HALMSTAD UNIVERSITY

Bachelor's Programme In Exercise Biomedicine, 180 credits

BACHELOR THESIS

Jump ability and knee stability in adolescents with different elasticity training

Filip Dahlström

Bachelor's Thesis In Exercise Biomedicine, 15 credits

Halmstad 2017-05-24

Jump ability and knee stability in adolescents with different elasticity training

Filip Dahlström

2017-05-24

Bachelor Thesis 15 credits in Exercise Biomedicine

Halmstad University School of Business, Engineering and Science

Thesis supervisor: Sofia Augustsson

Thesis examiner: Åsa Andersson

Abstrakt

Bakgrund: Hopphöjd, utnyttjandet av stretch-shortening cykeln (SSC) och knästabilitet är viktiga komponenter och avgörande faktorer för prestation. Dessa egenskaper tränas oftast med hjälp av plyometrisk träning, men denna träningsform anses medverka till höga krafter som utsätter kroppen för mycket stress. Trampolinträning är en aktivitet med ett växande antal utövare, speciellt bland ungdomar. Med trampolinträning kan även samma egenskaper tränas som vid plyometrisk träning. Dock har få studier undersökt trampolinträningens effekt på hopphöjd, användningen av stretch-shortening cykeln och knästabiliteten i jämförelse med plyometrisk träning. **Syfte:** Syftet med denna studien var att undersöka huruvida hopphöjden i ett countermovement jump (CMJ) och ett squat jump (SJ), användningen av SSC samt knästabiliteten i landningar skiljer sig hos ungdomar som utövar trampolinträning och ungdomar som utövar plyometrisk träning. **Metod:** Trettio (n=30) deltagare, 19 handbollsspelare och 11 trampolinutövare i åldrarna 14 till 18 år, genomförde denna tvärsnittsstudie. Studien involverade tre test, ett CMJ och ett SJ för att mäta hopphöjden och användandet av SSC samt ett double leg drop jump test för att mäta knästabiliteten. **Resultat:** Resultatet visade en signifikant skillnad mellan gruppernas relativa hoppvärde, där handbollsgruppen visade ett högre värde i CMJ och SJ jämfört med trampolingruppen. Vid utnyttjandet av SSC var det ingen signifikant skillnad mellan grupperna. Det fanns en signifikant skillnad mellan gruppernas knästabilitet, där trampolingruppen visade på en bättre knästabilitet jämfört med handbollsgruppen. **Konklusion:** Resultatet från denna studie visade att ungdomar bör utföra plyometrisk träning för att uppnå en högre hopphöjd och trampolinträning för att uppnå en bättre knästabilitet. Båda aktiviteterna hade samma utnyttjande av SSC och var därför oberoende till vilken aktivitet som utfördes. För att undersöka om detta resultatet är tillförlitligt bör fler studier undersöka mer homogena grupper med fler deltagare.

Abstract

Background: Jump height, utilization of the stretch-shortening cycle (SSC) and knee stability is key qualifications and important factors for athletic performance. This is usually practiced with the help of plyometric training. However, plyometric training is considered as an exercise with high-impact that adds stress on the body. Trampoline training is an activity with a growing number of adolescent's performers, and with the ability to train the same qualities that plyometric training. However, few studies have investigated trampoline trainings effect on jump height, utilization of the SSC and the knee stability in comparison to ordinary plyometric exercises. **Aim:** The aim of the study was to investigate whether the jump height in a countermovement jump (CMJ) and a squat jump (SJ), the use of SSC and knee stability at landings is different in adolescents who are training using a trampoline and adolescents training using plyometric exercises. **Methods:** Thirty (n=30) participants, 19 handballs players and 11 trampoline practitioners, aged 14-18 years, completed this cross-sectional study. This study involved three tests, a CMJ and a SJ for measuring the jump height and SSC and a double leg drop jump test for measuring the knee stability. **Results:** The result showed a significant difference in relative jump value between the groups, were the handball group showed a higher value in the CMJ and the SJ compared to the trampoline group. In the utilization of the SSC there were no significant difference between the groups. The result showed that there was a significant difference between the groups knee stability, were the handball group showed a greater knee degrees of varus compared to the trampoline group. **Conclusion:** Findings from this study suggests that adolescents might benefit from performing plyometric training to achieve a greater jump height and trampoline training to achieve a greater knee stability. Both activities had the same effect on the utilization of the SSC. More studies are needed, including a more homogenous group with larger sample sizes, to support the present results and investigate whether the results are reliable.

CMJ: *Countermovement jump* ***SJ:*** *Squat jump* ***DJ:*** *Double leg drop jump* ***SSC:*** *Stretch-shortening cycle* ***BMI:*** *Body mass index*

Table of Contents

1. Background

In many sports, jump performance, jumping height and knee stability are considered as key qualifications and are important factors for performance (Markovic, 2007; Salaj, Milanovic & Jukic, 2007; Taube, Leukel, Lauber & Gollhofer, 2012; Wikstrom, Tillman, Chmielewski & Borsa, 2006). In sports like handball and volleyball, the explosive jumping strength can be the factor that determines if the team will win or not. Athletes therefore often train to develop explosive strength and power with different plyometric exercises (Adriana, 2013). When plyometric exercises are part of a training program it produces high-impact forces in the landing (Atilgan, 2013), which unfortunately creates a high injury risk in the lower extremities (Salaj et al., 2007). Therefore, other alternative to plyometric training, with a lower risk of injury, such as trampoline training, is important to investigate (Ross & Hudson, 1997).

1.1. Trampoline training

Trampoline training has for a long time been performed by a small group of elite athletes, but the activity has recently started to grow with participants in all ages, especially among adolescents in the age 14 to 20 years (Esposito & Esposito, 2009; Smith & Shields, 1999). Trampoline training consist of different jumps on an elastic and unstable material which creates a great involvement of muscles in the lower extremities (Aalizadeh, Mohammadzadeh, Khazani & Dadras, 2016). However due to the material, trampoline training can also improve other psychical factors as explosivity, balance, acrobatic skills, coordination, anaerobic capacity and strength (Aalizadeh et al., 2016; Atilgan, 2013; Esposito et al., 2009; Ferris & Farley, 1997). Studies that have investigate the trampoline training's influence of jump height have shown different results. Most studies have shown that athletes jump height on the ground can be increased by training on a trampoline (Atilgan, 2013; Crowther, Spinks, Leicht & Spinks, 2007; Ross et al., 1997; Salaj et al., 2007). This improved performance can be explained by a greater jump technique that is transferred to jumping on the ground and to other jumps (Crowther et al., 2007; Márquez, Aguado, Alegre & Férnandez-del-Olmo, 2013; Ross et al., 1997). However, studies have also showed that athletes jumping height on the ground can be reduced by training on a trampoline (Márquez, Aguado, Alegre, Lago, Acero & Fernández-del-Olmo, 2010). One study that compared talented trampoline jumpers and novice trampoline jumpers found that the biggest difference between the two groups were that the talented jumpers used a less range of motion and had a higher muscular stiffness (Atilgan, 2013). These factors can affect the jumping height since studies have shown that an increased leg stiffness can lead to a decreased jump height (Márquez et al., 2010).

The elastic material in the trampoline has been shown to help athletes by reducing the need for crouch when jumping on the ground (Crowther et al., 2007). This results in a higher elastic energy utilization (Crowther et al., 2007). Elastic energy is created during the stretching of a muscle-tendon unit which could be used to enhance the muscle performance (Anderson & Pandy, 1993). Therefore, a higher elastic energy utilization can help athletes achieve a higher leg power in a jump which has been found to result in a greater jump height (Anderson et al., 1993; Crowther et al., 2007). The material also affects the leg stiffness according to the spring-mass model (Márquez et al., 2013). The model indicates that when the surface stiffness decrease, the stiffness of the legs increase (Márquez et al., 2013). The elastic material also affects the impact force by minimizing it, compared to jumping on the ground. This makes trampoline training a low-impact activity, which most likely will result in less tear on the body compared to plyometric training (Aragão, Karamanidis, Vaz & Arampatzis, 2011; Crowther et al., 2007).

Although there are many benefits of trampoline training, there is also a high injury risk for trampoline athletes. In America, every third day an adolescent that practice trampoline training is treated for severe injuries (Smith et al., 1999). This makes trampoline training a relatively risky activity (Smith et al., 1999). The most usual reported injuries from trampoline training are fractures, sprains and soft tissue injuries. There are also more serious consequences as permanent paralysis, head injury and death (Esposito et al., 2009). Despite this, many athletes find that the benefits outweigh the injury risk. Some of these positive qualities required from trampoline training are explosive strength and jump height (Esposito et al., 2009).

1.2. Plyometric training

Plyometric training consists of various rapid explosive exercises that combine strength and speed to train explosivity, power, strength, coordination and jump height (Adriana, 2013). It has been shown that explosivity and strength benefits from the use of the elastic energy, that is utilized in plyometric training. The reason why plyometric training often seems to be a good method to train power is because it utilizes both velocity and strength which are key factors in power development (Davies, Riemann & Manske, 2015). Plyometric training can also improve the ability to elicit the stretch reflex and energy stored in the series of elastic components which will improve both the jump height and the technique (Davies et al., 2015). Plyometric training has also been found to improve the jump technique by training the nervous system which makes the movements more automatic and develop coordination (Davies et al., 2015).

Unlike trampoline training, plyometric training is a high-impact activity, which results in a great deal of stress on the body. Studies have shown that the impact can generate a force that are ten times the body weight, which increases the stress on ligaments and joints (McArdle, Katch & Katch, 2014). This will both increase the injury risk and force athletes to a longer recovery between workouts. Therefore, it is important to consider if there are other ways to get the same training effect with reduced negative impacts (Crowther et al., 2007).

Results from an earlier study shows that of plyometric training reduces the ground reaction time and improves jump height (Patel, 2014). This can be explained both by improvement in the jump technique and the utilization of mechanical and neurophysical models (Taube et al., 2012). Both these models are active during the eccentric phase (when the muscles are shortening) and the concentric phase (when the muscles is extended). Both models need the transition between the eccentric and the concentric phase to happen rapidly and in the right range of motion, otherwise the stored energy will be lost as heat (Adriana, 2013). Hence, the key factor in plyometric training is that a fast transition will result in that the athlete will achieve a greater force (Adriana, 2013). This is possible by utilization of both the mechanical and neurophysical models or the stretch-shortening cycle (SSC) as it is commonly called (Taube et al., 2012).

1.3. Stretch-shortening cycle

An important part of jump height in both trampoline- and plyometric training is the SSC. The SSC is stimulated by extern stimuli that signals the series of elastic components and the stretch reflex to stretch the muscle with tendons and muscle spindles during the eccentric phase (Taube et al., 2012). The energy from SSC is therefore created in the eccentric phase and can then be used in the concentric phase of the jump. If the eccentric phase is in a short range, have high velocity and the transition happen immediately after the eccentric phase, the SSC is more likely to be activated and the jump height greater (Patel, 2014; Wilk, Voight, Keirns, Gambetta, Andrews & Dillman, 1993). SSC is used in a countermovement jump (CMJ) were the athlete is performing a fast transition after the eccentric phase and then try to jump as high as possible. To test the jump height without the use of the SSC, a squat jump (SJ) can be used. In the SJ the athlete pause between the eccentric and the concentric phase, which makes the transition time too long and, therefore, eliminating the use of SSC in the jump (Bobbert, Gerritsen, Litjens & Van Soest, 1996). By comparing CMJ and SJ jump heights, the SSC can be measured. The difference in the jump heights is due to the use of the SSC (Young, 1995).

A high muscular stiffness is believed to result in an improved capacity to store elastic energy and the activation of the SSC (Taube et al., 2012). As stated earlier, studies have shown that talented trampoline jumpers use a less range of motion and have a higher muscular stiffness during the jump compared to novice trampoline jumpers (Atilgan, 2013). Different landing material affect joint kinematics differently which in turn have an impact on the SSC. Thus, the elasticity of the trampoline may influence the SSC positively (Crowther et al., 2007). At the same time, the transition can take longer time due to the elastic material which in turn may affect the SSC negatively (Ross et al., 1997). In summary, studies conducted on trampoline training have shown that it can affect the SSC both positively and negatively, but few studies have investigated if there is any difference between the effect on the SSC in trampoline training and plyometric training.

1.4. Knee stability during jumping and landing

Knee stability is the knee joints ability to retain stable during shifting loads in activities (Wikstrom et al., 2006). A poor knee stability can result in involuntary knee movements during shifting load, for example in landings or rapid changes of direction (Wikstrom et al., 2006). The knee joint is affected by the forces that are produced during high-impact exercise like jumping. Hence, the ability of the knee joint to distribute the forces is a crucial factor for the jumping height (Wikstrom et al., 2006). This means that an athlete with a good knee stability can jump high and land safely. Therefore, it is possible to investigate subjects’ knee stability at landing with a drop jump test (Herrington & Munro, 2010). A drop jump test analyzes the knee angle in the lowest point of the landing with the help of a camera and then show if there is a varus (bow-leg) or valgus (knock-knee) motion in the landing (Herrington et al., 2010). Varus or valgus can depend on both anatomy and neuromuscular imbalance which affect the knee stability and the ability of the lower extremity muscles to absorb forces (Ford, Myer & Hewett, 2003). If the lower extremity muscles do not absorb the forces, a high load on the knee ligaments occurs and the injury risk increases (Ford et al., 2003). Therefore, athletes, with presence of knee varus or valgus during jumping and landing activities, may benefit from a training protocol aiming to correct the imbalance and, thus, improve knee stability (Ford et al., 2003). Plyometric training has previously been demonstrated to improve neuromuscular imbalance and knee stability (Hewett, Stroupe, Nance & Noyes, 1996), but few studies have shown whether trampoline training offer the same effects.

A study that compared differences between landing on a trampoline and on the ground found less angular displacement of the knee when the subject landed on a trampoline (Ferris et al., 1997). The range of motion was around 20 degrees less in knee flexion when subject performed jumps on the trampoline compare to the ground, which indicate as previously mentioned that the legs are stiffer when athletes is training on a trampoline (Crowther et al., 2007). It has also been shown that knee stability improves when legs are stiff due to a better joint load distribution and consequently establishing a better knee stability (Wikstrom et al., 2006). Yet, when an athlete lands with a knee extension between 0-20 degrees, the risk of injury increase (Ford et al., 2003). Hence, it is difficult to identify the impact of different kind of material on knee stability. However, as previously mentioned, trampoline training is performed on an elastic material and elastic material has shown to reduce the impact force and the amount of gravitational force exerted on an athlete (Crowther et al., 2007). Therefore, trampoline training might improve knee stability since it decreases stress that is placed on the knee joint compared to plyometric training. Nevertheless, this research area needs to be further investigated before we can make any definite conclusion in this matter (Aragão et al., 2011).

Although knee instability is a matter related to injury, it is unknown to what extent impaired knee stability, and the exact degrees of knee angles, that will predispose an athlete to future knee injuries (Ekegren Miller, Celebrini, Eng & MacIntyre, 2009). But since it is a factor that affects performance and jump height, it is still important to investigate the presence and try to prevent knee instability. It has been found that adolescents and females have a greater risk of a poor knee stability. Adolescents have high risk for knee instability due to growth and weight gain (Ford et al., 2003; Quatman, Ford, Myer & Hewett, 2006). Females knees are especially vulnerable due to anatomical, biomechanical and hormonal factors. Anatomical factors such as an increased hypermobility and an increased q-angle, which is the angle between a line drawn from the anterior superior iliac spine to the center of the patella and a line drawn from the center of the patella to the tibial tubercle (figure 1), increase knee instability. Biomechanical factors affect ligament and leg dominance while the hormonal factors affect ligament strenght and muscle recruitment (Ford et al., 2003). This makes females more vulnerable for knee injuries than men. These factors together with the fact that trampoline training is an activity with an increased number of participants in those ages, makes it important to see how trampoline training affects knee stability (Esposito et al., 2009).

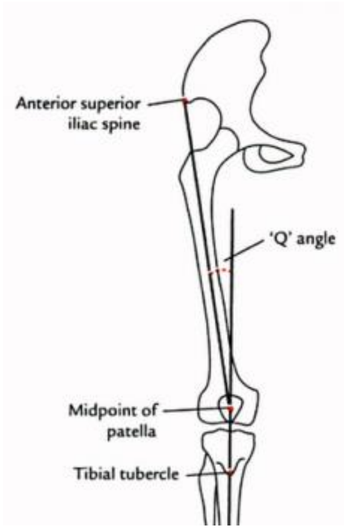

Figure 1. Detailed view of the two lines that shows the q-angle.

Taken together, both the SSC and knee stability are important factors for explosive strength and jump height. However, literature is insufficient when it comes to studies investigating the effects of knee stability training with trampoline compared to plyometric exercises. Thus, the present study will contribute new knowledge on the role of trampoline training and its effect on jump height, SSC and knee stability in contrast to plyometric exercises.

1.6. Aim

The aim of the present study was to investigate whether the jump height, the use of the stretch-shortening cycle and knee stability during landing differs in adolescents who are training using either a trampoline or plyometric exercises.

1.6.1. Research questions

This study was conducted on adolescents to investigate the following points:

(i) Is there a difference in how trampoline training and plyometric exercises affect the jump height in a CMJ and SJ?

(ii) Is there a difference in how trampoline training and plyometric exercises affect the use of the stretch-shortening cycle?

(iii) Is there a difference in how trampoline training and plyometric exercises affect knee stability at landing?

2. Methods

2.1. Subjects

Thirty-one (n=31) males (n=23) and females (n=8) were recruited from different handball teams and from a local trampoline gym in Halmstad, Sweden. 25 handball trainers from different local handball team with players between 14 and 20 years of age were contacted. Two teams reported interest and all their players (n=19) agreed to participate. Trampoline performers between 14-20 years that had conducted trampoline training over three months was given information about the study. Trampoline performers who met the criteria and wanted to participate in the study was included. Subjects were recruited by email, phone calls and personal contact where they received information about the study and was given an opportunity to ask questions. Inclusion criteria for participation in this study were adolescents between 14 and 20 years old that had either handball or trampoline as their main training activity, with a minimum of three session of practice per week, for the last three months. If any of the participants had acute injuries in terms of reduced mobility, swelling or pain in the lower extremities or in the lower back, they were excluded from the study. One subject was excluded from participation in the study due to an injury in the lower back. The remaining subjects (22 males and 8 females) met the criteria and completed the study.

2.2. Description of the study design

The study was carried out as an analytic cross-sectional study that investigate the difference in jump height, SSC and knee stability at landing between adolescents that train with the help of trampoline or plyometric exercises. To investigate this, a counter movement jump (CMJ), squat jump (SJ) and a double leg drop jump (DJ) test were conducted at one test session.

2.3. Testing procedures

To standardize the preparation of each participant, use of tobacco, caffeine intake and large meals were not allowed two hours prior to the test session. The participants were also not allowed to perform heavy training, that was described as training conducted over 79 percent of maximal heart rate or heavy weight training, 24 hours prior to the test session. The participants should not experience any symptom of the training that can affect performance during the test session (Tanner & Gore, 2012). The participants were instructed to wear proper shoes and shorts when performing the tests.

During every test session, the same two test leaders instructed and evaluated the tests. Before the test sessions, were age and anthropometric measures for each participant were collected. Weight was measured with a digital scale (Seca 701, Seca, Hamburg, Germany) and height was measured with a stadiometer (Seca 217, Seca, Hamburg, Germany). After age and anthropometric measures were collected, all participants conducted a five-minute warm up consisting of dynamic exercises. The warm up contained ten body weight squats, lunge walks and butt kicks for ten meters and five CMJ, these exercises were carried out in two rounds during warm up (Moir, Shastri & Connaboy, 2008).

2.3.1. Countermovement and squat jump test

To measure jump height and analyze any differences in the utilization of the SSC between adolescents, a CMJ test and a SJ test was used. The session started with a CMJ test where the test leader instructed that the participants should start from a standing position and then go down in a countermovement until their thighs were parallel to the floor and the knee flexion was 90 degrees. Participants were then instructed to directly try to jump for maximal vertical height with hands placed on the hips. Participants also received instructions that the legs would be straight during the jump and in the landing (Bellardini, Henriksson, Tonkonogi & Roberts, 2009). After the participants performed a test jump, they were instructed to performed three approved jumps for maximal height and the best attempt was used for further analysis.

The second test was a SJ test where the participant was instructed to start from a static position were thighs were parallel to the floor and the knee flexion were 90 degrees. The participant stayed in that position until the test leader counted to three and was then instructed to jump for maximal vertical height with hands placed on the hips. The participants also received instructions that their legs would be straight during the jump and in the landing (Bellardini et al., 2009). In the SJ participants also performed a test jump and then performed three approved jumps were the maximum jump height was used for analysis. To analyze the use of SSC, the jump height in SJ was subtracted from CMJ and the analyze was then performed on the result. Both the CMJ and the SJ were measured with an infra-red contact mat (IVAR Testsystem, SH sport & fitness, Mora, Sweden) which sensors were placed 1.5 meter apart. The participants were, in both tests, positioned so that it was possible to analyze the jump technique and knee flexion from the side to ensure consistency.

2.3.2. Double leg drop jump test

The third test was a DJ to measure knee stability in the landing. Before the DJ, center of the patella, anterior superior iliac spine and talus was marked with tape, for a detailed view of taped landmarks see figure 2. The test leader then instructed participants to stand on a 30 centimeter high box and then take a step out with an optional foot with hands on the hips and then land on the ground (Bellardini et al., 2009). If participants jumped instead of taking a step out from the box, the test was assessed as unapproved and the participant had to perform the test again. Four participants jumped instead of taking a step out of the box and therefore had to perform the test again. The participants first conducted a test landing and then performed one approved landing that was used for analysis. The test was recorded with the help of a film camera (Panasonic SDR- 526, Panasonic, Osaka, Japan) that was placed 2.8 meters from the box on a 0.58 meter high tripod. The film camera was recording in frontal plane and the data were analyzed in Dartfish (Dartfish, version 6.0, Fribourg, Switzerland). The analyze measured knee movements in the lowest point of the landing phase with help of the markers and showed how many degrees it differed from neutral knee position. In the analysis was varus defined as ≤178° and valgus as ≥182° (Sharma et al., 2012). Varus was expressed as positive values and valgus was expressed as negative values.

Figure 2. Detailed view center of the patella, anterior superior iliac spine and the talus that were taped during the DJ.

2.4. Validity and reliability of the testing procedures

2.4.1. Countermovement and squat jump test

Many studies have previous examined the validity and reliability of CMJ and SJ when measured with an IVAR. It has been shown that CMJ and SJ performed on an IVAR have a higher validity and reliability for measuring jump height when compared to force platforms, belt test and jump-and-reach tests (Kenny, Caireall & Comyns, 2012; Markovic, Dizdar, Jukic & Cardinale, 2004; Young, 1995). IVAR is also a time saving equipment with fast result and an easy processing of data when analyzing CMJ and SJ (Kenny et al., 2012). One factor that has been found affecting the validity of CMJ and SJ when using IVAR is that the equipment can measure flight time but not the jump height which is calculated. This affect the validity since jump height is not measured directly. Reliability can also be affected by allowing factors like arm swings and different depths (Cormack, Newton, McGuigan & Doyle, 2008). But if a standardization is used the tests have a high validity and reliability for measure flight time and the explosive strength of the lower extremity (Markovic et al., 2004). Studies that examined the reliability showed that the two tests have a high reliability between different participants, days and between test leaders with a intraclass correlation coefficient value between 0.93 and 0.98 (Cormack et al., 2008). Studies have also shown that a slightly higher reliability can be achieved by analyzing the participants highest jump instead of an average of all performed jumps (Moir et al., 2008).

To minimize cofounders when comparing heterogeneous groups containing adolescents with different distribution of genders, body size should be involved as a factor (Jaric, 2002). Studies have shown that the influence of body size should be used to achieve a fairer comparison of heterogeneous groups and gender in anaerobic tests like CMJ and SJ (Pennington, 2014). In adolescents, the effects of maturation affect both the body composition and the performance. Adolescents that are heavier or taller are usually stronger compared to lighter and shorter ones, but when looking at strength relative to body size the comparison become more equitable for all participants (Jaric, 2002). Thus, in the present study a relative value as jump height in relation to body mass index (BMI) was used when analyzing the two groups jump heights.

2.4.2. Measuring the stretch-shortening cycle

There are different ways to measure the use of SSC, the difference between CMJ and SJ is considered a good method to see how much the subject is using the SSC (Tufano, Walker, Seitz, Newton, Häkkinen, Blazevich & Haff, 2013). Greater height in CMJ compared with SJ can depend on the ability to use SSC (Tufano et al., 2013). The $CMJ_{cm} - SJ_{cm}$ equation is considered to have a good validity to examine a subjects' utilization of SSC capacity (Young, 1995), but since the method do not measure SSC directly the validity can be questioned. The method to measure SSC have showed a good reliability with a intraclass correlation coefficient value of 0.85, but the reliability is based and dependent on that CMJ and SJ is standardized (Young, 1995).

2.4.3. Double leg drop jump test

The DJ is a well-used test for measuring knee stability at athletes in landing. The DJ have shown a good validity compared to other field test to measure the knee stability. It has also showed a high reliability with a intraclass correlation coefficient value of 0.93 (Ortiz, Rosario-Canales, Rodríguez, Seda, Figueroa & Venegas-Ríos, 2016). When filming a DJ in frontal plane with a two-dimensional (2D) analysis, it has been shown to have a good reliability compared to three-dimensional (3D) analysis which is the golden standard (Ortiz et al., 2016). Although filming with a 3D system is preferable when analyzing kinetic data due to higher validity, a 2D analysis is a cost effective alternative and time efficient when analyzing a larger group of individuals (McLean, Walker, Ford, Myer, Hewett & van den Bogert, 2005). Although the validity of measuring knee stability with a 2D analysis in DJ has proved to be good, it can vary widely, since it is depending on the program that calculates knee angles accuracy (Ekegren et al., 2009). Former studies have shown that degrees between the dominant and non-dominant leg differ in athletes due to different muscular activity (Ludwig, Simon, Piret, Becker & Marschall, 2017). The dominant leg is also under more strain and usually have a higher risk for injuries compared to the non-dominant leg (Ekegren et al., 2009). Therefore, to ensure consistency in the analysis of knee stability, the dominant leg of each participant was analyzed.

2.5. Ethical and social considerations

All examinations were based on ethical considerations throughout the process in order not to risk the participants' rights, dignity or privacy in any way. Before participation, each participant had to sign an informed consent containing information about how the study would be implemented and the reason for the study was conducted, see appendix 1. Some of the participants were under the age of 15 and according to the Helsinki declaration (World Medical Association, 2013) must both participants and their parent or legal guardian sign the informed consent before participation. All participants were also informed that the participation was voluntarily and that they could choose to cancel their participation during the study without giving a reason. Participants were informed that all information connected to the them would be treated confidentially, meaning that personal information and data that was collected could not be connected to a specific participant. To achieve a high level of confidentiality, each participant was given an identification number which prevented unauthorized to see the participant’s results. All personal information that was collected were stored safely on an encrypted USB-drive, that only the test leaders could access. During the test session, test leaders were responsible for each participant’s safety and prosperous. Both the informed consent and the test procedure were approved by Halmstad University.

The social considerations of this study are going to contribute with knowledge of which training method is more favorable for jump height. This will lead to more effective training sessions for adolescents, which in turn will lead to a decreased training time to achieve the same benefits and possibly a reduced risk for injury. The study will also contribute with information about how different training methods might affect the knee stability. This may lead to a greater understanding of knee stability and different kinds of training regimes to improve jumping capacity and, in turn, hopefully an improve knee stability among adolescents and exercisers. A greater knee stability can result in a reduced expenditure for sports teams since athletes get a higher sports attendance. Knee injuries also have a high economic cost for society (Louw, Manilall & Grimmer, 2008), so by achieving greater knee stability the expenditure for society can be reduced since hospital and medicines costs will decrease. Knowledge about how the jump height and knee stability is affected by the two training methods can be helpful for coaches to understand how activities can be combined to get athletes to train and develop different qualities.

2.6. Statistics

The data was tested for normality using the Shapiro-Wilks test of normality. The Shapiro-Wilks test showed that the variables in the two groups were not normally distributed (p<0.05), and therefore, non-parametric statistic were used. Median, minimum and maximum (min-max) were used to describe distribution between the different groups. Since the variables were not normally distributed and there was an uneven distribution of the genders between the groups, a relative jump value was calculated. The relative jump value was calculated by dividing the participants jump height with each participant BMI ($\frac{Weight_{kg}}{Lenght_m * Lenght_m}$). To examine the difference between use of SSC in the groups a formula for SSC capacity were used ($CMJ_{cm} - SJ_{cm}$). The Mann-Whitney U-test was used to compare differences in relative jump value, SSC and knee stability between the groups. The significant value was set to p≤0.05 for each test (Bobbert et al., 1996; Herrington et al., 2010; Martínez-López, Benito-Martínez, Hita-Contreras, Lara-Sánchez & Martínez-Amat, 2012). All statistical analysis was performed in IBM SPSS version 20.0 for Apple (SPSS Inc., Chicago, IL, USA).

3. Result

The present study investigated if there were differences in jump height, the use of SSC and in knee stability at landing in adolescents with different elasticity training. Thirty (n=30) participants, nineteen handballs players (n=18 males, n=1 females) and eleven trampoline practitioners (n=4 males, n=7 females) met the inclusion criteria and were included in the analysis (table 1).

Table 1. Descriptive statistics of variables in their respective activity and the distribution among males and females.

Variable	**Handball group (n=19) Median (min-max)**	**Trampoline group (n=11) Median (min-max)**	**Males (n=22) Median (min-max)**	**Females (n=8) Median (min-max)**
Age	16.0 (15.0-18.0)	14.0 (14.0-20.0)	16.0 (14.0-20.0)	14.0 (14.0-17.0)
Weight (kg)	77.4 (58.9-87.2)	57.3 (44.5-74.4)	73.4 (55.5-87.2)	56.0 (44.5-77.4)
Height (cm)	182.0 (163.1-193.1)	165.7 (156.8-177.5)	180.8 (163.1-193.1)	164.0 (156.8-181.1)

3.1. Jump height

The analyze showed that the handball players achieved a significantly higher relative jump value in both the CMJ (p=0.011) and in the SJ (p=0.009) (table 2, figure 3).

Table 2. The two groups relative jump value in the Countermovement jump and the Squat jump.

	Countermovement jump		***Squat Jump***	
Group	Handball group (n=19)	Trampoline group (n=11)	Handball group (n=19)	Trampoline group (n=11)
Median	1.56 cm	1.35 cm	1.5 cm	1.24 cm
Min-max	1.32 cm - 1.95 cm	0.96 cm - 1.79 cm	1.25 cm - 1.88 cm	0.92 cm - 1.66 cm
Difference	0.21 cm		0.26 cm	

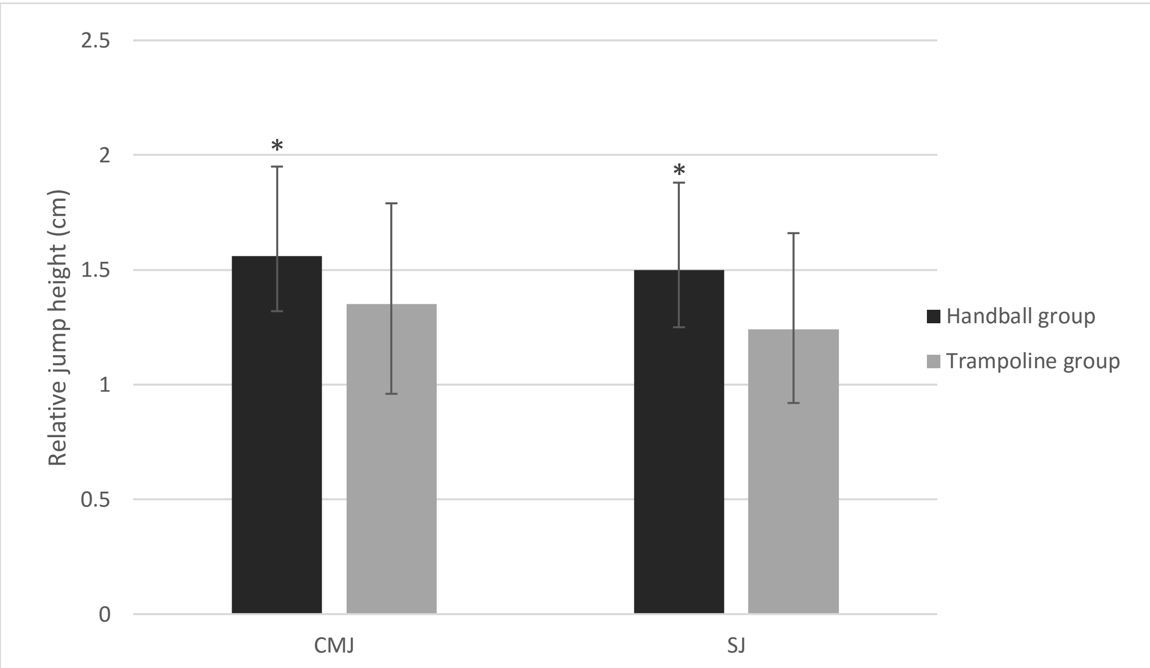

Figure 3. The two groups relative jump height in countermovement jump (CMJ) and squat jump (SJ). The range is presented as error bars. *******=*significant different from trampoline group (p<0.05).*

3.2. Stretch-shortening cycle

To obtain the use of SSC, the difference between the jump height in CMJ and SJ were examined. The result showed that the handball group had a difference value of 1.2 (min-max -1.4-3.0) cm and the trampoline group had a difference value of 1.2 (min-max -2.2 – 3.1) cm, see figure 4. There was no significant difference (p=0.763) between the groups in the valuation of the SSC.

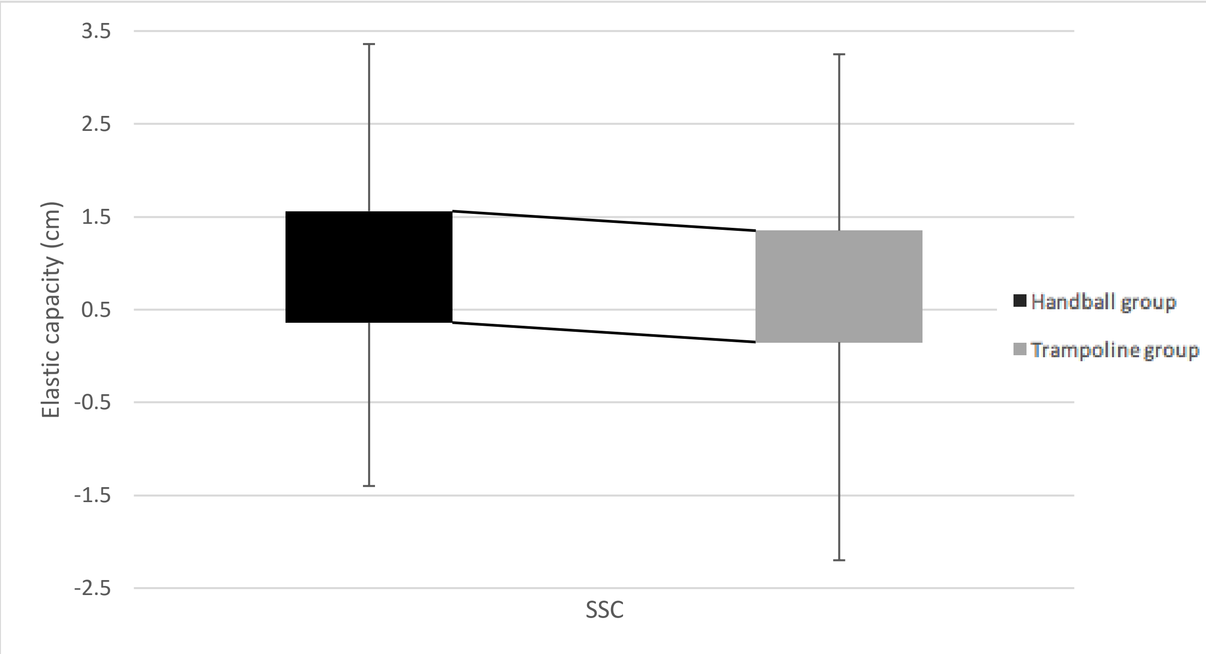

Figure 4. The difference between countermovement jump (CMJ) and squat jump (SJ) in the two groups, expressed as use of the stretch-shortening cycle (SSC). The min-max is presented as error bars.

3.3. Knee stability in landing

The result of the DJ found a significant difference (p=0.002) between the groups knee stability in the dominant leg, were the handball group had a greater degrees of knee varus (table 3).

Table 3. Descriptive statistics of the knee valgus and varus in the dominant leg between the two groups.

	Handball group (n=19)	**Trampoline group (n=11)**
Median	31.5°	14.1°
Min-max	11.9°- 64.1°	-26.0°- 39.4°
Difference	17.4°	

4. Discussion

The aim of the present study was to investigate whether the jump height, the use of SSC and knee stability during landing differs in adolescents who are training using either a trampoline or plyometric exercises. When it came to the jump tests the study found a greater jump height in the handball group in both CMJ and SJ whereas there was no difference in the utilization of SSC between the groups. In addition, the trampoline adolescents seemed to have a superior knee stability compared to the handball players.

4.1. Result discussion

4.1.1. Jump height

The result showed a significant difference (p=0.011, p=0.009) in relative jump values between the groups (table 2, figure 3), were the handball group showed a higher relative jump value. This result is in contrast with previous research by Markovic (2007) that have shown that plyometric training is a well-used method for improving jump height. The participants in Markovic (2007) study improved the jump height between 4.7-8.7 percent. Márquez et al (2010) have investigated jumps on trampoline and found that the participants jump height decreased after a period of training on elastic material. This turned out to be due to an increased leg stiffness and the range of motion. These factors were not investigated in the current study but could be one reason to why the two groups achieved different jump heights. Plyometric training has previously been proven to achieve a high jump height due to the utilization of the elastic energy (Davies et al., 2015). Crowther et al (2007) have proposed that trampoline training also achieves a high utilization of the elastic energy due to less crouch in the jump. However, since the trampoline group does not achieve the same jump height as the handball group, may this show that the utilization in trampoline training is not as good as in plyometric training. But more investigation of the elastic energy utilization is required before a conclusion can be drawn.

The present study results do not agree with studies conducted by Crowther et al (2007), Atilgan (2013), Salaj et al (2007) and Ross et al (1997) that all showed an improvement in jump height when conducted training on compliant material compared with training conducted on non-compliant material. Crowther et al (2007) showed that jump height is improved by training on a compliant material due to an improved technique and a reduced energy lost in the jumps. Both studies on trampoline training and plyometric training have shown that an improved jump height is a result of an improved technique (Crowther et al., 2007; Taube et al., 2012). It is possible that the jump technique from plyometric training is easier to transfer to the test in this present study, compared to jump technique from trampoline training. Since the jumps is performed on non-compliant material.

Atilgan (2013) and Salaj et al (2007) both conducted studies that showed that the jump height increased in the trampoline group by 3.0 respective 1.2-1.6 cm compared to the other group. The best improvements in jump height was shown by Ross et al (1997) that showed that after five weeks the participants improved their jump height by an average of 4.5 cm. In these studies, the participants only conduced trampoline training over a short period of time. This may have caused the participants to only show short-terms effects which can differ compared to the long-term effects, as shown in the present study. The studies were also performed as longitudinal studies which measured the progress in the individuals. This study is a cross-sectional study and can therefore not see the development in the two groups, only the differences. This study can therefore not tell if one activity had developed the participants jump height differently. However, the present study indicates that adolescents achieves a higher jump height when performing plyometric training compared to the height they would achieve if they would perform trampoline training instead.

4.1.2. Stretch-shortening cycle

The result showed that no significant difference (p=0.763) existed between groups utilization of SSC (figure 4). Previous study has shown that plyometric training is a good method for training the SSC, due to the rapid and explosive movements (Davies et al., 2015). Nevertheless, the present study demonstrates that jumping activities in handball and trampoline are equally when it comes to SSC utilization indicating that trampoline training may be a good training alternative. On contrary, previous results from Ross et al (1997) showed that it was not beneficial to train the SSC on a trampoline due to the elastic material. The elastic material made the time for the transition to long, which inhibited the utilization of SSC. On the other hand, Ross et al (1997) measured SSC in each muscle and not by comparing participants jump heights, as in this study. This might be an explanation, among others, for the different results between studies.

Previous studies have shown several factors that could affect the SSC positively in trampoline training, for example the material, the leg stiffness and the jump technique (Crowther et al., 2007; Márquez et al., 2013; Taube et al., 2012). Although the present study has shown that trampoline training is a good alternative to train SSC, it has not showed which factors that affect SSC positively. Even though the result from the present study displays the same utilization of SSC, it also shows that the two groups have different jump heights. This can indicate that the handball group have a better lower body strenght since they jump higher and that the trampoline group uses a greater part of the SSC during the jump. To further determine what cause this result, more research needs to be conducted to determine what mainly affect SSC in trampoline training.

4.1.3. Knee stability

There was a significant difference (p=0.002) between the groups in knee stability (table 3). A greater knee varus were found in the handball group compared to the trampoline group. In the trampoline group, there were one participant with knee valgus which reduced the median of the group compare to the handball group, which had no participant with knee valgus. Despite this, the result still shows that the trampoline group have a better knee stability. Both Ferris et al (1997) and Crowther et al (2007) have shown that athletes legs are stiffer when landing or training on a trampoline, and according to Wikstrom et al (2006) will stiff legs in the landing result in better knee stability. Factors like material, jump technique, balance, anatomy and neuromuscular imbalance have shown to affect knee stability (Ford et al., 2003; Hewett et al., 1996; Wikstrom et al., 2006). One study that examined effects of trampoline training among elderly also found that the trampoline created less stress on knees compared to plyometric training which affect the dynamic stability positively (Aragão et al., 2011). Therefore, it is difficult to say which factors that makes the trampoline group achieve a better knee stability.

The result from the present study differs from the result presented by Hewett et al (1996) and Ford et al (2003). Hewett et al (1996) have examined plyometric training effects on knee stability and concluded that plyometric training both improve neuromuscular imbalance and knee stability efficient. Plyometric training is therefore a good method to achieve a greater knee stability, however, the study did not compare the effects of plyometric training in relation to trampoline training (Hewett et al., 1996). The present study result shows that trampoline training is even better than plyometric training since the trampoline group shows a better knee stability. This can depend on that plyometric training is a high-impact activity and trampoline training a low-impact activity positively (Aragão et al., 2011; McArdle et al., 2014). Because both activities involve jumps, may the benefits from plyometric training might be achieved through trampoline training without the high-impact, which will result in a greater knee stability. Ford et al (2003) have also examine knee stability and concluded that when an athlete is landing with stiffer legs the chance of injury increase. As mentioned earlier is the trampoline athletes knees stiffer and therefore can be more exposed to injury. Although the present study shows a better knee stability among the trampoline group, it cannot show which group is at risk of developing a future injury. It is also possible that handball players landing with greater knee angles to achieve better balance since it is a close contact sport with more external requirements in relation to trampoline training. The distribution of genders between the groups differed and since females are more vulnerable for knee instability this could affect the result (Ford et al., 2003). Even though there were more females in the trampoline group, were all participants' knee stability values equal in that group regardless of gender. This could indicate that trampoline training is preferable for improving the knee stability compared to plyometric training.

4.2. Method discussion

4.2.1. Subjects

A trampoline group was compared to a handball group due to handball training consists largely of plyometric training. It is difficult to find adolescents that only perform plyometric training in the chosen age range and therefore were handball players chosen. The groups are heterogeneous since the distribution of gender, age, weight and height are different, which may affect the results since these are factors that affect performance (Jaric 2002). Between 14 and 20 years, maturity is an important factor for performance. Since the handballs players are older, the age difference could create a distorted result. Were the handball players can get better results because of a well-developed maturity in the group. To minimize that the groups distribution of weight and height affect the result, a relative jump value where the jump height was divided with BMI, was used for comparison between the two groups. There were also more females in the trampoline group compared to the handball group and since female knees is more vulnerable during puberty (Ford et al., 2003; Quatman et al, 2006), this may have affected the knee stability results. But the knee degrees in the trampoline group did not differ between the genders which indicate that trampoline training can be a good method for improve knee stability. Since females are more likely to experience knee instability, it is possible that females in the trampoline group earlier had focused on knee stability since there are more exposed to injuries. These factors along with that this study only included thirty participants makes it difficult to generalize the result to a bigger population.

4.2.2. Test procedure

All test was performed on a hard material which may be beneficial for the handball group since they train on this material. However, it is difficult to compare groups on two different material due to standardization. Previous studies have also shown that jump technique is transferable to jumps on hard material. The warm up protocol, used in the present study, has previously been proven to be suited when performing jump test and was therefore chosen (Moir et al., 2008). CMJ and SJ were chosen to measure the jump height and SSC since it previously has shown a good reliability and validity when measuring these factors (Markovic et al., 2004). To ensure that all participants thighs were parallel to the floor and the knee flexion were 90 degrees in CMJ and SJ, the depth was observed by the same researcher during the tests. However, to ensure that all participants was in the given range a film camera could have record the jumps and then measure the exact angles to achieve a higher consistency.

The DJ procedure is from Bellardini et al (2009) and were chosen since it is a usual movement in both activities. It may be possible that some participants were more familiar with the tests and therefore got a better result or that the participants consciously focused on the knee angle in the DJ landing and therefore affected the result. To reduce this factor, a more complex test with, for example, a jump after the landing could be used. Yet, to make it fair, all the participants were given the same instructions and performed a test jump before the test began. To minimize the effects of external factors on the tests, all participant where given the same information about preparation and the test session were conducted in the same way. The patella, anterior superior iliac spine and talus have been used as markers by Ortiz et al (2016) when investigate the knee angle in 2D and 3D during a DJ. However, Ortiz et al (2016) analyzed both legs at landing while the present study only analyzed the dominant leg. This to achieve a higher consistency since athletes have different degrees in the dominant and non-dominant leg due to a different muscular activity (Ludwig et al., 2017). To further minimize the sources of error in the knee analysis of the DJ, two persons performed the analyze to see if the analysis showed the same result.

5. Conclusion

In conclusion, the present study provides information about trampoline training in relation to plyometric training, based on jump height, SSC and knee stability. Handball athletes seem to jump higher than trampoline athletes, but with no difference in the utilization of the SSC. In addition, trampoline athletes seem to possess a superior knee stability in contrast to handball athletes. This study suggests that adolescent athletes should perform plyometric training to achieves a greater jump height and trampoline training to achieve a greater knee stability. However, additional studies are needed, with a more homogenous group and with larger sample sizes, to confirm these results. The significance of the present results is that it gives information about trampoline training is in relation to plyometric training, based on jump height, SSC and knee stability. This can help adolescents choose an activity to improve performance and prevent knee injuries.

6. References

Aalizadeh, B., Mohammadzadeh, H., Khazani, A., & Dadras, A. (2016). Effect of a trampoline exercise on the anthropometric measures and motor performance of adolescent students. *International Journal of Preventive Medicine, 7*(1), 91-91. doi:10.4103/2008-7802.186225

Adriana, M. (2013). Plyometrics and the effect on four typical vertical height. *Arena: Journal of Physical Activities, 13*, 17-29.

Anderson, F. C., & Pandy, M. G. (1993). Storage and utilization of elastic strain energy during jumping. *Journal of Biomechanics, 26*(12), 1413-27.

Aragão, F. A., Karamanidis, K., Vaz, M. A., & Arampatzis, A. (2011). Mini-trampoline exercise related to mechanisms of dynamic stability improves the ability to regain balance in elderly. *Journal of Electromyography and Kinesiology*, *21*(3),512-518. doi:10.1016/j.jelekin.2011.01.003

Atilgan, O. E. (2013) Effects of trampoline training on jump, leg strength, static and dynamic balance of boys. *Science of Gymnastics Journal, 5*(2)**,** 15-25.

Bellardini, H., Henriksson, A., Tonkonogi, M., & Roberts, C. (2009). *Tester och mätmetoder för idrott och hälsa*. Stockholm: SISU idrottsböcker.

Bobbert, M., Gerritsen, K., Litjens, M., & Van Soest, A. (1996). Why is countermovement jump height greater than squat jump height?. *Medicine & Science in Sports & Exercise*, *28*(11), 1402-1412.

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Doyle, T. L. (2008). Reliability of measures obtained during single and repeated countermovement jumps. *International Journal of Sports Physiology and Performance*, *3*(2), 131-144.

Crowther, R. G., Spinks, W. L., Leicht, A. S., & Spinks, C. D. (2007). Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. *Journal of Strength and Conditioning Research, 21*(2)**,** 460-465. doi:10.1519/00124278-200705000-00030

Davies, G., Riemann, B. L., & Manske, R. (2015). Current concept of plyometric exercise. *International Journal of Sports Physical Therapy*, *10*(6), 760-786.

Ekegren C. L., Miller, W. C., Celebrini, R.G., Eng, J. J., & MacIntyre, D. L. (2009). Reliability and validity of observational risk screening in evaluating dynamic knee valgus. *Journal of Orthopaedic & Sports Physical Therapy, 39*(9), 665-674. doi:10.2519/jospt.2009.3004.

Esposito, P. W., & Esposito, L. M. (2009). The reemergence of the trampoline as a recreational activity and competitive sport. *Current Sports Medicine Reports, 8*(5), 273-277. doi:10.1249/JSR.0b013e3181b8f60a

Ferris, D. P., & Farley, C. T. (1997) Interaction of leg stiffness and surface stiffness during human hopping. *Journal of Applied Physiology, 82*(1)**,** 15-22.

Ford, K., Myer, G., & Hewett, T. (2003). Valgus knee motion during landing in high school female and male basketball players. *Medicine & Science in Sports & Exercise, 35*(10), 1745-1750. doi:10.1249/01.MSS.0000089346.85744.D9

Herrington, L., & Munro, A. (2010). Drop jump landing knee valgus angle: Normative data in a physically active population. *Physical Therapy in Sport, 11*(2), 56-59. doi:10.1016/j.ptsp.2009.11.004

Hewett, T. E., Stroupe, A. L., Nance, T. A., & Noyes, F. R. (1996). Plyometric training in female athletes: Decreased impact forces and increased hamstring torques. *The American Journal of Sports Medicine, 24*(6), 765-773. doi:10.1177/036354659602400611

Jaric, S. (2002). Muscle strength testing: Use of normalisation for body size. *Sports Medicine, 32*(10), 615-631. doi:10.2165/00007256-200232100-00002

Kenny, I. C., Caireall A. Ó., & Comyns, T. M. (2012). Validation of an electronic jump mat to asses stretch-shortening cycle function. *Journal of Strength & Conditioning Research, 26*(6), 1601-1608. doi:10.1519/JSC.0b013e318234ebb8

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine, 41*(6), 349-355. doi:10.1136/bjsm.2007.035113

Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *The Journal of Strength and Conditioning Research, 18*(3), 551-555. doi:10.1519/1533-4287(2004)18<551:RAFVOS>2.0.CO;2

Martínez-López, E. J., Benito-Martínez, E., Hita-Contreras, F., Lara-Sánchez, A., & Martínez-Amat, A. (2012). Effects of electrostimulation and plyometric training program combination on jump height in teenage athletes. *Journal of Sports Science & Medicine, 11*(4), 727-735.

Márquez, G., Aguado, X., Alegre, L. M., & Férnandez-del-Olmo, M. (2013). Neuromechanical adaptation induced by jumping on an elastic surface. *Journal of Electromyography and Kinesiology, 23*(1), 62-69. doi:10.1016/j.jelekin.2012.06.012

Márquez, G., Aguado, X., Alegre, L. M., Lago, Á., Acero, R. M., & Fernández-del-Olmo, M. (2010). The trampoline aftereffect: the motor and sensory modulations associated with jumping on an elastic surface. *Experimental Brain Research, 204*(4), 575-584. doi:10.1007/s00221-010-2324-1

McArdle, W. D., Katch, F. I., & Katch, V. L. (2014). *Exercise physiology: nutrition, energy and human performance (8 ed.)*. Philadelphia: Lippincott Williams & Wilkins.

McLean, S. G., Walker, K., Ford, K. R., Myer, G. D., Hewett, T. E., & van den Bogert, A J. (2005). Evaluation of a two dimensional analysis method as a screening and evaluation tool for anterior cruciate ligament injury. *British Journal of Sports Medicine, 39*(6), 355-362. doi:10.1136/bjsm.2005.018598

Moir, G., Shastri, P., & Connaboy, C. (2008). Intersession reliability of vertical jump height in women and men. *Journal of Strength and Conditioning Research, 22*(6), 1779-1784. doi:10.1519/JSC.0b013e318185f0df

Louw, Q. A., Manilall, J., & Grimmer, K. A. (2008). Epidemiology of knee injuries among adolescents: a systematic review. *British journal of sports medicine, 42*(1), 2-10.

Ludwig, O., Simon, S., Piret, J., Becker, S., & Marschall, F. (2017). Differences in the dominant and non-dominant knee valgus angle in junior elite and amateur soccer players after unilateral landing. *Sports, 5*(1),14 -22. doi:10.3390/sports5010014

Ortiz, A., Rosario-Canales, M., Rodríguez, A., Seda, A., Figueroa, C., & Venegas-Ríos, H. (2016). Reliability and concurrent validity between two-dimensional and three-dimensional evaluations of knee valgus during drop jumps. *Open Access Journal of Sports Medicine,7*(1), 65-73. doi:10.2147/OAJSM.S100242

Patel, N. N. (2014). Plyometric training: A review article. *International Journal of Current Research and Review, 6*(15), 33-37.

Pennington, C. (2014). Determining the anaerobic power output differences between the genders in untrained adults. *American International Journal of Contemporary Research, 4(*4), 64-77

Ross, A. L., & Hudson, J. L. (1997). Efficacy of a mini-trampoline program for improving the vertical jump. In: J. D. Wilkerson, K. M. Ludwig, & W. J. Zimmermann (Eds.), *Biomechanics in Sports XV* (p. 63-69). Denton, TX: Texas Woman's University.

Salaj, S. S., Milanovic, D., & Jukic, I. (2007). The effects of proprioceptive training on jumping and agility performance. *Kinesiology, 39*(2), 131-139. doi:796.091.2:796.012.33:612.7-055.1

Sharma, L., Song, J., Dunlop, D., Felson, D., Lewis, C. E., Segal, N., Torner, J., Cooke, T. D. V., Hietpas, J., Lynch, J., & Nevitt, M. (2012). Varus and valgus alignment and incident and progressive knee osteoarthritis. *Annals of the Rheumatic Diseases, 69*(11),1940–1945. doi:10.1136/ard.2010.129742

Smith, G. A., & Shields, B. J. (1999). Trampoline-related injuries to children. *Archives of Pediatrics and Adolescent Medicine,152*(7), 694-699.

Tanner, R. K., & Gore, C. J. (2012). *Physiological Tests for Elite Athletes (2 ed.)*. Champaign, IL: Human Kinetics Publishers.

Taube, W., Leukel, C., Lauber, B., & Gollhofer, A. (2012). The drop height determines neuromuscular adaptations and changes in jump performance in stretch-shortening cycle training. *Scandinavian Journal of Medicine & Science in Sports*, *22*(5), 671-683. doi:10.1111/j.1600-0838.2011.01293.x

Tufano, J. J., Walker, S., Seitz, L. B., Newton, R. U., Häkkinen, K., Blazevich, J. A., & Haff, G. G. (2013). Reliability of the reactive strength index, eccentric utilisation ratio, and prestretch augmentation in untrained, novice jumpers. *Journal of Australian Strength and Conditioning, 21*(2), 31-33.

Wikstrom, E. A., Tillman, M. D., Chmielewski, T. L., &. Borsa, P. A. (2006). Measurement and evaluation of dynamic joint stability of the knee and ankle after injury. *Sports Medicine, 36*(5), 393-410. doi:10.2165/00007256-200636050-00003

Wilk, K. E., Voight, M. L., Keirns, M. A., Gambetta, V., Andrews, J. R., & Dillman, C. J. (1993). Stretch-shortening drills for the upper extremities: Theory and clinical application. *Journal of Orthopaedic & Sports Physical Therapy,17*(5), 225-239. doi:10.2519/jospt.1993.17.5.225

World Medical Association. (2013). World medical association declaration of Helsinki: Ethical principles for medical research involving human subjects. *Jama*, *310*(20), 21-25.

Quatman, C. E., Ford, K. R., Myer, G. D., & Hewett, T. E. (2006). Maturation leads to gender differences in landing force and vertical jump performance: A longitudinal study. *American Journal of Sports Medicine*, *34*(5), 806-813. doi:10.1177/0363546505281916

Young, W. (1995). Laboratory strength assessment of athletes. *New Studies in Athletics, 10*(1), 89-96.

6. Appendices

6.1. Appendix 1

Skillnad i knästabilitet, hopphöjd och bålstyrka
hos ungdomar som utövar olika typer av spänst träning.

HÖGSKOLAN
I HALMSTAD

Bakgrund
Det finns få studier som harundersökt hur trampolinträning kan påverka hopphöjd, bålstyrka och knästabilitet hos unga vuxna. Detta kan påverka personer med tidigare skadehistorik och deras prestationer i olika idrotter vilket gör det till ett viktigt område att studera vidare inom. Syftet med studien är därför att undersöka om knästabilitet vid landning, bålstyrka och hopphöjden skiljer sig hos ungdomar som tränar spänst med hjälp material som trampolin och hårt underlag.

Förfrågan om deltagande
Vi är två studenter från Högskolan i Halmstad som studerar Biomedicin inriktning fysisk träning och vi ska nu till våren 2017 genomföra en studie som vårt examensarbete. I studien vill vi undersöka hur hopphöjd, knästabilitet och bålstyrka kan påverkas av att man tränar på olika material som trampolin och hårt underlag.

Därför vänder vi oss till dig som är mellan 14–20 år och antingen har trampolinträning eller handboll som din huvudsakliga träning. Du ska ha utfört din huvudsakliga träning minst tre gånger i veckan de tre senaste månaderna. Om du har nedsatt rörlighet, svullnad eller smärta i ländryggen eller i benen kan du inte delta i studien då detta kan hindra dig från att utföra testerna ordentligt.

Hur går studien till?
Studien kommer att innebära fyra olika tester vid ett tillfälle i Högskolan i Halmstads lokaler. Innan testerna kommer en lätt uppvärmning på cirka fem minuter att utföras. Testerna kommer bestå av två olika hopptester, ett knästabilitet test och ett test för att mäta stillastående bålstyrka. Du kommer få muntliga och visuella instruktioner innan varje test av testledarna. Du kommer även ha möjlighet att själv prova att utföra testet innan det riktiga testet genomförs.

Testet för knästabilitet kommer att filmas och testresultaten från övriga tester kommer antecknas i protokoll men endast finnas tillgängliga för oss ansvariga för studien. Vid testtillfällena kommer även information kring ålder, längd och vikt samlas in. Inga andra kommer vara närvarande vid dina tester utom du själv och vi testledare.

Tidsåtgång
Samtliga tester kommer totalt att ta cirka 40 minuter att genomföra**.**

Förberedelse inför testtillfället
Inför testerna är det viktigt att du <u>minst två timmar innan</u> inte ätit någon större måltid samt inte intagit någon alkohol eller använt tobak som cigaretter eller snus. Undvik också tung träning 24 timmar innan testtillfället. Ha med dig träningskläder och ordentliga träningsskor

till testtillfället. Träningsskor kan innebära de skor som du normalt sett tränar i och träningsbyxor behöver vara korta, exempelvis träningsshorts eller byxor du lätt kan vika upp till ovanför knäna för att vi enkelt ska kunna se knät under knästabilitet testet.

Vilka fördelar innebär studien för dig som deltar?
Fördelar med studien är att du får en insikt kring hur egenskaper som hopphöjd, knästabilitet och bålstyrka påverkas av träning på olika material. Något som i slutändan kan ge en större förståelse för hur du ska kunna maximera din prestation och eventuellt anpassa din träning för att undvika skador inom din idrott. Du kommer även få en inblick i hur det är att ingå i en studie, hur kliniska idrottstester genomförs samt hur det är att studera på högskolan.

Finns det risker?
Deltagandet i studien kan komma att innebära en risk för skada som kan uppkomma genom de fysiska tester som kommer genomföras. Skador som stukningar, vrickningar och muskelsträckningar är de mest logiska följderna. Du kan också komma att känna dig både fysiskt och mentalt utmattad efter testerna, därav kommer det att finnas tillgång till frukt efter att testerna genomförts. Det är vi som testledare som har ansvar för att testerna utförs under säkra förhållanden samt att säkerhetsställa att utförande av testerna sker korrekt och riskfritt.

Hantering av data och sekretess
Alla insamlade personuppgifter sker i avidentifierad form. Detta betyder att ditt namn och personuppgifter ersätts av en kod och inte kommer att publiceras i studien. Högskolan i Halmstad är personuppgiftsansvarig och är skyldig för att dina personuppgifter behandlas riktigt enligt personuppgiftslagen (1998:204) samt att du skyddas av sekretess. Du har rätt att se vilka uppgifter som behandlar dig samt ångra att de används i studiesyfte. Du har även rätt att kräva rättelse av dina personuppgifter om du anser att de som behandlas är felaktiga. Dina personuppgifter samt video kommer att hanteras så att inga obehöriga kan ta del av dem och förstöras i slutet av studien. Resultatet kommer att redovisas och publiceras som två olika examensarbeten.

Frivillighet och rätten att avbryta
Medverkan i denna studie är helt frivillig och du som deltagare har rätten till att avbryta din medverkan och återkalla ditt samtycke utan att behöva ange orsak när som helst under studiens gång. Du tar då kontakt med någon av testledarna och insamlad data som behandlar dig förstörs.

Ansvariga för studien
Huvudansvariga för studien
Filip Dahlström Telefon: [redacted] Mail: Fildah14@student.hh.se
Anna Karin Liljebjörk Telefon: [redacted] Mail: Annlil14@ student.hh.se

Forskningshuvudman och personuppgiftsansvarig
Högskolan i Halmstad

Behörig forskningshuvudman
Sofia Ryman Augustsson, Med Dr, leg sjukgymnast, universitetslektor på akademin för teknik, ekonomi och naturvetenskap.

Samtycke

Nedan ger du ditt samtycke till att delta i studien. Läs noga igenom all information innan du skriver under. Genom att signera detta dokument ger du samtycke till att du har:

- tagit del av informationen kring studien och förstår vad den innebär.
- fått ställa de frågor du önskar och vet vem du ska kontakta om ytterligare frågor dyker upp
- förstått att ditt deltagande i studien är frivilligt och att du kan avbryta ditt deltagande utan att ange en orsak
- godkänner att dina resultat kommer användas som grund för den här studien om du inte återtar ditt samtycke

....	....	....
Datum	Deltagares Namnteckning	Namnförtydligande
....	....	....
Datum	Målsmans Namnteckning	Namnförtydligande

HALMSTAD
UNIVERSITY

PO Box 823, SE-301 18 Halmstad
Phone: +35 46 16 71 00
E-mail: registrator@hh.se
www.hh.se