387.)

The adaptive system helps the person to take an old skill and adapt it into different environments with varying demands. This system modifies the sensory input and provides motor output that can best be used in that specific task or environment. The muscles in the ankles, knees and hip must have to be used correctly in relation to the surface to maintain balance in different situations. (Gallahue & Ozmun 2002, 387; Enoka 2008, 401.) Additionally, the free ranges of motion in various joints have an effect on different balance challenges. Finally, the differences in body morphology cause changes in stability. These factors include height, center of mass, foot length and body weight distribution. (Gallahue & Ozmun 2002, 387)

Postural muscle response synergies are essential in maintaining postural control (Gallahue & Ozmun 2002, 387; Abrahamová & Hlavačka 2008; Enoka 2008, 401). It refers to the co-operation and activation of muscle groups that help sustain balance. Therefore it is important that the right muscle groups can contract at the right time and help prevent falls. However, it is important to remember that this co-operation of muscles also rely on the information provided by the visual, vestibular and somatosensory systems. These systems give information of the positions of the limbs in relation to the environment. (Gallahue & Ozmun 2002, 387; Enoka 2008, 401.)

Interestingly, patients with a loss of one of these senses are able to rely on other sensory information to help maintain balance. On the other hand, aging decreases the ability to pick up the right sensory input, which leads to a different action for maintaining balance. The ability to sustain balance is often measured from the displacement of the individual's center of pressure when standing. (Enoka 2008, 401.) That is also the reason why this study used a force plate to measure the changes in the subjects' center of pressure during fast and slow perturbations.

2.2.1 Age-related changes in balance

The aforementioned neuromuscular and sensory (vestibular, somatosensory and visual) systems deteriorate with age, especially the proprioception sensors and the tactile-proprioceptive feedback (Abrahamová & Hlavačka 2008; Woo et al. 2014). This leads to a lower neural activity, which can delay the stabilization process (Woo et al. 2014). In addition to lower neural activity, aging also has a negative effect on the sensory system, muscle strength, the amount of muscle fibers and muscle volume (Abrahamová & Hlavačka 2008). Older age is often accompanied with the deterioration to control automatic movements like gait and posture (Abrahamová & Hlavačka 2008; Enoka 2008, 401). These changes are also closely connected to the decline in the amount of walking and performance in other activities in the elderly population (Enoka 2008, 401). The change in posture control affects the body's ability to maintain balance, which can lead to falls and serious injuries in the elderly (Abrahamová & Hlavačka 2008; Enoka 2008, 401; Woo et al. 2014). Additionally, the loss of muscle strength and balance may amplify the physical deterioration (Enoka 2008, 401).

Force platform tests have showed that the amount of sway is the smallest in adulthood. During slower unexpected perturbations and static movement, maintaining balance requires activation in the ankle to bring the person upright again. (Haywood & Getchell 2009, 227; Piirainen 2014.) This is in contrast to the back and forth movement where the person knows the direction of the next perturbation. In this case the person uses visual information to stabilize the upper body and head. In both of these cases the ankle muscles responded to the loss of balance and tried to help the person regain balance. However in an even faster perturbation, the hip muscles are needed to regain balance. (Haywood & Getchell 2009, 227.)

Earlier studies have shown that older adults suffer a decline in the ability to maintain balance as they age. In an upright position over 60-year-olds sway more than younger adults, especially while in a leaning position. These results have been experienced on movable platform tests, where the older participants showed a longer time period before the muscles reacted to the perturbation. Sometimes the upper leg muscles responded before the lower muscles, like ankles, which is the opposite to that of younger adults. (Haywood & Getchell 2009, 227.)

The age-related decline in maintaining balance could be related to many different physiological changes that the body goes through as it ages. The most important factor in these changes is the nervous system. (Haywood & Getchell 2009, 227; Ostry et al. 2013.) Studies have shown that ageing has a negative effect on nerve condition velocity and receptor morphology. This means that the nerve conduction speed in both central and peripheral nervous systems slow down with age. Some older adults have also shown structural changes in the kinesthetic receptors, especially in the lower limbs. (Abrahamová & Hlavačka 2008; Haywood & Getchell 2009, 227-228; Ostry et al 2013). Ostry et al. (2013) stated that introducing textured materials could stimulate peripheral receptors that are not otherwise being stimulated.

The changes in visual and vestibular systems may cause further challenges especially to people over 70 years of age (Abrahamová & Hlavačka 2008; Haywood & Getchell 2009, 227). As the body ages, it also faces a loss of fast-twitching muscle fibers or a decrease in muscle strength, which can slow down the person’s ability to respond to sudden loss of balance (Haywood & Getchell 2009, 227-228).

2.3 NEUROLOGICAL BACKGROUND OF MOTOR LEARNING

Motor learning occurs, when the brain forms a plexus of nerves out of individual nerve cells. Later on these plexuses will join with each other to for a complex mesh of nerves. (Eloranta 2007.) This mesh of nerves forms a schema (Hikosaka et al. 2002; Eloranta 2007; Magill 2007, 92) which allows the person to learn different skills and their combinations (Eloranta 2007; Magill 2007, 92). Schemas are a diverse and comprehensive combination of nerves (Hikosaka et al. 2002; Eloranta 2007) that guide the thoughts, execution and perception of an individual (Eloranta 2007). Schemas are always formed individually and are based on the person's experiences, feelings, perception and interpretation (Hikosaka et al. 2002; Eloranta 2007).

The central nervous system, especially the brain, has a key role in controlling motor activity in the human body (Eloranta 2007; Magill 2007, 65). The information from the environment is received through the spinal cord (Gallahue & Ozmun 2002, 369; Magill 2007, 71) and it is handled by both the conscious and subconscious areas of the brain (Eloranta 2007). This information in the central nervous system is received through other sense organs in the body (Magill 2007, 71; Wong et al. 2011). The majority of the factors that control the motor behavior of the body are located in the subconscious area of the brain (Jaakkola 2013). This means, that an advanced system to communicate between them is needed (Eloranta 2007). Due to this, the human brain has approximately a 100 billion of brain cells, which form their own intricate messaging system (Gallahue & Ozmun 2002, 369). This gathered information is delivered electrochemically through axons, which are then received by other nerve cells through dendrites (Gallahue & Ozmun 2002, 370; Eloranta 2007; Magill 2007, 633-64). The junction between an axon of a neuron and another neuron is called a synapse (Magill 2007, 64), in which the transmitted electronic signal from one neuron to another is first turned into a chemical signal and then back to an electrical signal (Gallahue & Ozmun 2002, 370). The released chemical substances are known as neurotransmitters (Gallahue & Ozmun 2002, 370).

In motor learning this means that the information caused by a stimulus, like a sound or smell, induces a reaction in the body (Gallahue & Ozmun 2002, 375; Eloranta 2007; Magill 2007, 71), which allows the information to pass on from one nerve cell to the next (Eloranta 2007). This means that the chemical transmitter has gotten more responsive to that certain stimulus through repetition, which can also be enhanced through repeating it more (Eloranta 2007).

The foundation of human movement is based on the collaboration of the central nervous system and the musculoskeletal system (Gallahue & Ozmun 2002, 375; Eloranta 2007; Magill 2007, 77). This system works as the received information is transmitted to the brain and the musculoskeletal system simultaneously. This means that the human body works in a constant interaction between different systems of the body. (Eloranta 2007.) The development of skills is determined by how well the body reacts according to the information that is gathered through various senses (Gallahue & Ozmun 2002, 369-386; Eloranta 2007). This information is directed to the central nervous system (Gallahue & Ozmun 2002, 369; Eloranta 2007; Magill 2007, 76), where it creates the muscle response needed to perform the movement (Magill 2007, 72). This decision is based on the already created schemas of the individual (Eloranta 2007). From there, the central nervous system sends the information to the musculoskeletal system where the actual motion is done (Eloranta 2007; Magill 2007, 71-72). These types of closed skills need the coordination and fundamental movements learned in the first stages of learning (Magill 2007; 267-268), since the learning is based on repetition and experiences from former executions (Eloranta 2007; Magill 2007, 267-268). Due to the nature of learning new skills, no schema is identical to the original, because it constantly builds more information on top of the original schema. (Eloranta 2007.) In other words, the person’s senses are guided by former experiences (Gallahue & Ozmun 2002, 305; Eloranta 2007; Magill 2007, 267-268). This cycle of learning leads to more skillful executions. (Eloranta 2007.)

2.4 COMPRESSION MATERIALS AND THEIR PHYSIOLOGICAL EFFECTS

This section of the thesis provides insight to what compression materials are and how they affect the human body during exercise. At first the focus is on the material and its properties, with references to earlier studies that state the material's possible effects during exercise. The text will also take a look at how compression materials affect the blood flow and lactate removal during and after exercise. However, the physiological effects of compression materials will give a deeper insight on the matter, as well as taking a look at the effects during high-intensity exercise and on injury prevention. These facts work as a transition towards the compression materials effects on proprioception and skill learning later on in the thesis.

2.4.1 What are compression materials?

The idea behind compression materials in sports is to create a garment that prevents injuries, reduces chaffing while enhancing performance (Kraemer et al. 1998; Doan et al. 2003). These garments are often custom made to be smaller than the measurements of the athlete, depending on the amount of compression wanted. Due to the material's properties, it stretches to almost 100% of the original measurements while compressing the tissues under the skin. This creates a highly compressive fit, which allegedly enhances athletic performance by improving peripheral circulation, enhancing blood flow and accelerating the clearance of metabolites from the blood stream. (Sperlich et al. 2013.). The inside of the garment is sticky to reduce sliding on the skin surface. Due to their performance enhancing nature, compression materials, along with different braces, taping, bandages and other factors represent the latest trend in top-tier sports. (Doan et al. 2003; Akseki et al. 2012.) At the moment, different compression garments like sleeves, pants and shirts are mainly being used in sports requiring good neuromuscular control such as basketball, golf, volleyball and tennis. (Bottaro et al. 2011.)

Early studies have shown that tight-fitting compressive garments reduce the amount of lactate in the blood when worn during exercise (Kraemer et al. 1998; Doan et al. 2003; Ali et al. 2007;

Bottaro et al. 2011). When comparing the effects of compressive tights and compressive stockings, Bringard et al. (2006) found that reduced amounts of lactate were only evident when compression stockings were worn. The reason for this might have been in the material in the tights not being compressive enough when compared to the stockings. There are also signs that the right amount of external pressure to the muscle reduces the blood flow velocity of the venous system as well as increase the arterial inflow (Kraemer et al. 1998: Bringard et al. 2006; Sperlich et al. 2013). Kraemer et al. (1998) stated that compression stockings or tights reduced the venous stasis in the lower extremities. "*However, it also has been suggested, that reduced levels of blood lactate are attributable to a greater retention of the molecule within the muscle*" (Sperlich et al. 2013, 1). On the other hand, too much of external pressure from the compressive garment will reduce the blood flow in the muscle (Sperlich et al. 2013).

Other studies showed compression materials to have no effect on oxygen consumption, maximum heart rate during the exercise (Kraemer et al. 1998; Ali et al. 2007) or perceived delayed onset muscle stress after the exercise (Ali et al. 2007). This leads to a conclusion that evidence of reduced myofibril damage by using compression material is insufficient. (Ali et al. 2007.)

2.4.2 The effect of compression materials during high-intensity exercise

Two different studies have shown a significant reduction in hip range of motion, when the compression garment was used during exercise (Doan et al. 2003; Bernhardt & Anderson 2005). Doan et al. (2003) stated that this was caused by the reduction of the maximum hip flexion angle while sprinting. It indicates the increase in stride frequency, although it was not measured in the tests. There was no significant difference in sprint times between the experimental conditions, even with the reduced hip flexion. Additionally, wearing the garment did not change the kinematics or sprinting, because it did not interfere with the natural range of motion of the hip or the knees. This result indicates that compression materials do not have a negative effect on the stride while sprinting. In fact, the elasticity of the garment may increase the acceleration of the leg at the end of the stride. (Doan et al. 2003.)

According to Doan et al. (2003), a jump-power test showed single maximal countermovement increased significantly when the compression material was used. This was also evident in the average results in jump height of the athletes tested. Using the compressive materials increased the jump height by an average of 2.4cm compared to the control garment. (Doan et al. 2003.) Though, this result is contradictory to the results of Kraemer et al. (1998) where researchers did not detect a significant difference in jump height when compression materials were used. On the other hand, the tests revealed an enhanced power output during a repetitive jump test (Kraemer et al. 1998; Bottaro et al. 2011). Sperlich et al. (2013) concluded that the subjects recovered faster after a vertical jumping exercise, when compression garments were worn. Doan et al. (2003) found that the squat angle for the jump reduced significantly when compression materials were used, which led to a more optimal squat depth and greater impulse in the jump's concentric stage. (Doan et al. 2003.) Additionally, compression garments showed less adverse effects in vertical jumps than most other activities (Bernhardt & Anderson 2005). These results suggest that athletes, who perform vertical jumps in their sports would benefit from the use of compression materials compared to other sports.

Most of the research of the positive effects of compression materials are made using high-intensity exercises, rather than in submaximal levels of performance. Bringard et al. (2006) found out that wearing compression materials decreased energy cost in submaximal intensity exercises in comparison to normal loose shorts. Though, this outcome was not apparent, when compared to regular tight-fitting shorts. (Bringard et al. 2006.)

2.4.3 The effect of compression materials on injury prevention

While jumping, the compression garment may hinder the hip extension beyond 180° degrees. Due to this, the garment may assist the eccentric movement of the hamstrings which may result in reduced risk of injuries. (Doan et al. 2003.) This is due to the change in neuromuscular control in the lower extremities (Bernhardt & Anderson 2005; Cameron et al. 2008). This may result in a lowered risk of injuries, because one of the biggest risk factors in hamstring injuries is poor neuromuscular control (Cameron et al. 2008). In short, the garment seemed to be beneficial in preventing injuries, while allowing the functional movement of the limb (Bernhardt & Anderson 2005).

There are also signs that compression materials may help the muscle to keep in shape so that less structural damage is caused by the exercise. This may help reduce the delayed onset muscle soreness (Ali et al. 2007; Bottaro et al. 2011) as well as reduce muscle swelling (Born et al. 2013; Sperlich et al. 2013) in high-intensity sports. Compression materials are designed also to help the lymphatic outflow, which should aid the muscles to release metabolites to the blood stream. However, if the compression to the muscle is too strong, it would prevent a natural blood flow, which could render the theory useless. (Sperlich et al. 2013.) McNair et al. (1996) on the other hand, researched knee bracing's effect on proprioception. Through electromyography tests they found that the knee's proprioception was increased by up to 11%, when an elastic bandage was placed on the joint. This led to a better knee joint position while flexing. (McNair et al. 1996.) McNair and Heine (1999) stated that the trunk's position during activity and work are closely related to a possible risk of injury. Also, wearing compression garments can help improve the proprioception in places, where a person has lowered sense of proprioception due to former injury. (McNair & Heine 1999).

Doan et al. (2003) showed that both anterior-posterior and longitudinal muscle oscillation in the thigh reduced significantly when the compression garment was used. Kraemer et al. (1998) stated that compression materials reduced the vertical velocity of muscle movement upon landing significantly. This may help reducing fatigue due to enhanced neurotransmission, a more optimal muscle activity and increased support of the active muscles. (Kraemer et al. 1998; Bringard et al. 2006.) These results indicate that the reduction of oscillation is based on enhanced technique and reduced fatigue. This increase in ergonomics may lead to optimized neurotransmission and mechanics in the molecular level of the muscle. (Doan et al. 2003; Bringard et al. 2006.) This leads to a reduction in myoelectric activity, which can be seen as better exercise tolerance (Bringard et al. 2006).

There is also proof that using compression materials increases the skin temperature significantly compared to normal loose-fitting gym shorts. This result may translate to lower risk of injuries and in enhanced athletic performance. (Doan et al. 2003.) According to a research by Miller et al. (2005), the skin temperature was 1.4°C greater when the subjects wore neoprene sleeves. On the other hand, during exercise the neoprene sleeves showed to increase the skin temperature by 3.1°C compared to not wearing them. The muscles did not seem to reach higher temperatures during exercise, but the after the exercise the temperatures were 0.5°C higher when the neoprene sleeves was used. In short, the neoprene sleeves prevented muscle cooling, but did not enhance the heating of the muscle. These effects were more prominent for the first 15 minutes after the exercise. (Miller et al. 2005.) However, a research by Sperlich et al. (2013), showed an increase in both body and skin temperatures during and after exercise. The reason behind this may be in increased blood flow to the muscles. (Sperlich et al. 2013.) These results may be beneficial for athletes, who have long periods between inactivity an activity, because neoprene sleeves keep the muscles warm for an extended period of time. (Miller et al. 2005.)

2.5 COMPRESSION MATERIALS AND IMPROVED PROPRIOCEPTION

Proprioception or kinesthesia consists of sensory functions that involve the mechanical status and spatial awareness of the body (Gallahue & Ozmun 2002; Stillman 2002; Magill 2007, 109; Bottoni et al. 2013). It allows the person to feel where body segments are in space, as well as speed, force and the direction of its movements (Bernhardt & Anderson 2005; Magill 2007, 109-110). It can also be described as "*the sensations of position and movement of body segments, and of the force and timing of muscle contractions*" (Cameron et al. 2008, 346). This includes the sense of balance, position and movement of the body (Stillman 2002; Taylor 2009). These sensations are gathered from sensors in the joints, skin, muscles (Bernhardt & Anderson 2005; Magill 2007, 110; Taylor 2009; Bottoni et al. 2013) ligaments and tendons (Magill 2007, 110). Through these senses the body is able to adjust its limb positions and movements, stiffness, viscosity, force and heaviness. (Bernhardt & Anderson 2005; Taylor 2009; Bottoni et al. 2013.) However, studies show that proprioceptive acuity is also improved as a result of learning a new skill (Ostry et al. 2010; Wong et al. 2012). Movement control is enabled by the nervous system, and is shaped by the received sensory input. (Witney et al. 2004) Through this dynamic co-operation of senses, the body is able to adapt to changing environments (Stillman 2002; Witney et al. 2004).

2.5.1 Why is improved proprioception important?

Many studies have shown that compression garments also have a positive effect on proprioception on various parts of the body (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014). These results have been proved by using elastic neoprene sleeves on shoulders, ankles, trunk and knees (Cameron et al. 2008).

Proprioception is a key factor in motor control (Riemann & Lephart 2002; Stillman 2002; Magill 2007, 112; Taylor 2009). This requires the sensory information to be as accurate as possible

(Riemann & Lephart 2002; Vidoni et al. 2010). Nowadays it is widely known that good proprioception prevents athletes from injuries as well as making treatment more efficient (Akseki et al. 2012). Proprioception is also vital in learning new skills (Stillman 2002). However, the exact effect of each proprioceptor in the total control mechanism is not known (Bernhardt & Anderson 2005; Akseki et al. 2012). Even though there is a lot of research done about the proprioceptive process, it is still unknown, how many mechanoreceptors are activated through internal or external impulses, and how the activation occurs (Akseki et al. 2012). In addition, whether motor experience, sensory experience or their combination has the biggest effect on sensory remapping is not known (Ostry et al. 2010). Wong et al. (2012) hypothesized, that new behavior is led by changes in both motor and sensory changes.

Ali et al. (2007) stated that using compression stocking help heightening perceptual feelings during exercise. Skin stretch has been proved to being an important source of proprioceptive feedback (Bernhardt & Anderson 2005). Since the kinesthetic sense primarily consists of tactile receptors and muscle, it is safe to say that an improvement in these areas can be visible in joint position awareness (Bernhardt & Anderson 2005; Robbins et al. 1995). If compression garments enhance this effect, it would increase the sensitivity in the area it is being used in (Bernhardt & Anderson 2005). Growing evidence has shown that using compression materials improve the balance of athletes, because they provide additional feedback from the muscle. This could be a result of enhanced joint proprioception and muscle coordination leading to a better joint positional awareness. (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014). Kraemer et al. (1998) suggested that the results may also occur due to reduced muscle oscillation during impact or psychological factors. Birmingham et al. (1998) found that 72% of the subjects felt that using neoprene sleeves improved their performance in a closed supine test of the knee joint. However, the sleeves had only a small effect on the performance. McNair and Heine (1999) concluded that the physiological changes might also occur due to proprioceptive feedback from Golgi tendon organs (McNair & Heine 1999). According to Michael et al. (2014), the improvement in joint placement and proprioception were most evident, when the visual input was reduced. This was due to the fact, that the material might provide the mechanoreceptors with additional input leading to a better muscle coordination and joint stability. Additionally, these effects could also result in a lowered injury risk, better rehabilitation and better injury management. (Michael et al. 2014.) On the other hand, not all studies conclude these findings. Bottoni et al. (2013) found no effect in the proprioception of the knee when a knee support was used. The conclusion of this was that the starting position and movement direction influenced the kinesthetic sense during the movement. It is not clear which movements or positions have a positive or negative effect on proprioception. (Bottoni et al. 2013.)

To maintain a good control of posture, a person needs a working relationship between sensory information gathered by the visual and vestibular systems and the musculoskeletal systems that regulate movement and posture of the limb (Michael et al. 2014; Woo et al. 2014). According to Woo et al. (2014) proprioceptive and tactile systems provide the most information (70%) for healthy individuals' postural control in a well-lit and stable environment. Therefore, these systems may benefit from the additional sensorimotor feedback given by the compression garment. (Michael et al. 2014). This improvement in proprioceptor feedback is a result of the compressive garment's ability to act as a cutaneous skin afferent and compress the soft tissue underneath, which improves muscle and joint perception (Birmingham et al. 1998; Kraemer et al. 1998; Birmingham et al. 2000; Callaghan et al. 2002; Bernhardt & Anderson 2005; Cameron et al. 2008; Pearce et al. 2009; Bottoni et al. 2013; Orth et al. 2013). These might have been ”*directly compensated for the less accurate kinesthetic signal from spindle activity, or reflexively biased kinesthetic pathways, resulting in a better knee joint position*” (Birmingham et al. 2000, 307). The afferent signals from spindles can also change based on the context of the movement (Wong et al. 2012). McNair and Heine (1999) had similar results as well, when they researched the effect of neoprene braces on the trunk. There neoprene braces had a positive effect on trunk position awareness. This may help design products to alleviate the problems of people with lower back pain, since the braces may increase mechanical stability. (McNair & Heine 1999.) Kraemer et al. (1998) on the other hand, concluded that enhanced proprioception and improved position sense signals are more important in fatigued musculature.

Some studies have shown that the poorer the individual's proprioception is the more positive effects compression materials have on proprioception (Callaghan et al. 2002; Bernhardt & Anderson 2005). This might be a result of having a proprioception good enough to not need any external influence (Birmingham et al. 1998; Callaghan et al. 2002). Cameron et al. (2008) had similar results when working with elite Australian football players, where the use of neoprene shorts helped to judge the backward swing of the leg while kicking in some players. This result was apparent only in the lower neuromuscular control ability part of the team, whereas compression materials seemed to hinder the kicking performance of the higher neuromuscular control ability group. (Cameron et al. 2008.) This result also resembles the findings of Callaghan et al. (2002), where only the subjects with poor proprioceptive feedback benefitted of using patellar taping in the knee.

2.5.2 The role of proprioception in learning new motor skills

The awareness of different movements and postures are vital for learning new motor skills (Stillman 2002; Ostry et al. 2010; Vidoni et al. 2010). These senses are acquired through proprioception (Stillman 2002; Vidoni et al. 2010). As a certain skill gets progressively better, the feedback gathered from different segments are stored in the brain as new and enhanced movements. As the skill has been fully learned, the actual movement requires less proprioceptive consciousness. (Stillman 2002.) Motor learning is a process, where sensorimotor adaptation changes motor signals as well as sensory systems (Ostry et al. 2010; Wong et al. 2011; Wong et al. 2012). These results indicate, that perceptual changes, such as visuomotor adaptation and proprioceptive changes are linked to movement and learning (Ostry et al. 2010). It has also been proposed, that both motor and sensory systems depend on sensory perception. These systems can also evolve through recent motor learning. (Ostry et al. 2010; Wong et al. 2012.) This supports the theory that motor skills are build up on former experiences.

Many studies have been conducted on the effect of proprioception on movement, mainly on animals and patients with polysensory neuropathies (Hepp-Reymond et al. 2009; Vidoni et al.

2010). The findings suggest that proprioceptive and cutaneous feedbacks are vital in updating motor memories. However, these findings indicate that visual information may only adjust motor commands. (Hepp-Reymond et al. 2009.) Vidoni et al. (2010) hypothesized that sensory feedback has an important role in creating internal models for movements. Ostry et al. (2010) concluded that the sensorimotor system's ability to adapt is a vital factor in motor learning.

Proprioception and cutaneous senses are important in maintaining a complex automated motor movement, such as handwriting (Magill 2007, 145-146; Hepp-Reymond et al. 2009). In addition to a working proprioception, the skill also needs touch in order to work properly (Hepp-Reymond et al. 2009). Cutaneous feedback also plays a key role in acquiring a predictable force and grip control (Witney et al. 2004; Jones & Piateski 2006). This affects how the muscles react to the input (Jones & Piateski 2006). Examples of dependence of feedback on skill acquisition include a child trying to tie his shoelaces (Witney et al. 2004) or cut with scissors (Gallahue & Ozmun 2002, 46). This shows how integral part the touch or feel is in learning new motor skills.

Certain movements require feedback from the proprioceptors even before the movement starts. This occurs when performing extremely fast movements. However, with slower movements, the proprioceptive system has time to adjust to the task at hand and possibly make adjustments in the movement. (Stillman 2002.) This skill is particularly useful in adapting to unexpected situations or environments precisely and quickly (Stillman 2002; Witney et al. 2004; Ostry et al. 2010). According to Akseki et al. (2012), it is becoming more evident that many body functions are related to proprioception. One example of this is handwriting. (Akseki et al. 2012.) The increased proprioceptive activity could indicate that compression materials help learning motor skills, but this needs additional research in the future.

3 PURPOSE OF THE STUDY

Many studies have shown that compression garments also have a positive effect on proprioception on various parts of the body (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014;). These results have been proved by using elastic neoprene sleeves on shoulders, ankles, trunk and knees (Cameron et al. 2008). Proprioception is a key factor in motor control (Riemann & Lephart 2002; Stillman 2002; Magill 2007, 112; Taylor 2009) and a vital factor in learning new skills (Stillman 2002).

The purpose of this study is to evaluate the effect of compression socks on motor learning, specifically balance and agility after an 8-week training program. The aim of the study is to find out:

What is the effect of medical compression socks on balance skills when compared to socks without medically compressive properties?

1) What is the effect on static balance skills?

2) What is the effect on dynamic balance skills?

The added proprioceptive feedback provided by compression materials have a positive effect on the kinesthetic sense (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014), which is closely linked to skill learning (Stillman 2002). Thus, compression materials should also have a positive effect on balance skills when compared to normal uncompressed socks (McNair et al. 1996; Birmingham et al. 1998; Kraemer et al. 1998; McNair & Heine 1999; Birmingham et al. 2000; Bringard et al. 2006; Cameron et al. 2008; Pearce et al. 2009; Michael et al. 2014).

4 STUDY MATERIALS AND METHODS

This Master's thesis is a part of the Fidipro –project (Designing textured materials and environments for motor learning in physical activity and sports; TEKES Projekti 1389/31/2011) carried out by the University of Jyväskylä in the Department of Sport Sciences in 2014. An ethical approval of the study was granted by the University of Jyväskylä on 20.2.2014.

The subjects of the study were recruited from a local newspaper as well as through internet. The training program consisted of one hour lessons twice a week for a total of 8 weeks. Due to a few drop-outs, the final amount of subjects was 40.

4.1 Subjects and Background information

The participants were a group of 49 males and females between the ages of 18-75. They were non-athletic adults who were matched by experience with physical activity and sport as well as their age. A preliminary survey was done to ensure that the subjects' medical conditions were good. The subjects were divided into two equal groups, of which the test group used compression socks (Zeropoint Oy) during an 8 week training period. The control group had the same training program and wore socks with similar thickness, but without the compressive effect. The baseline measurements determined how the two groups were divided. The groups had to be at a similar level of balance. The balance was measured by a force plate: one legged stance with eyes both open and closed for 30 seconds. The number of people in the both test and control groups were 15-20. The program consisted of 8 weeks/2 one hour sessions per week. The progression was measured by pre- and post-training tests. Mean age of the experimental group was 53.8 (sd 17.0), and 45.9 (sd 15.8) years for the control group. The mean value of the center of pressure (COP) area was 3564 (sd 1729) mm2 for the experimental group and 3552 (sd 1359) mm2 for the control group (t-test p= 980).

Due to the fact that the subjects were mostly elderly there were a few drop-outs. These were mostly due to minor injuries, such as sprains, or illnesses. In some cases the reason for drop-out was unknown. Out of the preliminary 49 participants 40 stayed in the training program for the whole 8 weeks. The researchers gave the subjects a survey once a week, to track if they wore the compression socks outside the training sessions. The survey was also used to track how often the subjects took part in the training sessions. On the last week there was another survey to see what the participants' overall thoughts of the training program.

4.2 Description of the compression socks

The compression socks used in this study were made by Zero Point Finland Oy. The materials consisted of 20% Nylon, 20% Lycra and 60% Coolmax. The socks that were used were the *Intense Compression Socks*, which are also the most compressive (20-30mmHg) sock product the company offers. The socks were designed to have a graduated compression that was tighter around the ankle while decreasing the compression closer to the knee. The other test product was a *running compression* sock from Pro Touch that was made from 98% Polyamide and 2% Elastane.

4.3 Intervention

The program consisted of 8 weeks/2 one hour sessions per week in a university gymnasium. The progression was measured by pre- and post-training tests. The participants were divided into two groups and they both had identical training sessions, which consisted of a variety of static balance and dynamic balance exercises as well as exercises that improve kinesthetic sense and agility. These included several balancing and postural control tests, such as Romberg stance on one leg and both legs. These were done with both eyes open and eyes closed. Dynamic balance was trained by landing on different surfaces on one or two legs. This also served as resistance training for the lower limbs. The exercises were designed in collaboration with sports experts and took safety issues into account. Every session also started with a 10-minute warm up and ended with a 10-minute stretching part.

During training the test group used a graduated compression sock made by Zeropoint Finland. The right sized socks were given after measuring the shoe and calf sizes during the preliminary tests. The control group used a similar-looking sock made by Pro touch (www.protouch.eu) which did not have similar compressive properties. The participants were not aware whether they belonged in the experimental group or not.

The exercises were constructed and executed by physical education master students in the guidance of the researchers. The students were not aware of the control groups to prevent bias.

4.3.1 Examples of intervention program

Week 1.

1. Warmup 12 min
- Lunges with different stretches (upper body/lower body), slow paced running (High knees/touching heels with palms).
2. Main exercise 3x10 min
- Balance exercises on a soft shallow beam or an otherwise uneven or soft surface (horizontal stand, walking with high knees, standing on one leg, walking sideways catching a bean bag while standing on a beam etc.)
- Ladder run exercises (different coordination challenging exercises)
- A course that required agility and throwing (course was constructed of buckets filled with bean bags, the subject collected them as he/she went on to the throwing zone).
3. Cool down 12 min
- Different stretches.

Week 5.

1. Warmup 12 min
- Afro dance -type warmup with appropriate music and moves, stretches
2. Balance circuit training 2x15min
- Circuit training workout designed to challenge balance skills as well as enhance physical fitness (jump rope, bench jump, Pilates-style abs workout with gym ball, squats on a balance board, kettle bell exercise, air boxing, plank on your back with your feet on a gym ball, balance/core workout in pairs, pushup on a basketball, jumping jacks etc. These exercises were done on solid ground or a soft mat that was roughly 5 centimeters thick.)
3. Cool down
- Using a tennis ball to massage the body, stretches.

Week 6.

1. Yoga session (Vinyasa style) 60 min
- A yoga session that challenged the balance and coordination of the participants, not too intense but still physically tiring. Combined actual Vinyasa yoga poses, asanas, into a smooth, flowing movement (downward facing dog pose, cobra, upward facing dog pose, warrior I & II, child's pose, revolved side angle, tree pose etc.).
- These exercises were done on solid ground or a soft mat that was roughly 5 centimeters thick.

4.4 Mechanical characteristics of the force platform

The development of balance skills were measured by a force platform/balance board (BT4 balance platform, HurLabs Oy, Tampere, Finland) test before and after an 8-week training program. The platform used horizontal perturbations to simulate a natural movement of the body. The device consists of two steel frames (middle 910 x 610 mm, bottom 910 x 910 mm) that are constructed from four steel tubes (60 x 30 mm). The force plate sits on top of a steel plate, which sits on top of the middle frame. There are wheels under the middle frame as well as the upper steel plate to enable sideways movement of the middle plate and antero-posterior movement of the upper steel plate. There are two electromechanical cylinders (EMC, Bosch Rexroth, Germany) to produce movement of the frames. Their maximal amplitude is 300 mm with a maximal force of 4000 N and a maximal velocity of 70cm/s. The cylinders are connected to three-phase motors (MSK030B, Bosch Rexroth, Germany) and frequency encoders (HCS02, Bosch Rexroth, Germany). These are controlled via by an NI 4-channel analogue card (NI 9263, National Instruments, USA) and a NI 8-channel digital card (NI 9472, National Instruments, USA). Both cards are connected to a computer by a USB port (NI cDAQ-9172, National Instruments, USA). The perturbations in the test are controlled manually by Labview (National Instruments, USA) and IndraWorks (Bosch Rexroth, Germany) software and it measures perturbation parameters such as amplitude, acceleration and velocity.

4.5 Measurements

Subjects were ranked from lowest to highest based on the COP area (mm2) during slow anterior perturbation. Thereafter the subjects were divided with every second subject to test group and every second subject to control group. For more detailed analysis to examine the effect of training COP maximal deviation and time for COP maximal deviation were analyzed in anterior conditions using two perturbation velocities (Piirainen et al. 2013). This data was used to divide the groups due to the fact that it provided immediate information after the preliminary tests. This data was not included in the actual measurements afterwards.

4.5.1 Force plate measurements

To measure dynamic balance the force plate moved in the horizontal direction in two conditions: max acceleration 0.5m/s2 and 2.5m/s2, max velocity 15cm/s and 25cm/s, constant displacement 15 cm. The program delivered a total of four balance perturbations in posterior (plate moved backwards) and anterior (the plate moved forwards) directions in 6 to 8 second intervals. The movements were randomized and done in a 1 minute period in both conditions. A black mark was set to a wall 2.8m from the subject at eye level. This helped to stabilize the subject's visual focus during the measurements. The average of four perturbations will be calculated for each speed and direction. A COP (center of pressure) displacement was also analyzed. The subjects used a safety harness during the measurements to prevent falling.

5 STATISTICAL ANALYSES

The analyses of the study were done by SPSS version 22 for windows. Subjects who were unable to take part in both the preliminary test and the post training test (n = 8) were excluded. In total, 40 subjects were eligible to be measured. One subject had missing data in the dynamic balance tests (Flamingo test, 8-running test), which lead it to be excluded from the study. One subject also had missing data in the force plate test, which lead it to be excluded from the study.

The variables were analyzed by pairwise t-tests to examine the differences between the experimental and control groups. In the statistical tests, differences were significant when p= <0.05.

6 RESULTS

This study focuses on the changes in the subjects' center of pressure (COP) during slow anterior perturbations (SAP) and fast anterior perturbations (FAP). These are described in the tables as max_h. Additionally, the tables show the time to peak balance displacement during slow and fast anterior perturbations. These are described in the tables as maxh_t. Preliminary test results are shown as PRE and the results after the training period are shown as POST. The experimental group is shown as EXP and the control is shown as CTRL.

6.1 Effectiveness of the training program

The experimental group showed a significant improvement in peak balance displacement during both fast and slow anterior perturbations. The time to peak balance displacement during fast and slow anterior perturbations seemed to reduce slightly, but with no real statistical significance.

The experimental group had a significant reduction (p= ,009) in peak balance displacement during a fast anterior perturbation (table 1), which means that the subjects were able to retain better balance during a fast perturbation. Additionally, the experimental group also had a significant reduction (p= ,031) in peak balance displacement during a slow anterior perturbation, where the center of pressure displacement was decreased. This shows an improvement in retaining balance during a slower anterior movement as well.

Tables 1 and 2 present the abbreviations of the balance parameters

Abbreviations of the balance parameters

PRE_SAP_maxh	Peak balance displacement during a slow perturbation, pre-training test
PRE_SAP_maxh_t	Time to peak balance displacement during a slow perturbation, pre-training test
PRE_FAP_maxh	Peak balance displacement during a fast perturbation, pre-training test
PRE_FAP_maxh_t	Time to peak balance displacement during a fast perturbation, pre-training test
POST_SAP_maxh	Peak balance displacement during a slow perturbation, post training test
POST_SAP_maxh_t	Time to peak balance displacement during a slow perturbation, post-training test
POST_FAP_maxh	Peak balance displacement during a fast perturbation, post-training test
POST_FAP_maxh_t	Time to peak balance displacement during a fast perturbation, post-training test

The control group showed no significant change in the peak balance displacement during fast or slow anterior perturbations (table 2). However, during a slow anterior perturbation (SAP) the time to peak balance displacement was significantly reduced (p= ,014). This result indicates that even though the peak balance displacement reduced slightly, the participants experienced a faster time to peak balance displacement than before. This shows that the participants were able to regain their balance quicker after the perturbation so that the peak balance displacement is not as great as before.

Table 1. Pre and post measures of balance parameters for experimental group, t-test

Variable	Pre measurement	Post measurement	p=
SAP_maxh	68,5	63,8	,031
	(n=25)	(n=23)	
SAP_maxh_t	,47	,45	,237
	(n=25)	(n=23)	
FAP_maxh	119,1	99,3	,009
	(n=25)	(n=23)	
FAP_maxh_t	,54	,50	,360
	(n=25)	(n=23)	

Table 2. Pre and post measures of balance parameters for control group, t-test

Variable	Pre measurement	Post measurement	p=
SAP_maxh	71,8	65,6	,104
	(n=24)	(n=17)	
SAP_maxh_t	,43	,35	,014
	(n=24)	(n=17)	
FAP_maxh	118,4	107,5	,055
	(n=24)	(n=17)	
FAP_maxh_t	,46	,50	,517
	(n=24)	(n=17)	

6.2 Differences between test groups

Both groups showed a decrease in SAP during the intervention, but not enough to be statistically significant. The groups showed no significant improvement in balance parameters in pre- and post-measurements during fast anterior perturbations (FAP) or the peak balance displacement during a slow anterior perturbation. However, the experimental group showed a significant (p= ,007) improvement the time to peak balance displacement during a slow perturbation in a post-training test (table 3).

Table 3. Balance parameter means for experimental and control groups, t-test

Variable	Experimental group	Control group	p=
PRE_SAP_maxh	67,7	71,7	,275
	(n=25)	(n=24)	
POST_SAP_maxh	63,8	65,6	,461
	(n=23)	(n=17)	
PRE_SAP_maxh_t	,46	,44	,465
	(n=25)	(n=24)	
POST_SAP_maxh_t	,45	,35	,007
	(n=23)	(n=17)	
PRE_FAP_maxh	121,7	113,8	,470
	(n=25)	(n=24)	
POST_FAP_maxh	99,3	107,5	,490
	(n=23)	(n=17)	
PRE_FAP_maxh_t	,54	,46	,099
	(n=25)	(n=24)	
POST_FAP_maxh_t	,50	,50	,928
	(n=23)	(n=17)	

7 DISCUSSION

This study examined the possible effects of compression materials on balance skills and skill learning. The study groups consisted of mainly elderly people, which provided additional info on how to prevent possible injuries caused by slipping or falling. Additionally, since most slips and falls happen in the anterior direction (Piirainen et al. 2013), this study excluded the changes occurring during balance perturbations in the posterior direction.

Ageing affects the nerve condition in the somatosensory system. The compression materials stimulate certain peripheral receptors (Orth et al. 2013.) which should help maintain better balance. The experimental group had a significant reduction (p= ,009) in peak balance displacement during a fast anterior perturbation, which means that the subjects were able to retain better balance during a fast perturbation. The experimental group also showed a significant reduction (p= ,031) in peak balance displacement during a slow perturbation. These changes might prove to be important if a person slips, where the time to react to changes in balance is important. Hopefully this will also prevent injuries, due to the reduction in falls or slips especially in the elderly. In short, this study concluded that combining compression socks with a balance exercise program yielded better results than without compression socks.

While this study showed a positive effect of compression socks on balance during an 8-week training period, it did not study any immediate changes in balance when the socks were used. This could be a fruitful area of future research, because the immediate proprioceptive changes in the limbs are not well known. The study might also prove to be difficult to conduct due to the fact that the measuring needs two consecutive tests with and without the use of compression materials. There is also a problem with the fact that the second try might yield better results due to the learning curve of the participants, which would ultimately result in inaccurate research data.

One other idea for future research is to try and find out how permanent the changes in balance skills are. This would require a retention test for the same group of people in the future. The gathered information could provide vital information on how well balance skills are maintained and how fast the skill might deteriorate. This data could be compared between the experimental and test groups or between the younger and older participants to see if there are any statistically significant changes or differences between age groups or test groups.

Although there is some controversy surrounding the positive effects of compression materials in athletic performance, the general consensus seems to indicate, that compression garments have a positive effect on performance especially in high intensity sports (Kraemer et al. 1998; Doan et al. 2003; Bottaro et al. 2011). Research has also shown that these materials help preventing injuries by improving proprioception and guiding the limb towards a more efficient movement. Even after the exercise, these materials keep the limbs warmer and should help boost the removal of lactate from the body through the increase in increased blood flow. However, the present results of an increased lactate removal after the exercise are contradictory (Bernhardt & Anderson 2005). Compression materials do seem to have their place in modern high-level sports as well as recreational exercising. They are already being used in helping the motor functions patients with cerebral palsy (Pearce et al. 2009).

When comparing the effects of compression materials in different sports, one has to remember that the possible effects are related to how compressive the material is, where it is worn and what kind of sports it is being used in. Birmingham et al. (2000) argued that the contributions of compression garments are also dependent of the motion of the limb. For example, active and passive movements need different sensory channels to work on the most efficient level. This means that a special garment may send too much information to the muscle during a passive movement, or vice versa. (Birmingham et al. 2000.) This leads to a conclusion that compression materials might only provide additional proprioceptor help for people who are not top-tier athletes. Other physiological factors still exist, which means, that it is up to the athletes or coaches to decide, whether using compression materials to enhance their performance is needed (Bottaro et al. 2011).

One weakness in the studies made from compression materials is that most of them are concentrating on their effect on the body during high-intensity sports, rather than longer anaerobic exercises (Bringard et al. 2006). The effects of compression garments on fatigue during longer exercises could be a possible area for future research in the field of compression materials. This means that there is a need for future research in the other effects that compression materials may have.

There is a lot to be known from the effects of compression garments in learning new skills. The current knowledge of physical sensations in motor learning is mostly based on animal models (Vidoni et al. 2010). However, motor learning in humans could prove to be difficult to measure, since learning is such an individual process. For example Kraemer et al. (1998) stated that the perception of joint movement or joint proprioception is a highly developed physiological function that requires an effortless interaction between ligaments, joints, muscles and skin receptors. Due to the complexity of the different receptors active in proprioception, it is very difficult to pinpoint the reason for an improvement in the kinesthetic sense (Bernhardt & Anderson 2005). The real problem in this might lie in the fact that it is challenging to observe whether learning the skill is faster when using compression garments, because on the possible second measurement period there is already a cognitive idea about the movement. In addition, comparing two different groups together only brings out the individual factors of the participants learning styles and speeds.

Wong et al. (2012) reported that adding proprioceptive training to visual presentation resulted in faster motor learning. This shows the important interaction between proprioception and motor learning. Although the measuring of skill learning has its difficulties, it does not reduce the interest in the subject. The research of the effects of somatosensory feedback on motor learning is just getting started (Vidoni et al. 2010).

The ethical aspects about these studies may prove to be a problem in the future, because many sportswear companies might want to get a share of this growing market. These companies may fund a study to try and prove the positive effects of these garments. If the results are not to the company’s liking this time, they might just convey another study hoping for better results. However, it’s up to the research facilities to be as unbiased in the results as possible even when a big company is funding it. Nevertheless, it is safe to say that the sports industry is living an interesting time, where even the slightest changes in materials may have an impact on the performance. How big of an impact compression materials have in top-tier sports remains to be seen.

7.1 Study limitations

The variability between the groups had to be considered, when working on a group as heterogeneous as this. This had to be taken into account when developing the exercises for the lessons. The subjects were mainly elderly with varying physical conditions. Other physical factors included height, weight, age and strength. However, after the initial tests the group was divided into two according to their balance skills. Because the groups had identical lessons, this confirmed that the possible results were not altered due to training methods.

The aforementioned limitations combined with the fact that the group was mainly non-athletic were possible reasons why the study encountered a significant drop-out percentage (18.4%). However there were no serious injuries through the course of the study.

This Master’s thesis focuses on the data gathered from the preliminary test and the post-training tests from the force plate, which leaves little room for human error. However, due to an error in communication, one of the participants was not able to take part in the post training tests. The participant was later on excluded from the data used in this study.

Although this study showed a significant improvement in the test group's peak balance displacement during a fast anterior perturbation (p= ,009) and peak balance displacement during a slow anterior perturbation (p= ,031), it is hard to measure the sustainability of balance skills in a longer time period. Since there are multiple different variables that have to be taken into account, it is challenging to pinpoint the exact reason for the positive results in this study. Changing the materials, training program, test group or the level of compression might yield different results.

7.2 Conclusion and recommendations

The evidence showing the effects of a balance training period paired with the use of compression materials improved the participants' balance slightly, but not statistically significantly. However, the results showed a significant improvement in peak balance displacement in fast (p= ,009) and slow (p= ,031) perturbations in the experimental group. These results were from a mostly elderly group of people, which may yield different results with younger participants. This raises a few interesting questions for future research, such as "do children benefit from the additional somatosensory feedback?" Furthermore, it would be interesting to see how these kinds of effects could be translated into different types of sports. A recommendation for future study could be to examine an athlete's balance skill progression with a regular or specialized training program. This might provide an interesting insight on how much additional help, if any, the athlete would get from the use of compression materials.

Although this study revealed some information on the effects of compression materials on balance skills in a short 8-week program, there is no proof of what the effects may be on a longer time period. The results could be similar, or the differences between the two groups could be even greater. However, it may also show that the balance skills are acquired faster with the use of compression materials, but would even out later on.

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APPENDIX

JY/EETTINEN TOIMIKUNTA

Tutkimuksen nimi: The effect of compression socks on motor learning, specifically balance and agility/Kompressiosukkien vaikutus motoristen taitojen oppimiseen

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Tutkimuksen taustatiedot

Tutkimusorganisaatio ja tutkimuksen suorituspaikka: Jyväskylän yliopisto, Liikuntatieteellinen tiedekunta/Viveca

Tutkimus on yksittäinen tutkimus, joka liittyy Fidipro-hankkeeseen.

Valmistuvat opinnäytetyöt: Kaksi pro gradu-tutkielmaa (Jaakko Niemi-Nikkola & Miikka Sinko ja Daniel Kiikka)

Tutkimus toteutetaan keväällä 2014

Tutkimuksella ei ole erillistä rahoitusta, tutkimus toteutetaan tutkijoiden omalla työllä

Tutkimuksen tarkoitus, tavoite ja merkitys

Tutkimuksen sisältö, tarkoitus ja tavoitteet:

Koe- ja kontrolliryhmä harjoittelevat motorisesti monipuolista liikuntaa 2 kertaa viikossa 8 viikon ajan Vivecan liikuntasalilla, tarkoituksena arvioida kompressiosukkien (”puristavat sukat”) vaikutusta motoristen taitojen kehittymiseen. Koeryhmällä on kompressiosukat ja kontrolliryhmällä vastaavanlaiset sukat ilman kompressio-ominaisuutta. Tavoitteena on analysoida koe- ja kontrolliryhmien eroa taitojen kehittymisessä.

Tutkimuksen tieteellinen ja käytännöllinen merkitys:

Testataan kompression merkitystä taitojen oppimiseen ja siten testataan aiemmin kirjallisuudessa esitettyjä teoreettisia hypoteeseja. Käytännön merkitys: jos kompressiosukilla on vaikutusta taitojen oppimiselle, sukkien käyttöä voidaan lisätä eri ihmisryhmille motoristen taitojen, mm. tasapainotaidon edistämiseksi.

Tutkimusaineiston käyttötarkoitus, käsittely ja säilyttäminen

Aineistoa käytetään tutkimuskäyttöön.

Manuaalista aineistoa säilytetään tutkimuksen aikana Jyväskylän yliopiston lukituissa työtiloissa. Digitaalista aineistoa säilytetään yliopiston tietokoneella käyttäjätunnuksen ja salasanan takana.

Aineistoa käytetään ja säilytetään ennen sen tuhoamista elokuun 2014 loppuun, jolloin aineiston analysointi on saatu päätökseen. Aineistolla ei ole jatkokäyttöä.

Menettelyt, joiden kohteeksi tutkittavat joutuvat

Tutkittavat on rekrytoitu ilmoitustauluille laitettavien ilmoitusten ja ilmaisjakelulehden ilmoituksen avulla. Valinnan perusteena on, että osallistujat ovat terveitä ja eivät harrasta säännöllisesti liikuntaa.

Tutkittavien yhteystietojen lähde on tutkittavien oma ilmoitus s-postitse tutkijoille.

Toimenpiteet, jotka kohdistuvat tutkittaviin:

Alku- ja loppumittaus

Mittaukset suoritetaan liikuntaharjoittelun alussa ja lopussa JYU/Viveca-rakennuksen liikuntasalissa professori Vesa Linnamon organisoimana.

1. Toiminnalliset motoristen taitojen testit - Flamingo -testi (yhdellä jalalla seisominen; osa Eurofit Testistöä) ja kahdeksikkojuoksutesti (K. Keskinen, K. Häkkinen & M. Kallinen (Eds.) Kuntotestauksen käsikirja. Tampere: Tammer-paino. 125 – 188).

2. Mittalaitteiden avulla suoritettavat testit

Bioimpedanssin (kehonkoostumus) mittaaminen InBody-laitteella (segmental multifrequency bioimpedance analyzer (SMFBIA); InBody 720, Biospace Co. Ltd., Seoul, South-Korea). InBody 720:ssä on 8 elektrodia käsissä ja jaloissa ja laite mittaa kehon koostumuksen tutkittavan seisoessa siten, että elektrodit on kiinnitetty iholle.

Tasapainon mittaus tasapainolevyn avulla (BT4 balance platform, HurLabs Oy, Tampere, Finland). Levyllä seistään ja laite mittaa huojuntaa (tasapainoa). **Tutkittaville asetetaan turvavaljaat levyn päältä putoamisen estämiseksi.**

Harjoittelu

Liikuntaharjoittelu 2 kertaa viikossa yhden tunnin ajan kerrallaan 8 viikon ajan JYU/Vivecan liikuntasalissa. Harjoitukset sisältävät paljon tasapaino- ja kehonhallintaharjoittelua, kuten seisomista yhdellä jalalla silmät auki ja kiinni, dynaamisen tasapainon harjoittelua hypäten alas erilaisilta korokkeilta yhdellä jalalla ja kahdella jalalla, silmät auki ja kiinni. Harjoitukset suunnitellaan liikunta-alan asiantuntijoiden toimesta turvallisuusnäkökohdat huomioiden. Liitteessä on esitetty yksityiskohtaisempi liikuntaharjoittelun toteutus tasapainon osalta.

Tutkimuksen hyödyt ja haitat tutkittaville

Tutkittavat hyötyvät osallistumisestaan tutkimukseen sen, että saavat ilmaiseksi kehittää harjoittelun avulla motorisia taitojaan ja saavat ilmaiseksi sukat, joita käytetään harjoittelussa. He saavat myös tietoa tutkimuksen tuloksista ja henkilökohtaista liikuntaneuvontaa.

Tutkimuksen riskit on pyritty minimoimaan laatimalla harjoitusohjelma asiantuntijaryhmän kesken. Lisäksi tutkittavat täyttävät terveyskyselyn, jonka laadinnan on ohjeistanut liikuntalääketieteen professori Urho Kujala (JYU/Terveystieteiden laitos). Kyselyn perusteella päätetään, ketkä voivat osallistua tutkimukseen. Tutkittavat on vakuutettu JYU:n toimesta. Alku- ja loppumittaukset suoritetaan käyttämällä standardoituja testejä niiden toteuttamisessa kokeneiden tutkijoiden toimesta. Ensiapuvarusteet on hankittu tutkimuksen käyttöön Vivecan liikuntasalille.

Mahdollisesti aiheutuvat haitat liittyvät liikunta- ja testitilanteissa sattuviin fyysisiin vahinkoihin. Käytettävät menetelmät ovat aiemmissa tutkimuksissa laajalti käytettyjä ja turvallisiksi havaittuja. Riskit ja haitat ovat erittäin epätodennäköisiä (vähemmän todennäköisiä kuin omatoimisessa liikunnassa, koska liikuntaharjoittelu ja testit toteutetaan asiantuntijoiden toimesta). Tapaturmiin ja ensiapuun on varauduttu vastaavasti kuin liikuntatieteellisessä tiedekunnassa yleisesti tapahtuviin liikunta- ja testitilanteisiin.

Miten ja mihin tutkimustuloksia aiotaan käyttää

Tutkimuksen tuloksia on tarkoitus julkaista kahdessa pro gradu -tutkimuksessa sekä kansainvälisen vertaisarvioidun tiedelehden julkaisussa ja kansainvälisissä kongresseissa sekä liikuntatieteellisen tiedekunnan opetuksessa soveltuvin osin. Kaupallinen hyödyntäminen: Zeropoint Oy, joka on Fidipro -hankkeen yhteistyöpartneri saattaa hyödyntää tutkimuksen tuloksia tuotekehityksessään.

Tutkittaville tiedotetaan tutkimuksen tuloksista kirjeellä ja sähköpostilla tutkimuksen tulosten valmistuttua.

Tutkittavien oikeudet

Osallistuminen tutkimukseen on täysin vapaaehtoista. Tutkittavilla on tutkimuksen aikana oikeus kieltäytyä tutkimuksesta ja keskeyttää tutkimukseen osallistuminen missä vaiheessa tahansa ilman, että siitä aiheutuu heille mitään seuraamuksia. Tutkimuksen järjestelyt ja tulosten raportointi ovat luottamuksellisia. Tutkimuksesta saatavat tutkittavien henkilökohtaiset tiedot tulevat ainoastaan tutkittavan ja tutkijaryhmän käyttöön ja tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta tutkijaryhmän jäseniltä missä vaiheessa tahansa.

Jyväskylän yliopiston henkilökunta ja toiminta on vakuutettu. Vakuutus sisältää potilasvakuutuksen, toiminnanvastuuvakuutuksen ja vapaaehtoisen tapaturmavakuutuksen.

Tutkimuksissa tutkittavat (koehenkilöt) on vakuutettu tutkimuksen ajan ulkoisen syyn aiheuttamien tapaturmien, vahinkojen ja vammojen varalta. Tapaturmavakuutus on voimassa mittauksissa ja niihin välittömästi liittyvillä matkoilla. Vakuutusyhtiöt eivät kuitenkaan korvaa äkillisen ponnistuksen aiheuttamaa lihas- tai jännerevähdystä, ellei siihen liity ulkoista syytä. Tapaturmien ja sairastapausten välittömään ensiapuun mittauksissa on varauduttu tutkimusyksikössä. Liikuntasalissa on ensiapuvälineet ja varusteet, joiden käyttöön henkilökunta on perehtynyt. Tutkittavalla olisi hyvä olla oma henkilökohtainen tapaturma/sairaus- ja henkivakuutus, koska tutkimusprojekteja varten vakuutusyhtiöt eivät myönnä täysin kattavaa vakuutusturvaa esim. sairauskohtauksien varalta.

Liite. Liikuntaharjoitusten toteutuksen kuvaus, esimerkki tasapainoharjoittelun osuudesta

Appendix 3. Example of balance skills training session

Task	Important aspects	Variations
Jump in the air	Silent landing	Eyes closed
Jump from the box	Wooden box, 30 cm high, controlled landing on gymnastic mat	Eyes closed
Jump from the box	Wooden box, 30 cm high, controlled landing on gymnastic mat	Telemark landing, alternating leading leg
Jump down backwards	Wooden box, 30 cm high, controlled landing on gymnastic mat	Eyes closed
Jump down sidewards	Wooden box, 30 cm high, controlled landing on gymnastic mat	Left / right side
Jump down with 90 degrees turn	Wooden box, 30 cm high, controlled landing on gymnastic mat	Turn left / right
Jump down backwards with 90 degrees turn	Wooden box, 30 cm high, controlled landing on gymnastic mat	Turn left / right
Jump down with full turn (360 degrees)	Wooden box, 30 cm high, controlled landing on gymnastic mat	Turn left / right
Jump down backwards with full turn (360 degrees)	Wooden box, 30 cm high, controlled landing on gymnastic mat	Turn left / right

Suostumus tutkimukseen osallistumiseksi

Kompressiosukkien vaikutus motoristen taitojen oppimiseen -tutkimus

Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, kerättävän tutkimusaineiston käyttöön, tutkittaville aiheutuviin mahdollisiin haittoihin sekä tutkittavien oikeuksiin ja vakuutusturvaan. Suostun osallistumaan tutkimukseen annettujen ohjeiden mukaisesti. En osallistu mittauksia tai fyysistä rasitusta sisältäviin tutkimuksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä tutkimukseen osallistumisesta missä vaiheessa tahansa. Tutkimustuloksiani ja kerättyä aineistoa saa käyttää ja hyödyntää sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.

Päiväys Tutkittavan allekirjoitus

Päiväys Tutkijan allekirjoitus

TERVEYSKYSELY

On tärkeää, että tiedämme terveydentilastasi ja elintavoistasi ennen kuin päätämme oletko soveltuva tutkimukseemme. Tästä syystä pyydämme Sinua vastaamaan seuraaviin kysymyksiin huolellisesti.

Nimi_________________________Syntymäaika____________Paino_________Pituus________

Ei Kyllä

1. Onko Sinulla todettu hengitys-, sydän-, tai verenkiertoelimistön sairauksia (esim astma, verenpainetauti, sepelvaltimotauti, synnynnäinen sydänvika)? □ □

   Mitä?_______________________________________
2. Onko sinulla todettu sokeritauti? □ □
3. Onko sinulla todettu korkea kolesteroli? □ □
4. Onko sinulla muita sairauksia? □ □

   Mitä?_______________________________________¨
5. Onko joku läheinen sukulainen (isä, äiti, veli, sisko) kokenut sydänkohtauksen tai onko hänelle tehty sydänkirurginen toimenpide ennen ikää 50? □ □
6. Käytätkö säännöllisesti lääkkeitä? □ □

   Mitä?_____________________________________
7. Onko sinulla ollut rintakipuja tai hengenahdistustuntemuksia
   a. levossa? □ □
   b. rasituksessa? □ □

   Miten usein ja millaisia?__________________________

   ____
8. Onko sinulla ollut rasituksen aikana rytmihäiriöitä, huonovointisuutta tai tajuttomuuskohtauksia? □ □
9. Onko sinulla selkävaivoja tai muita tuki- ja liikuntaelinten pitkäaikaisia tai usein toistuvia vaivoja? □ □

Mitä?____

10. Oletko viimeisen kahden viikon aikana sairastanut □ □
jotakin tulehdustautia (flunssa, kuumetauti)?

11. Oletko raskaana? □ □

12. Onko sinulla kehossasi elektronisia laitteita □ □
(esim. sydämen tahdistin)?

13. Tupakoitko? □ □
Jos kyllä, montako savuketta/vrk?____________
Jos olet lopettanut tupakoinnin, milloin (vuosi)?___________

14. Koska olet viimeksi nauttinut alkoholia?_____________Kuinka paljon?___________

15. Mikä on nykyisen työsi fyysinen rasittavuus?
-toimistotyö tai vastaava □
kevyt ruumiillinen työ □
raskas ruumiillinen työ □

16. Miten kuljet työmatkasi?_________________ Työmatkan kesto _________min/päivä

17. Kuinka usein olet **harrastanut liikuntaa** viimeisen kolmen kuukauden aikana?
-en lainkaan □
-kerran viikossa □
-2-3 krt viikkossa □
-säännöllisesti yli 4 kertaa viikossa □
Mitä liikuntaa olet harrastanut?
____

18. Arvio oma kuntotasosi asteikolla 1=heikko, 2=välttävä, 3=keskitasoinen, 4=hyvä, 5=erinomainen
Kuntoarvio:____________________

Vakuutan antamani tiedot oikeiksi,

Jyväskylässä ___________/_________/2014

Allekirjoitus____

Jyväskylän yliopiston eettiselle toimikunnalle

Pyydän Jyväskylän yliopiston Eettistä toimikuntaa antamaan lausunnon oheisesta tutkimussuunnitelmasta

“The effect of compression socks on motor learning, specifically balance and agility”

Vastuullinen tutkija: liikuntapedagogiikan professori Jarmo Liukkonen

Tutkimus on osa Liikuntatieteellisen tiedekunnan Fidipro -hanketta (Designing textured materials and environments for motor learning in physical activity and sports; TEKES Projekti 1389/31/2011). Tutkimuksen eettisyyteen liittyen tutkimuksessa on kyseessä hyvin tavanomaiset liikuntabiologian tutkimuksen eettiset kysymykset. Lausunto tarvitaan myös tutkimustulosten kansainvälistä julkaisemista varten.

Tutkimus ei kuulu K-S Sairaanhoitopiiriin vaan yliopistolle, koska siinä ei tutkita potilaita eikä terveyttä.

Jyväskylässä 20.2.2014

Jarmo Liukkonen, professori

Jyväskylän yliopisto, Liikuntakasvatuksen laitos

p. 040 8053 961; jarmo.liukkonen@jyu.fi

LIITTEET:

1. Tiivistelmä
2. Tutkimussuunnitelma
3. Koehenkilötiedote/suostumuslomake
4. Rekisteriselostuslomake

IKÄMOTO: HAASTATTELU TELINERATAAN LIITTYVISTÄ TUNTEMUKSISTA

1. Yleiset kokemukset telineradalta (jumpasta):

Kerro jokin myönteinen kokemus tai tapahtuma, mikä on jäänyt mieleen jumpasta.

Kerro jokin kielteinen kokemus tai tapahtuma, mikä on jäänyt mieleen jumpasta.

Mitkä tekijät lisäsivät motivaatiotasi jumpan aikana?

Mitkä tekijät laskivat motivaatiotasi jumpan aikana?

2. Fyysiset tuntemukset:

Miten jumppa (telinerata) kohensi fyysistä kuntoasi? Missä tilanteessa olet huomannut, että fyysinen kuntosi on kohentunut?

Millaisia vaikutuksia jumpalla on ollut päivittäiseen toimintakykyysi?

Tunsitko mahdollisesti kipuja kehossasi jumpan aikana tai sen jälkeen? Millä tavalla kipu rajoitti liikkumistasi telineradalla? Vähensikö jumppa aikaisempia kipuja? Missä?

Miten motoriset liikuntataitosi kehittyivät tämän kevään aikana? Millaisia vaikutuksia olet huomannut kehonhallinnassa?

Yöuni?

3. Psyykkiset tuntemukset:

Kuvaa jumpan vaikutuksia mielialaasi.

Rentouttiko jumppa vai lisäsikö se jännittyneisyyttä? Millaiset olivat tuntemuksesi jumpan jälkeen?

Kerro jokin konkreettinen onnistumisen kokemus jumpasta. Kerro jokin epäonnistumisen kokemuksesi jumpasta. Arvioi mistä ne johtuivat ja millaisia tuntemuksia ne herättivät?
Koitko mahdollisesti pelkoa tai epävarmuutta? Missä? Vaikuttiko tunne suoritukseesi tai motivaatioosi?

4. Sosiaaliset kokemukset:

Kuvaa kokemuksiasi ryhmässä? (Oliko ryhmässä helppo olla?)

Saitko uusia tuttavuuksia tai ystävyyssuhteita?

Olisitko toivonut, että jumpassa olisi ollut vielä enemmän yhteistoiminnallista toimintaa?

Vetäjä(t)?

5. Jumpan vaikutukset tulevaisuuteen

Arvio, miten osallistumisesi jumppaan vaikuttaa tulevaisuuteesi?

Ikämoto: Kysely telinerataan liittyvistä kokemuksista
Puolivälissä harjoittelujaksoa 16-17.4.2007

Millaisia vaikutuksia koit telineradalla (jumpassa) olevan?

	Paljon	jonkin verran	ei/en ollenkaa
	1	2	3
Virkistikö jumppa henkisesti?			
Koitko jumpassa onnistumisen tunteita?			
Koitko jumpassa epäonnistumisen tunteita?			
Vaikuttiko jumppa mielialaasi?			

-jos vaikutti, niin millä tavalla
____
____

Lisäsikö jumppa kipuja? Missä?____________
Vähensikö kipuja? Missä__________________

Mielestäni jumppa oli rentouttavaa?
Mielestäni kuntoni parani?
Mielestäni päivittäinen toimintakykyni parani?
-missä asioissa ____________________

Saitko uusia ystäviä?
Oliko ihmisten tapaaminen tärkeä osa jumppaa?
Koitko jumpan yleensä itsellesi tärkeäksi?
- miksi? __________________________

Oletko aikaisemmin harrastanut ryhmäliikuntaa?
- mitä? ____________________________

Miten muuttaisit jumppaa itsellesi vielä sopivammaksi?
____

Mielestäni pitäisi kysyä lisäksi (jos niitä ei vielä kysytä):
-Oletko osallistunut kaikkiin mahdollisiin jumppakertoihin?
1. Kyllä
2. En
Joe et niin syys:

- Onko jumppa ollut
1. Fyysisesti raskasta
2. sopivaa
3. kevyttä

Onko jumppa vaikeaa?
1. vaikeaa
2. sopivaa
3. helppoa

Oletko pystynyt tekemään kaikki harjoitteet?

1. kyllä
2. 2. ei

Mitkä harjoitteet ovat olleet vaikeita?

Kysely harjoittelujaksoon liittyvistä kokemuksista

5=erittäin paljon ..…………1 = ei lainkaan

Tunnit virkistivät minua henkisesti	5	4	3	2	1
Tunnit kohensivat fyysistä kuntoani	5	4	3	2	1
Päivittäinen toimintakykyni parani	5	4	3	2	1
- Missä asioissa?					
______________________________					
______________________________					
Koin tasapainojeni parantuneen harjoitusjakson aikana	5	4	3	2	1
Koin erikoissukat miellyttäviksi	5	4	3	2	1
Koin erikoissukkien helpottavan harjoittelua	5	4	3	2	1
Aion käyttää erikoissukkia jatkossakin tutkimuksen päätyttyä	5	4	3	2	1
Harjoitukset paransivat mielialaani	5	4	3	2	1
______________________________					
______________________________					
Harjoitukset lisäsivät kipuja	5	4	3	2	1
- Missä?					
______________________________					
______________________________					
Harjoitukset vähensivät kipuja	5	4	3	2	1
- Missä?					
______________________________					
______________________________					

Omat liikuntataitoni kehittyivät	5	4	3	2	1
Koin harjoittelun itselleni tärkeäksi	5	4	3	2	1

Kuinka usein jouduit jättämään harjoituskerran väliin?

____

____

Miten muuttaisit harjoituksia itsellesi vielä sopivammaksi?

____

____

____

____

Jos tällainen harjoitusjakso järjestetään ensi syksynä, kuinka todennäköisesti osallistuisit?

5. erittäin todennäköisesti osallistuisin
4. todennäköisesti osallistuisin
3. en tiedä
2. todennäköisesti en osallistuisi
1. en osallistuisi

Mitä muuta haluaisit vielä sanoa?

____

____

____

Mukavaa kesää!

-Daniel, Jaakko ja Miikka

Jyväskylän yliopiston eettiselle toimikunnalle

Pyydän Jyväskylän yliopiston Eettistä toimikuntaa antamaan lausunnon oheisesta tutkimussuunnitelmasta

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Jyväskylässä 20.2.2014

Jarmo Liukkonen, professori

Jyväskylän yliopisto, Liikuntakasvatuksen laitos

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LIITTEET:

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4. Rekisteriselostuslomake

Nimi: ____

Mieti kulunutta viikkoa. Millaista liikuntaa olet harrastanut? Kuinka pitkään pysyit yhtäjaksoisesti liikkeellä? Liikunnaksi käy kaikki fyysinen toiminta aina salitoiminnasta kaupassa käymiseen. Jos käytit erikoissukkia liikkuessasi, merkitse **X** toiminnan ja keston jälkeen. **(Esim. kävelylenkki 25 min X.)**

Päivä:	**Perjantai 7.3.**	**Lauantai 8.3.**	**Sunnuntai 9.3.**	**Maanantai 10.3.**	**Tiistai 11.3.**	**Keskiviikko 12.3.**	**Torstai 13.3.**
Toiminta & kesto:							

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Eettinen toimikunta

LAUSUNTO

Professori Jarmo Liukkonen on pyytänyt Jyväskylän yliopiston eettiseltä toimikunnalta lausuntoa tutkimukselle "The effect of compression socks on motor learning, specifically balance and agility". Eettinen toimikunta edellyttää oman lausuntonsa perusteeksi saatekirjeen, lausuntoa hakevan hankkeen tutkimussuunnitelman ja sen tiivistelmän, tiedotteen ja suostumuslomakkeen tutkittaville sekä rekisteriselostelomakkeen.

Tutkittaville jaettavasta informaatiosta tulee ilmetä:

1. tutkijoiden yhteystiedot sekä vastuullinen tutkija
2. tutkimuksen taustatiedot soveltuvin osin: tutkimuslaitos tai -laitokset, tukiorganisaatiot tai -henkilöryhmät
3. tutkimusaineiston säilyttäminen
4. tutkimuksen tarkoitus, tavoite ja merkitys
5. menettelyt, joiden kohteiksi tutkittavat joutuvat
6. hyödyt ja haitat, joita tutkittavat/koehenkilöt kohtuudella voivat odottaa; erityisesti tutkimuksen aiheuttamat mahdolliset rasitteet tai terveydelliset riskit tutkittaville sekä niiden todennäköisyys
7. miten ja mihin tietoja aiotaan käyttää
8. tutkittavien oikeudet: että he voivat kieltäytyä osallistumasta tutkimukseen, että he voivat missä tahansa vaiheessa kysyä lisätietoja tutkimuksesta ja että he voivat missä vaiheessa tahansa perua osallistumisensa tutkimukseen
9. onko tutkittavat vakuutettu tutkimusprojektin puolesta vai oletetaanko, että tutkittavat osallistuvat tutkimukseen omien henkilökohtaisten vakuutustensa varassa.
10. tutkittavan tai hänen huoltajansa/laillisen edustajansa suostumus tutkimukseen osallistumisesta

Eettinen toimikunta on käsitellyt Liukkosen lausuntopyynnön kokouksessaan 10.3.2014. Liukkonen on täydentänyt lausuntopyyntöä toimikunnan edellyttämällä tavalla, eikä toimikunta näe tutkimushankkeen toteuttamiselle estettä, mikäli se suoritetaan tutkimussuunnitelmassa esitetyllä tavalla.

Laki lääketieteellisestä tutkimuksesta (488/1999 muutoksineen) edellyttää, että lain soveltamisalaan kuuluvalle tutkimukselle saadaan sairaanhoitopiirin eettisen toimikunnan suostumus. Eettisen toimikunnan käsityksen mukaan lausuntopyynnön kohteena ei ole laissa tarkoitettu lääketieteellinen tutkimus.

Jyväskylässä 14.3.2014

Sirpa Leppänen
varapuheenjohtaja

Maria Vârre
sihteeri