Halmstad University
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Asymmetry in Elite Snowboarders

A Study comparing Range of Motion in the Hip and Spine, Power in Lower Extremities and Circumference of Thigh

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Abstract

Snowboarding is a relatively young sport and has grown since the birth in the 1960-70. Today, snowboarding still is a lifestyle to many, but also an accepted mainstream sport and has been an Olympic sport since the Olympic Winter Games in Nagano, Japan 1998 (18,35,36). The movement pattern and body position is asymmetric, since you stand sideways with the front foot ahead of the rear foot in the line of direction (14,18,28). Several studies that have investigated the biomechanics of snowboarding have showed that the loading of the lower extremities are different in the front leg compared to the rear leg during riding (14,18, 22,23,28).

The purpose of this study was to investigate if the asymmetric body position in snowboarding causes differences between front and rear leg considering; circumference of thigh, range of motion (ROM) in the hip joints, power in lower extremities, or causes asymmetrical ROM in the spine in the test group compared to the control group.

Two groups were used, one test group consisting of ten elite snowboarders (n=10) with an average age of 18 years, and one control group consisting of eight high level skiers (n=8), average age 17,25 years. All subjects were students at Malung/Sälen Alpine Elite Gymnasium. Measurements of ROM in hip and spine were made with a myrin incline goniometer and universal plastic goniometer. A one leg countermovement jump (CMJ) was made as a test of power in the lower extremities using Ivar ump & speed analyzer. Measurements of circumference of thighs were made using a soft tape measure.

The results show significant differences in four of the ten measurements in test group and in two of the ten measurements in the control group. There are significant differences in hip passive flexion ($P<0,05$) and adduction($P<0,05$) in both groups (Tables 2,3) suggesting that in these movements there are individual differences. The one leg CMJ and circumference of thigh shows significant differences, ($P>0,05$) and ($P<0,001$), between front and rear leg in the test group (Table 2), but no such differences can be seen in the control group (Table 3) suggesting that these differences may be caused by the asymmetrical body position during snowboarding.

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1. Introduction

Asymmetrical movements of the human body, that is, where one side of the body has a different movement pattern compared to the other side, can be seen in daily life. Most humans use one hand, one arm, one foot, one eye and one ear over the other when performing a number of tasks. Approximately 90% of the population uses the right hand, 9-10% uses the left hand, and ca 1% is ambidextrous, using both right and left hand (2).
Asymmetrical movement patterns can also be found in many different sports. Some asymmetrical sports are for example golf, baseball, ice hockey, soccer. Sports that have a symmetrical movement pattern (movements that are the same bilaterally) are for example alpine skiing, cross-country skiing, cycling and running. The effects that these sport specific asymmetric demands have on the athletes physical status can be clearly seen when watching the top athletes of these sports. Visually examining, even for the untrained eye, differences can be seen in for example highly skill tennis athletes, where the dominant used arm in hitting the ball is noticeable larger in muscle mass compared to the non-dominant arm, also in volleyball players, where their dominant arm and shoulder for attacking the ball is larger in muscle mass compared to the non-dominant arm. While some of these differences can be visually compared, as mentioned above, some differences have to be more closely examined to be found.

The movements and the position of the body during snowboarding is asymmetrical (14,18,28) and similar to the position used in other board sports, such as surfing and skateboarding (14,28,29) but there are differences in the technique which makes biomechanics of snowboarding unique (18). Since the board has a nose and tail (3,15,19,34) and you travel sideways (14,18), with the front foot ahead of the rear foot in the direction of travel (14), the body is rotated towards the nose of the board and the direction of travel (fig 1) (3,19,34). The forward rotation occurs in the hips, upper body and shoulders (3) but also in lower extremities (18). Since boards, bindings, boots, personal style of stance and anatomical differences differs between riders, the position of the body during snowboarding also varies a lot between riders (14,18). It is not yet well studied which differences that the asymmetrical body position of snowboarding creates.

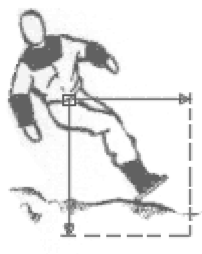

Figure 1. Bodyposition during snowboarding.

Several studies have examined the range of motion and differences between sides. A study by Boone et al (9) measured active Range of Motion (ROM) in 109 male subjects, age from 18 months to 54 years old. Significant differences were found between right and left side in only a few motions, primarily in the shoulder and elbow, but also in foot eversion, suggesting that asymmetric ROM does occur in the human body. Another study by Macedo et al (26) on 90 women, age 18-59, measured both active and passive ROM, and found significant differences between dominant and non-dominant sides for 34 of the 60 ROM measured. One study of handball athletes showed a difference in retrotorsional angel of humerus between the dominant and non dominant arm, where the dominant arm had a significant larger angel (9,4°) then the non-dominant arm (33). A study of 30 male competitive volleyball athletes showed a different muscular and capsular pattern in the playing shoulder compared to the opposite shoulder, where the playing shoulder was depressed, with the scapula lateralised, and the dorsal muscles and the posterior and inferior part of the shoulder capsule shortened (24). The authors also suggested that muscular balance (symmetry) is very important for preventing shoulder injuries in volleyball athletes (24).

The purpose of this study was to investigate if the asymmetric body position in snowboarding causes any differences between front and rear leg considering; circumference of thigh, ROM in the hip joints, power in lower extremities, or causes asymmetrical ROM in the spine in the test group compared to the control group. The hypothesis was that there may be a difference in the circumference of front and rear thigh, range of motion between front and rear leg hip joint, difference in power between front and rear leg and difference in range of motion in the spine in snowboard athletes compared to alpine ski athletes.

2. Background

Research in snowboarding is mainly focused on injuries associated with the sport, and in particular injuries of the ankle, wrist and head, where many of the injuries in snowboarding seem to occur (14). Of all injuries in snowboarding, 33% involves the lower extremities (22). There are few studies that have investigated the biomechanics of snowboarding (18,22), and to the authors knowledge there are no studies that have examined which effect the asymmetric body position in snowboarding has on the ROM in hips and spine and strength in lower extremities. The asymmetrical position used in snowboarding causes many differences between the front and rear leg in movement pattern, and the loading of the lower extremities. When comparing the distribution of the bodyweight on front versus rear leg, a study by Deleromre, 2004, shows the largest weight on the front leg during turning (14). Another study by Krüger A., Edelmann-Nusser J., 2009, shows that in the landing phase when performing a jump, the snowboarder leans towards the tail of the snowboard, creating forces on the rear leg of 3.8 times body weight, compared to forces on the front leg of 1.2 times bodyweight (23). Deleromre also found that there was a difference in flexion/extension angles in the knee joint between front and rear leg during turning (14). Other studies shows that he largest ankle joint moments occurs in the rear leg, compared to the front leg (18,22). A study by Meighan A., Tietjens B., studied 14 cases of knee ACL injuries in snowboarders and skateboarders, 11 men and three females with an average age of 26 years (28). All were advanced level riders and all injuries occurred in the front leg. They suggest that the asymmetric stance in board riders results in an internal tibial rotation of the front leg, which may preload the ACL prior to injury. Some of these studies suggest that more research and knowledge about joint loading in ankle, knee and hip-joints and structural biomechanics in snowboarding could be used to prevent injuries and enhance performance (22).

2.1 Snowboarding History

Snowboarding has its roots in earlier board sports such as surfing and skateboarding (3,15). There are several people who have played an important role of the snowboard invention during the 1960´s, through the 1970´s. In 1963 Tom Sims from New Jersey, USA, designed a “skiboard” as a part of a school project (3,15,34). Sometime between 1965-66 Sherman Poppen invented the “snurfer” for his daughters as a Christmas gift, by putting two skis together (3,15,19) and in February 18, 1968 the world´s first Snurfer competition was held in Blackhouse Hills, Muskegon, Michigan, USA (3,15,34). In 1969 Dimitje Milovitch started building snowboards from surfboards constructed like skis were built. Two years later he patented his invention (3,15) and in 1972 he founded his company Winterstick and began selling several snowboard models. In winter 1969 Jake Burton Carpenter received a Snurfer as a Christmas present (15,34) but it wasn’t until 1977, when Burton had graduated from the New York University, that he started making his own boards. At the same time in 1977 Tom

Figure 2. Snurfer ad 1960

Sims also produced his first snowboard model (3). In these early days, snowboarding was seen as a reckless and dangerous sport and was prohibited in many ski resorts (3,15,18,34). After a couple of years Snowboarding increased in popularity and number of riders and the Ski resorts started to open up their slopes to the snowboarders (3,15). The first World Championships in Snowboarding were held in Livigno, Italy and Breckenridge, Colorado, USA in 1987 (15) and eleven years later, in 1998, snowboarding became an Olympic sport at the Olympic Games in Nagano, Japan (18,34,36). Today, snowboarding is a both a lifestyle and an accepted mainstream sport. A Swedish survey made in 2009 by *Svenska Lift Anläggningars Organisation* (SLAO), showed that snowboarders occupied 9,9% of the Swedish ski areas, whereas in the USA and Canada, snowboarding seem to be larger, occupying 41% of the ski slopes in USA 2001 (14) and 30% in Canada 2005 (18). The amount of snowboarders in USA was estimated to 5,1 million in 2007 in a survey (appendix 8) made by the National Ski & Snowboard Retailers Association.

2.2 Snowboarding Equipment

Snowboards

There are mainly three different types of snowboards; Freeride, Freestyle and Alpine snowboards (14)(figure 2). The range of length varies from 140-170cm and widths of 20-30 cm (18). Freestyle snowboarding is the most common (3,9,13). A study by Delorme S. (14) claims the use of freestyle snowboarding to be 35%, freeeride model to be 60% and alpine snowboarding to be 5% of the market The *Freestyle boards* are mainly used for performing different tricks in obstacles like big jumps, halfpipes or on different styles of rails and boxes (3,18). They are shorter, with a softer flex than freeride and alpine boards, making them easier to turn and manoeuvre when performing tricks (3,14,18). In freestyle snowboarding you compete in Halfpipe (HP), Big Air (BA), and Slopestyle (SS) (3). *Freeride boards* are longer and wider than freestyle boards, and therefore more used when riding in higher velocities and in deep snow (3,18). With freeride boards you compete in freeride events and in Snowboardcross (SBX)(3). The *alpine snowboard*s are made for speed and carving (3,14). It is stiffer than freestyle and freeride boards, with a straight tail without kick and has different side-cut radius than freestyle boards (3,14,15,34). The alpine snowboard is used for competing in the Parallel Giant Slalom (PSL), Parallel Slalom (PSL) and SBX disciplines (3).

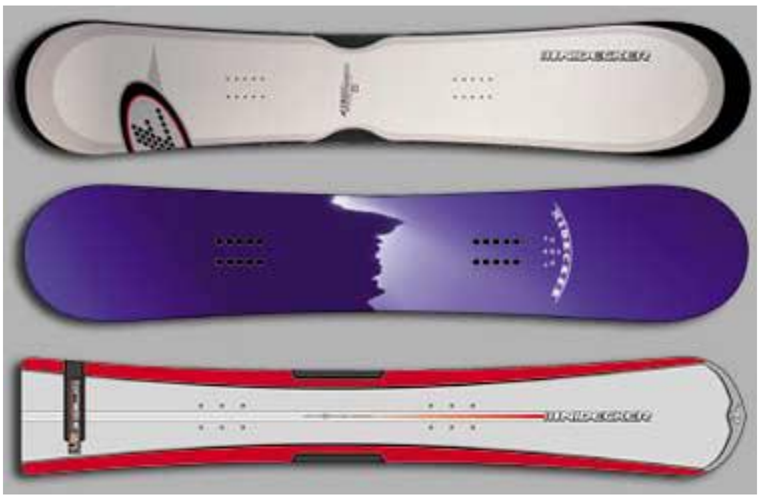

Figure 3. Different types of snowboard used.
From top Freeride snowboard, Freestyle Snowboard and Alpine Snowboard. (14)

Boots

Snowboard boots are used to fasten the snowboarder's foot to the snowboard through the binding (12). There are two different kinds of snowboard boots, "soft boots" and "hard boots" (3,14,18,19).The soft boot model allows bigger ROM for the ankle (3,14,18) and therefore used when riding freestyle and freeride snowboards where the rider performs different manoeuvres (3,14,18,19). The Alpine riders use hard boots similar to ski boots (3,14,15,18,19,34). Since the shell of the boots is made of plastic they are stiffer than softboots, giving more support but also allowing less ROM for the ankle (3,14,18). The soft boot model is the most common with reports of 70-90% (18,21) of the existing market.

Bindings

Binding are used to attach the boots to the boards and designed to not release during a fall (3,14,18). There are generally two different models of bindings, the freestyle strap binding and the plate binding (3,14,18,19). There are hybrids of these bindings in forms of step-in bindings (3,14,19), but these hybrids are not so commonly used (18), therefore not described further. The strap binding is the most common model and is used together with the soft boot model (3,14,18,19). The boots is attached to the binding through two straps and is supported by a high-back. The plate binding is used together with the hard boot model and the boot is attached the same way as a ski binding (3,14,19).

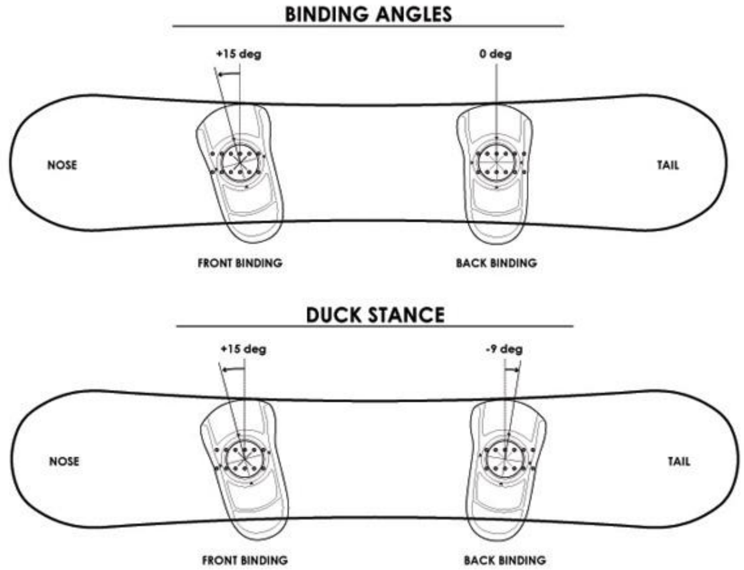

Figure 4. Different types of stance-settings used in Snowboarding.

Binding stance

The style of stance is an individual choice of what feels the best, and varies between riders (14,18). The stance is the space between the fixed bindings and the angle that the bindings are fixed on the board. Travelling with the left foot as front foot is named "regular" and the opposite is "goofy" (with right foot as front foot) (3, 14,15,18,19). About 70% of snowboarders are regular stance riders (15). The width between the bindings is dependent of the height of the rider, e.g. the taller the rider, the wider is the stance (18).
The angle of the bindings are either *positive* (toes pointing towards the nose of the snowboard) or *negative* (toes pointing towards the tail of the snowboard)(10).

Stance with both bindings in positive angles makes the movement from edge to edge faster and therefore common when riding alpine snowboards, carving and competing in the alpine events (3,18)."Duck" stance is when the front binding has a positive angle and the rear binding has a negative angle. (18).This makes travelling switch stance (with the rear foot first) easier and is more used in the freestyle disciplines, in tricks that involves rotation, landing or starting switch stance (10,18).

2.3 Range of Motion (ROM)

The range of motion is the arc of motion that occurs in a joint or in a multiple of joints. Measurements are made in degrees or cm (1,5,31). Measurements are made of internal/external rotation in the transverse plane around a vertical axis, flexion/extension in the sagittal plane around a medial-lateral axis, and abduction/adduction in the frontal plane around an anterior-posterior axis. *Active range of motion* (AROM) is the arc of motion in a joint or multiple joints made by the subject with no assistance from an examiner while *passive range of motion* (PROM) is the arc of motion made by an examiner without assistance from the subject (1,5,31). The amount of PROM is determined by the anatomical structures, ligaments and muscle tissue surrounding the joint (1,5,31). Normally PROM is slightly larger than AROM due to a small amount of motion that is not under voluntary control (1,5,31).

2.4 Power

Power is the product of force and velocity in the movement (20, 32) and muscular power has been identified as an important factor of performance in many sports (4,32). Some of the different factors determining the power output of a muscle are motor unit recruitment and activation, motor neuron firing rate, and amount of neural inhibition (17). Muscle fiber types and muscle cross-sectional area (CSA) are also important for power production (11,12).
All movements in the human body are initiated by the brain through motor units (1). A motor unit consists of a nerve cell attached to a muscle fiber (1). An increased number of recruited and activated motor units will increase the power output in a muscle. An increase of discharge rate of motor neurons and decrease of neural inhibition further increases the power output (1,17).There are three different types of muscle fibers, slow twitch fibers (type 1) and fast twitch fibers (type 2A and type 2X) (1,11,12). Muscle fiber type 2 has a larger cross sectional area (CSA) compared to type 1. The CSA of a muscle is important for producing power. Muscle fibers with a larger CSA contains more myofibril's, which performs the actual contraction of the muscle, and are therefore able to produce more power than a muscle with smaller CSA considering all the other factors affecting the power output are equal (1,11).
In a dynamic movement, when an eccentric muscle contraction (which has a stretching effect on the muscle tissue) is immediately followed by a concentric muscle contraction (muscle shortening) the stretch-shortening cycle (SSC) occurs. This SSC improves the power in a movement with a eccentric pre-stretch phase prior to a concentric shortening movement compared to a movement without a pre-stretch phase (7,8). The higher power produced by the SSC can be explained by the stretch reflex-caused by the muscle spindles, elastic energy stored in the muscle tissue and tendons during the eccentric phase (7,8), and the inhibit effect from Golgi tendon organs (8).

3. Method

Electronic databases such as PubMed, Science Direct and journals such as The American Journal of Sport Medicine, Journal of Strength and Conditioning, Journal of Applied Biomechanics, Journal of the American Physical Therapy Association, were searched for scientific research in the topic of interest from December 2009 to May 2010.
Email contact was also held with Paul Hiniker, USA and Jason Harding, Australia, both well known strength and exercise coaches/researchers of board sport athletes, such as surfers and snowboarders, to get their input in this particular subject.
The method used was quantitative empiric study.

Ethical considerations
The study was approved from an ethical viewpoint by the examiner and supervisor at Halmstad University. All subjects were orally and written informed (appendix 2) of the purpose of the study, and that their participation was voluntary. They were also free to ask questions before signing informed consent (appendix 1). The tests were also approved by the headmaster and the responsible coaches of Malung/Sälen Alpine Elite Gymnasium.

3.1 Subjects
Two groups of subjects were used (n=18), who were all students at Malung/Sälen Alpine Elite Gymnasium. The test group which is described in table 1, consisted of 10 snowboarding subjects, whereof eight men and two females, in the age 16-20 years. The control group was an age-matched group of alpine skiers.

TABLE 1
Age, Height, Weight, BMI and Time of Experience of Test group and Control group

Variable	Test group (n=10)	Control group (n=8)
	Mean ± Sd	Mean ± Sd
Age (years)	18 ± 1,4	17,25 ± 1,5
Height (cm)	175,3 ± 9,4	177,4 ± 6,8
Weight (kg)	65,0 ± 6,1	75,6 ± 9,6
BMI	21,26 ± 2,2	23,9125 ± 1,4
Time of experience (years)	10,9 ± 2,1	12,625 ± 2,5

Six of the subjects were riders with a regular stance position, and four of the subject used a goofy stance position. All riders were using a duck stance binding setup. The range of stance angle varied from +12° to +15° of the front binding, and from -9° to -15° on the rear binding,
.
All the subjects in the test group were freestyle snowboarders and competed both nationally and internationally in the disciplines of Slopestyle and Big Air. Five of the subjects also competed in Halfpipe.
The control group consisted of eight highly nationally ranked alpine skiers, six men and two females, age 16-20 years. All the subjects in the control group competed in the highest national tour and some of the subject also in international nordic competitions.

3.2 Equipment

Anthropometric measurements

Body weight (kg) was measured using an EKS weight scale to the closest 0,5kg. .
Body height (cm) was made with the subject in standing straight up position against a wall; marking the top of head on the wall and measuring with a soft tape measure from the floor to the marking to the closest 0,5 cm. BMI was measured (bodyweight/height x height= BMI).
A soft tape measure (5,31) was used for measuring circumference of thigh.

ROM measurements

The different measurements in ROM was made by an examiner equipped with a half-circled bodied plastic universal goniometer (Medema)(fig.5), (5,31) as used in other studies of ROM (24) and a myrin incline goniometer (fig 6)(5,31). The myrin incline gonimeter uses a needle that reacts to gravity to measure motions in the sagittal and frontal plane and a compass needle that reacts to the earth’s magnetic fields to measure motions in the horizontal plane. A metal bodied tape measure (5,31) was used for measuring the difference in distance in test for active lateral flexion as used in earlier studies (26). The measurements were recorded in degrees (°) or centimetres (cm).

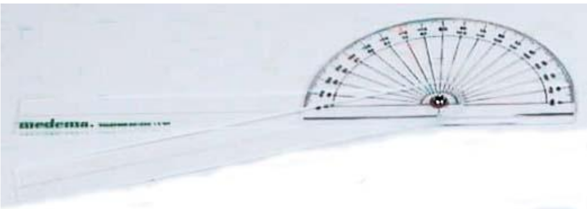

Figure 5. Shows a half-circled bodied plastic universal Goniometer.

Figure 6. Shows a Myrin Incline goniometer.

Power measurements

A one leg counter movement jump (CMJ) was performed as a test of muscle power output of the lower extremities as made in previously studies (30).
The tests of CMJ on left/right leg were made using Ivar Jump & Speed analyser (25). This apparatus consist of a receiver and two Infra-red light sensors. These sensors form a web of infra red beams in between them where the subject is positioned.
When one or more infra red beams are being broken a result is being registered into the receiver. The apparatus then calculates the jump height from the flight time (25).

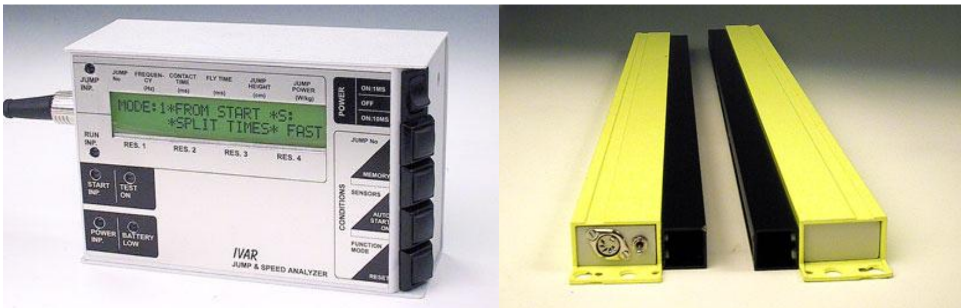

Figure 7. Ivar Jump & speed analyzer receiver (left) and Infra- red light sensors (right)

3.3 Test procedures

The data collection was performed 20100315 to 20100319.
The subjects did not participate in any kind of hard physical activity 12 h prior to the testing occasion. During the tests the subjects used light or tight clothing to ensure valid palpation and visual sureness. The ROM measurements were performed as described in *Measurement of Joint Motion – A guide to Goniometry 4th edition* by Norkin C.C., White D.J. (31) and *Joint Range of Motion and Muscle Length Testing*, by Berryman Reese N., Bandy W.D. (5). Further description of the subjects' positions during the ROM examination is available in Appendix 3 and order of tests in Appendix 4.

<u>Passive hip external rotation</u>
The subject was placed in prone position (abdominal part down) on a bench (Tarsus) with the hip in neutral position (0° of rotation, abduction and adduction), knee flexed 90° on the leg being measured, with the non measured leg straight. Landmarks that were located and palpated were anterior mid-area patella, the mid area between lateral and medial malleoli and crest of tibia. The myrin goniometer was placed on a horizontal midline of Tibia and the mobile pinpoint needle was aligned with the crest of tibia. The examiner then passively externally rotated the hip. At end of ROM, measurements were recorded. Measurements were recorded for each leg.

<u>Passive hip internal rotation</u>
The subject was placed in prone position lying on a bench with the hip in neutral position, knee flexed 90° on the leg being measured, with the non measured leg straight. Landmarks that were located and palpated were anterior mid-area patella, the mid area between lateral and medial malleoli and crest of tibia. The myrin goniometer was placed on a horizontal midline of tibia and the mobile pinpoint needle was aligned with the crest of tibia. The examiner then passively internally rotated the hip. At end of ROM, measurements recorded. Measurements were recorded for each leg.

<u>Passive hip flexion</u>
The subject was placed lying on his/hers back (supine position) on a bench with both knees in extended position and the hip in neutral position. Landmarks that were located and palpated were proximally great trochantor of femur and distally lateral epicondyle of femur. The myrin goniometer was placed mid femur and the horizontal line of the myrin gonimeter was manually aligned with femur using great trochantor and lateral epicondyle of femur as reference landmarks. The examiner then flexed the hip by first lifting the thigh of the bench, flexing the knee and leading the knee towards the abdomen. At end of ROM, measurements recorded. Measurements were recorded for each leg.

<u>Passive hip extension</u>
The subject was placed lying in supine position on the end of the bench, with both leg outside the bench. Landmarks that were located, palpated and marked were proximally trochantor major of femur and distally lateral epicondyle of femur. The myrin goniometer was placed mid femur and the mobile horizontal pinpoint needle of the myrin gonimeter was manually aligned with femur using great trochantor and lateral epicondyle of femur as reference landmarks. The examiner flexed the hip and knee of the leg not being measured at the time, putting the foot of the non measured leg on the side of the examiners abdomen. The examiner then extended the hip by pressuring the leg being measured down while remaining the pelvis in neutral position. At end of ROM, measurements were recorded. Measurements were recorded for each leg.

Passive hip abduction

Subject was placed in supine position with the hip in neutral position and both knees extended. A soft fabric corduroy band was placed around the bench and over the subjects' pelvis, strapping the subject to the bench, ensuring minimum pelvic movement and error in measurement. Landmark that were located, palpated and marked were anterior superior iliac spine (ASIS) and anterior mid-area patella. The axis of the goniometer was placed over ASIS of the side of the leg being measured. The proximal, stationary arm of the goniometer was aligned on a visually horizontal line extending from one ASIS to the other ASIS. The distal, mobile arm of the Goniometer was aligned with the anterior midline of femur, using the anterior mid-area of patella as a reference. The examiner then, by using one hand pulled the subjects leg into abduction. At end of ROM, measurements were recorded for each leg.

Passive hip adduction

Subject was placed in supine position with the hip in neutral position and both knees extended. A soft fabric corduroy band was placed around the bench and over the subjects' pelvis, strapping the subject to the bench, ensuring minimum pelvic movement and error in measurement. Landmark that were located, palpated and marked were ASIS and anterior mid-area patella. The axis of the goniometer was placed over ASIS of the side of the leg being measured. The proximal, stationary arm of the goniometer was aligned on a visually horizontal line extending from one ASIS to the other ASIS. The distal, mobile arm of the Goniometer was aligned with the anterior midline of femur, using the anterior mid-area of patella as a reference. The examiner then by using one hand pulled the subjects leg into adduction. At end of ROM, measurements were recorded for each leg.

Active thoracolumbar rotation

Subject was placed in lunge position with left side foot on the floor with knee and hip in 90° of flexion. On the other side the toe was placed on the floor, knee on floor and hip in neutral position to help stabilize pelvis and with the cervical, thoracic, and lumbar spine in neutral position (0° of extension, flexion and lateral flexion). Spine was in upright and pelvis neutral position. Landmarks that were located and palpated were the acromion on both sides. The examiner then instructed the subject to hold a 150cm wooden bar on the shoulders, over one acromion to the other. The myrin gonimeter was placed on top of the bar with the pinpoint needle aligned with the bar. The subject was orally instructed to rotate his/hers upper body towards the side of the knee in front of him/her while keeping the abdomen straight and keeping the knee in front always straight forward. The end of ROM is obtained when pelvis starts to rotate. At the end of ROM measurements of rotation were made and recorded bilaterally.

Active lateral flexion

Subject was placed in standing position, with feet shoulder width apart, knees in extended position and arms vertically aligned with the body, and hand palms flat against the body with fingers extended. The distance from the middle finger to the floor was measured. Then the subject was instructed to maximally bend to, following the outline of the body with the palm of the hand of the side being measured, while maintaining both feet on the ground. At the end of ROM, examiner measured the length from the middle finger to the floor. The difference of distance of the middle finger from the standing positing to the lateral flexed position was recorded as a measure of lateral flexion. Measurements were recorded bilaterally.

Circumference of thigh

The circumferences of left and right thigh were. The measurements of circumference of the right and left thigh were made directly on the skin, with the subject in standing positioning. Measurement were taken in horizontal plane in visually mid length of femur, using marks of the skin to ensure the same place being measured on each leg. Measurements were recorded for each leg.

Jump test procedure

Subject performed a warm-up procedure consisting of 5 min cycling on an exercise bike (Monark Ergo Medic 884 Es) with a 0,5kg resistance and speed of 60 RPM. The subjects were then instructed of the test procedure and how to perform the jump. They were each given two sub maximal jumps on each leg to feel comfortable with the movement. Three one legged countermovement jumps (CMJ) was performed and recorded on each leg. The subject started in an upright position, with hands on the hips, squatted down and immediately jumped up again, without pausing in the bottom position, keeping the hands on the hips throughout the movement (25). The subjects performed every other jump on their right and left leg, with the first jump on the right leg. The mean score of the three jumps on each leg was recorded and used as a measure of power in front and rear leg. Measurements were recorded in cm.

Figure 8. Subject performing one leg counter movement jump (CMJ).

Statistics

Statistical analysis of the collected data was made using Microsoft Excel (2007). Mean and standard deviation were calculated for each measurement. A two tailed, paired t-test were made for the analysis made within the group as made in earlier studies (9,11) and a two-tailed, homoscedastic t-test for the analysis between groups. Level of significance was $p<0,05$.

4. Results

Hip ROM

There was a significance difference (P<0,05) in Hip Passive Flexion ROM between front and rear leg in the test group, where the ROM is larger in front leg (120,9° ± 5,06°) then in rear leg (117° ± 6,03°) (Table 2). There was also a significant (P<0,05) difference in Hip Passive Flexion ROM in the control group were the left leg had a larger ROM (125,6° ± 6,2°) compared to the right leg (120,6° ± 7,4°) (Table 3). A significant difference in Hip Passive Adduction between front and rear (left and right) leg were found in both test group (P<0,05) and control group (P<0,05). In the test group the subjects had a larger ROM in the rear leg (21,7° ± 2,7°) compared to the front leg (19,5° ± 2,8°) (Table 2). The control group showed a larger ROM in the right leg (22,6° ± 3,7°) compared to the left leg (18° ± 1,5°) (Table 3).

Spine ROM

When comparing the ROM in the spine, the results shows no statistically significant differences between front and rear side (left and right side in control group) in groups or between groups, in either active thoracolumbar rotation or active lateral flexion.

Power and circumference in Lower Extremities

The results in between the group there showed a significant difference (P<0,05) in the one leg Counter Movement Jump between front and rear leg in the test group. The result of the front leg was lower (17,4 ± 2,9cm) than the results of the rear leg (19,3 ± 3,5cm) (Table 2). In the control group no such differences were found (Table 3). The subjects' individual results in the one leg CMJ are shown in Appendix 5, Table 4 & 5. When comparing the circumference of the front and rear thigh, there was a significant difference (P<0,001) in the test group. The rear leg showed a larger (51,5 ± 3,9cm) circumference then the front leg (50,09 ± 3,9cm) (Table 2). The control group showed no difference in circumference between left and right leg (Table 3). The subjects' individual results in circumference of thighs are shown in Appendix 6, Table 6 & 7.

TABLE 2

Difference between front and rear leg/side in test group (n=10), by joints and movements, using a two-tailed paired t-test

Movement	Mean ± Sd Front leg/side	Mean ± Sd Rear leg/side	Significance level (P)
Hip			
Passive External rotation (°)	57,2 ± 4,565	59,1 ± 5,586	0,228
Passive Internal rotation (°)	46,4 ± 6,077	45 ± 6,548	0,094
Passive Flexion (°)	120,9 ± 5,068	117 ± 6,036	0,021*
Passive Extension (°)	14,8 ± 7,004	16,2 ± 4,442	0,449
Passive Abduction (°)	47 ± 6,446	45,3 ± 5,926	0,212
Passive Adduction (°)	19,5 ± 2,877	21,7 ± 2,7507	0,037*
Spine			
Active Thoracolumbar rotation (°)	73,2 ± 7,420	73,7 ± 6,129	0,806
Active Lateral flexion (cm)	20,2 ± 2,888	20,45 ± 1,707	0,797
Lower Extremities			
One Leg Counter Movement Jump (cm)	17,421 ± 2,988	19,326 ± 3,575	0,040*
Circumference of thigh (cm)	50,09 ± 3,988	51,5 ± 3,915	0,0001***

* Statistically significant P <.05

** Statistically significant P <.01

*** Statistically significant P <.001

TABLE 3

Difference between left and right leg/side in control group (n=8), by joints and movements, using a two-tailed paired t-test

Movement	Mean ± Sd	Mean ± Sd	Significance level (P)
	Left leg/side	Right leg/side	
Hip			
Passive External rotation (°)	49,75 ± 4,166	53,5 ± 6,117	0,073
Passive Internal rotation (°)	49,875± 6,642	52,125± 5,026	0,199
Passive Flexion (°)	125,625 ± 6,277	120,625 ± 7,424	0,041*
Passive Extension (°)	15 ± 6,324	16,125 ± 6,334	0,465
Passive Abduction (°)	45,375 ± 8,782	48,5 ± 6,023	0,353
Passive Adduction (°)	18 ± 1,511	22,625 ± 3,777	0,011*
Spine			
Active Thoracolumbar rotation (°)	75 ± 4,898	73,25 ± 10,024	0,539
Active Lateral flexion (cm)	22,4375 ± 4,858	21,9375± 2,744	0,708
Lower Extremities			
One Leg Counter Movement Jump (cm)	17,025 ± 3,586	16,629 ± 2,246	0,62
Circumference of thigh (cm)	57,7125 ± 3,839	57,587 ± 3,815	0,379

* Statistically significant P <.05.

** Statistically significant P <.01

*** Statistically significant P <.001

5. Discussion

5.1 Discussion of results

The results show significant differences in four of the ten measurements in test group and in two of the ten measurements in the control group. There are significant differences in Hip Passive flexion ($P<0,05$) and adduction($P<0,05$) in both groups (Tables 2,3) suggesting that in these movements there are individual differences. The one leg countermovement jump and circumference of thigh shows significant differences, ($P>0,05$) and ($P<0,001$), between front and rear leg in the test group (Table 2), but no such difference can be seen in the control group (Table 3) suggesting that these differences may be caused by the asymmetrical body position during snowboarding.

Hip ROM

There was a significant difference between front and rear (left and right in control group) in both the test group and the control group in passive hip flexion ROM and hip passive adduction (Table 2). Why just these movements, and in both groups, showed significant differences between sides are hard to explain. This might show that there are individual differences in all humans, and in these movements the difference is larger than in other movements.

Spine ROM

The hypothesis was that there would be a difference in the ROM of the spine in the test group compared to the control group. Since the test group subjects rotates the upper body in the line of direction, as earlier mentioned, you might believe that the ROM would be greater in the front direction compared to the rear. The results showed no such difference in either thoracolumbar rotation or active lateral flexion (Table 2). There were no significant differences of ROM in the spine in the control group either (Table 3).

Power and Circumference in Lower Extremities

The results showed a significant difference ($P<.001$) of circumference between front and rear thigh in the test group (Table 2) compared to difference of circumference between left and right thigh in the control group (Table 3). This result could maybe be explained by the different nature of the sports, such as the asymmetric body position used in snowboarding compared to the symmetric body position in skiing. One of the factors that could affect this result is the weight distribution. In skiing, due to the symmetrical movements that are made, the weight is equally distributed on both legs. This way the muscles in both left and right leg are being exposed to the same amount of loading and respond with the same amount of hypertrophy and CSA of the muscle fibres. This is shown as bilaterally equal circumference of the thighs, and probably the same also for other muscles in the lower extremities. In snowboarding, the weight distribution is different in front and rear leg. In one study by Deleromre (14) the weight distribution showed higher values in the front leg compared to the rear leg during turning. This study was made on nine male intermediate level riders turning in a course between ten gates.

Figure 9. Difference between front & rear thigh circumference in a regular stance test group subject. The difference was 3 cm.

The study by Krüger A., Edelmann- Nusser J., 2009, (22) showed higher values of forces on the rear leg compared to the front leg during landing from a jump. The snowboarders used in this study are all freestyle riders and their type of riding consists of less alpine riding and more jumping. Other factor that may cause differences in weight distribution is different snowboard disciplines, since boards, boots, bindings and turning technique used differs between them (36). Level of experience can be another factor since there may be a difference in riding technique between novice and elite riders (36). The larger circumference, which probably is caused by a larger CSA in the rear thigh, may be explained by the higher forces acting on the rear leg during landing (23). Even though it might seem obvious that the larger circumference were caused by a larger CSA, skin fold measurements could have been made, to ensure the same amount of fat tissue stored externally on both thighs. There was also a significant difference ($P<0,05$) between front and rear leg in one leg counter movement jump in the test group (Table 2) were the front leg had a jump height of 17,421cm ± 2,988cm compared to the rear leg (19,326cm ± 3,575cm)(Table 2). This difference may also be due to the heavier weight distribution to the rear leg showed by Krüger A., Edelmann- Nusser J., 2009 (23) which may cause a larger CSA in the rear leg. As previously mentioned, one important factor of a muscles ability to produce power, is the CSA of a muscle fiber (1,11).No difference between left and right leg in one leg CMJ were seen in the control group (Table 3) indicating this difference may be caused by the asymmetric body position in Snowboarding.

5.2 Discussion of methods

The Snowboarders used as a test group in this study are the upcoming new breed of elite freestyle snowboarders in Sweden. The Malung/Sälen alpine elite gymnasium is the only sports gymnasium in Sweden that is credited by the Swedish Sports Confederation and therefore the standard of the riders is the highest, only the best ranked riders are attending the school. To use these riders as a test group was a choice because of the fact of the high amount of active snowboard riding time they have. No other group in Sweden could match this factor. Since the Swedish National Team in Snowboarding consists of only one rider, which competes in the alpine disciplines, this group was chosen as the highest level of riders in Sweden right now. Also the ability of making the tests on all athletes in one place, one short time, with all instruments available, was a factor for choosing this group. Due to the young age of the athletes between 16-20 years, they have not had as many years experience of snowboarding. Testing older athletes at the highest level, with a longer history of snowboarding experience, could have shown greater differences between front/rear legs since the riders have been exposed for the asymmetric body position in snowboarding for a longer time. All of the riders were freestyle discipline riders. Since the equipment used, such as boards, boots, bindings and stance angles, differs between different disciplines it would have been interesting to see if there exist any differences of ROM and strength, anthropometry between disciplines.

Alpine skiers at the same school were chosen as a control group. They were age-matched with the test group, and have approximately the same amount of training dose. The two sports are similar in the way that they are performed on snow, travelling downhill. The difference is the equipment used and the body position when riding, therefore any possible conclusions that are made can be done from the fact that the body positions are different. However, the control group cannot be compared as an average population, due to the specificity of the sport they perform, especially at their level of competition and training. Using an additional control group consisting of subjects from a normal population would have been interesting, and maybe more conclusions could have been made. There is a possibility that the control group are more symmetrical than a group consisting of normal population, since their sport has a symmetric movement pattern that could even out any “natural” asymmetry. Also, a study with a higher number of subjects should provide more statistically stronger results. Both men and female subject were used in this study, to be able to generalize the results to both men and females. Comparisons between the different sexes were not a part of the purpose of this study, but the data collected could be used for this and would be interesting to conduct. However, there were only four female subjects participating in this study, which represent 22% of the total amount of subjects, and to compare the sexes more female subjects should be preferred.

Validity & reliability of goniometry

Validity is that an instrument measures what it is intended to measure (31). Good reliability ensures that the measurements are consistence when measuring the same subject of the same variable under the same conditions at different occasions. For a measurement of ROM to be useful it must be reliable and valid (31). Using the universal goniometer is the most common method of measuring ROM (31) and several studies have been made to establish the methods by recognising validity and reliability (6,13,16). Norkin et al. (31) claims that measurements of ROM of extremities with a universal gonimeter have generally found to have good-to-excellent reliability. A study comparing the standard gonimeter with an electronic Orthoranger goniometer showed greater intraclass correlations and confidence levels for the standard goniometer in all movements of the hip, knee and ankle plantar and dorsiflexion, except hip lateral rotation, (16). To enhance the validity and reliability and reduce the risk of error in measurements the subjects were instructed to use tight clothing or if possible only underwear. Bony landmarks were located and palpated to ensure valid measurements and the examiner aimed to use the same amount of manual forced to move the body part during the examination (5,31). In this study all measurements were made by the same examiner which, according to Norkin et al. (31), gives a higher reliability compared to if the measurements had been taken by different examiners. In this study only one measurement were made of each measurement, as Boone et al. (6) found no significant differences between repeated measurements made by the same examiner during the same session. Using the universal gonimeter is not an easy task, and for the author, this type of instrument has not been performed regularly on a daily basis. The positions used for the ROM-tests were performed as described in the books earlier mentioned, however due to the fact that the examiner was less experienced and performing the test alone of his own some of the positions had to be changed, in cooperation with physiotherapists, to be able to perform. Re-tests are a great way of showing the reliability of the tests performed in the study and would have been wishful to conduct. However, due to the time limit and the logistics of this study it was not possible to perform re-tests.

Validity & reliability of Ivar jump & speed analyzer

A study by Viitasalo et al (37) showed low coefficients of variation between photocell contact mat analyzers and force platform, suggesting that the photocell contact mat is an accurate instrument for measuring ground contact time. This method could be discussed, since the equipment initially measures the flight time and then, by using calculations, shows the jump height. Measuring the jump height initially could have given a more accurate result, however, when performing the one leg CMJ there are practical difficulties of using for example soft tape measure. The soft tape measure could create limitations for the movement when performing the jump. Performing other measurement of jump height such as the sergeant jump test (touching the wall with the hand) was found to inconsistent and unreliable.

Statistic analysis
In this study different versions of t-tests were used. In order to be able to draw stronger conclusions of these data more advanced and stronger analysis has to be made using for example the SPSS software and ANOVA models. By using the ANOVA model it is possible to analyze several parameters at the same time which maybe could revile some other interesting results. This could have been wishful to conduct in this study, however was not made due to the existing amount of time and knowledge of using the SPSS software.

5.3 Further analysis of data
By using the collected data it is possible to compare the ROM obtained in the different joints between groups, and even though this was not the purpose of this study, it can be interesting to mention.

Hip ROM
When comparing the ROM in each leg, spine and power and circumference of lower extremities the results show a significant difference in ROM in both right leg external rotation ($p<0,05$) and left leg external rotation ($p<0,01$) in the test group compared to the control group (Appendix 7, Table 8). This difference might be due to the fact that different type of stance is used in snowboarding compared to skiing. The subjects in the test group showed a stance angel variation from +12° to +15° of the front binding, and from -9° to -15° on the rear binding, a duck-stance setup whit both front and rear leg externally rotated (figure 4). In skiing this setup is always 0° in both legs, assuring the skis are in the line of direction. This might have an effect and could explain the larger ROM in external rotation in the test group compared to the control group. In addition the internal rotation was smaller in both legs in the test group, compared to test group, but only significant in the right leg ($p<0,05$ (Appendix 7, Table 8). A factor that might have an effect on this might be that in snowboarding both bindings are fixed on the same board, assuring that the feet's are always in the same position related to each other. In skiing the feet´s are separated standing on one ski each and therefore the relationship between the feet´s always changes, and the subject needs to maintain the foot position in line with the direction of travel, using muscle force.

Spine ROM
The test group seem to have a slightly smaller ROM in Active Lateral Flexion in both right and left side compared to the control group but no significant differences can be found (Appendix 7, Table 8). The author has now explanation to this tendency, but this needs to be examined further with a larger amount of subjects, before any conclusions of what may cause this tendency may be.

Power and circumference in lower extremities
There was a significant difference ($P<0,01$) in circumference of both left and right thigh (Appendix 7, Table 8) where the test group had a smaller circumference compared to the control group. This cannot be explained by the nature of the sports, rather by the different training regimes in the different sports. It is generally more common with strength induced resistance training in Alpine Skiing compared to Snowboarding. Interestingly, even though the control group showed a larger circumference of the thighs which indicates a larger CSA of the muscles, the test group showed higher values, even though not statistically significant, of power output in the one leg CMJ (Appendix 7, Table 8). As mentioned earlier a muscle with larger CSA is able to produce higher power output than a muscle with smaller CSA considering the fact that all the other factors affecting the power output are equal. This shows that the power output is not a result of CSA only. There are a number of factor such as,

jumping technique, effect of the short stretching cycle (SSC), amount of activated motor units, amount and synchronization of action potentials are important as well. The nature of the sport may also have an impact, where in snowboarding, and especially freestyle snowboarding, performing jump movements are an essential part of performance compared to skiing that has a more static movement pattern, always trying to keep the skis on the snow surface. In this case it is important not to neglect the difference in bodyweight, since it is one of the factors affecting the jump height. Compared to bodyweight these results would probably give a more even result in jump height.

6. Conclusion

The results show that there are differences between front and rear leg/side in snowboard athletes that might be caused by the asymmetric body position used when riding. The circumference of thigh showed a significant difference (P<0,001) between front and rear leg, probably caused by larger CSA in rear thigh. Power in lower extremities showed a significant difference (P<0,05) between front and rear leg, were the rear leg were able to produce a higher jump (more power) than rear leg.

Future research
The purpose of this study was to investigate if the asymmetric body position in snowboarding causes any differences between front and rear leg considering; circumference of thigh, ROM in the hip joint or, power in lower extremities, or causes asymmetrical ROM in the spine in the test group compared to the control group. The results showed that there were differences that could be due to the asymmetric body position in snowboarding. The effect that this asymmetry may have on snowboarding performance and injury prevention is an interesting and important topic of discussion, however was not the purpose of this study, but will hopefully be more investigated in the future. More scientific research on the movements and the forces acting on the athlete’s body during snowboarding needs to be done to further understand the biomechanics of snowboarding. This is of importance to understand the sport specific demands and to be able to develop more sport specific physical training programs, to enhance the performance and avoid injuries.

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Key words: Snowboard, Range of Motion, Asymmetry, Goniometry, Hip

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Figure 8) © Tommy Danielsson

Figure 9) © Tommy Danielsson

Appendix 1

Skriftligt, informerande godkännande till att delta i en studie om effekterna av den asymmetriska positionen i snowboardåkning.

Jag har blivit muntligt och skriftligt informerad om studiens syfte, hur informationen samlas, används och förvaras samt fått möjlighet att ställa frågor. Jag har också blivit informerad om att studien är frivillig och att jag närsomhelst kan avbryta mitt deltagande i studien utan att ange orsak.
Härmed accepterar jag att delta i denna studie och dess testprotokoll angående effekterna av den asymmetriska positionen i snowboardåkning.

Plats/Datum/År:______________________________
Underskrift:__________________________________
Förtydligande av underskrift: _________________________

Testledares underskrift:______________________________
Förtydligande av underskrift: _________________________

Handledares underskrift:_____________________________
Förtydligande av underskrift: _________________________

Appendix 2

Information om deltagande i en studie på effekterna av den asymmetriska positionen i snowboardåkning.

Mitt namn är Tommy Danielsson och jag är student vid Högskolan i Halmstad. Jag studerar på ett program inom Biomedicin inriktning fysisk träning och i mina studier ingår att på egen hand utföra en studie som kommer presenteras i skriftlig form på högskolan.
Syftet med denna studie är att undersöka om den asymmetriska positionen i snowboardåkning ger en skillnad i rörelseomfånget mellan främre och bakre höftled och ryggrad, samt om den ger en skillnad i kraftutveckling mellan det främre och det bakre benet.
Deltagande i denna studie betyder att du kommer genomgå ett program av olika tester för att utvärdera ditt rörelseomfång i de leder som är viktiga inom snowboardåkning och hoppförmåga på höger respektive vänster ben. Du kommer också få fylla i ett kort frågeformulär om ditt snowboardåkande.
Rörlighetstesterna fokuserar framförallt på höftlederna och ryggen. Testerna kommer att göras av mig och jag kommer använda mig av en s.k. Gonimeter som är en sorts vinkelmätare.
I hopptesterna kommer jag använda mig av Muscle Lab utrustning och en infraröd matta som mäter hopphöjd. Risken för skada bedöms som mycket låg och du kommer innan hopptesterna att värma upp i ca 5 min.
Testerna beräknas ta ca 45 minuter. Resultaten kommer att sparas på dator, i dokument separat från uppgifter om dig som person och kommer finnas tillgängligt endast för projektgruppen.
Ditt deltagande är frivilligt och du kan när som helst avbryta om du vill, utan att meddela orsak. Denna studie är granskad och godkänd av den Lokala Etiska Nämnden på Högskolan i Halmstad och är en del av min utbildning inom Biomedicin inriktning fysisk träning på Högskolan I Halmstad.
Studien är godkänd av Malung-Sälens Gymnasieskolas Rektor Annika Borg.
Om du väljer att delta i denna studie kommer du få en tid för när testerna kommer att genomföras.
Om ni har frågor kontakta gärna mig på nedanstående kontaktinformation!
Med Vänliga Hälsningar

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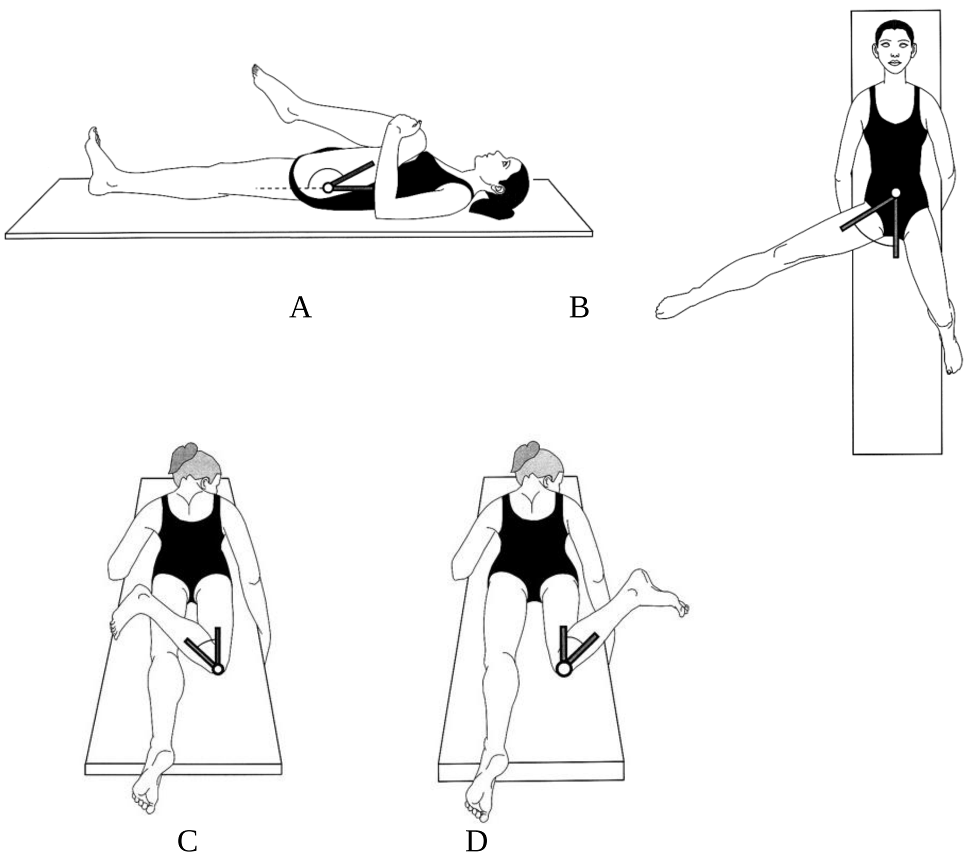
Appendix 3

Pictures below shows the subjects position during ROM measurements (6).



Subjects position when measuring passive hip flexion (A), passive hip abduction (B), passive external hip rotation (C), passive internal hip rotation (D)

Appendix 4

Testing protocol procedure
The test protocol was performed in ca 40 min/subject.

Testing order:
Measurements made with a weight scale
1. Weight (kg)

Measurement made with a soft tape measure
2. Height (cm)

Measurement made with a Myrin Goniometer
3. Passive External rotation of the hip (Right)
4. Passive Internal rotation of the hip (R)
5. Passive External rotation of the hip (Left)
5. Passive Internal rotation of the hip (L)
6. Passive Hip flexion (R)
7. Passive Hip extension (R)
8. Passive Hip flexion (L)
9. Passive Hip extension (L)

Measurements made with a plastic bodied Goniometer
10. Passive Hip abduction (R)
11. Passive Hip adduction (R)
12. Passive Hip abduction (L)
13. Passive Hip adduction (L)

Measurement made with a Myrin Incline Goniometer
14. Active Thoracolumbar rotation (L)
15. Active Thoracolumbar rotation (R)

Measurements made with a metal bodied tape measure
16. Active Lateral flexion (L) (cm)
17. Active Lateral flexion (R) (cm)

Measurements made with a metal bodied tape measure
18. Measurements of circumference of thigh (L) (cm)
19. Measurements of circumference of thigh (R) (cm)

5-min. warm-up cycling
Measurements made with jump & speed analyzer
20. One leg Counter Movement Jump (cm)

Appendix 5

TABLE 4

Circumference of Front and Rear thigh in Test group (n=10)

TP	FRONT (cm)	REAR (cm)
2	42,7	43,5
3	51	52
4	53,7	55
5	54,5	56
1	51	53
6	55	56
7	48,5	50
8	46,5	48
9	51,5	52
10	46,5	49,5
Mean	50,09	51,5
SD	3,988163041	3,915780041
t-test		***0,000134178***

TABLE 5

Circumference of Left and Right thigh in Control group (n=8) analyzed

TP	LEFT (cm)	RIGHT (cm)
11	56,4	56
12	58	58
13	53,5	54
14	59	59
15	56,2	55,5
16	53,5	53,2
17	65,3	65
18	59,8	60
Mean	57,7125	57,5875
SD	3,839061455	3,815920597
t-test		***0,379586081***

Appendix 6

TABLE 6

Results in average One-leg Countermovement Jump in Test group (n=10)

TP	Front (cm)	Rear (cm)
2	17,2	24,25
3	18,8	19,96666667
4	14,93333333	14,33333333
5	12	14,4
1	19,93333333	23,15
6	22,05	21,6
7	14,7	18,56666667
8	18,46666667	17,16666667
9	16,36666667	17,13333333
10	19,76666667	22,7
Mean	17,42166667	19,32666667
SD	2,988435013	3,575743038
t-test		***0,040692397***

TABLE 7

Results in average One-leg Countermovement Jump in Control group (n=8)

TP	Left (cm)	Right (cm)
11	23,96666667	19,06666667
12	13,53333333	14,9
13	16,73333333	18,83333333
14	16,53333333	15,73333333
15	15,3	15,13333333
16	18	16,43333333
17	19,5	19,5
18	12,63333333	13,43333333
Mean	17,025	16,62916667
SD	3,586560011	2,246368323
t-test		***0,620926053***

Appendix 7

TABLE 8

Difference in ROM in joints and movements, between Test group and Control group using a two-tailed, homoscedastic t-test

Movement	Testgroup (n=10)	Controlgroup (n=8)	Significans level (P)
	Mean ± Sd	Mean ± Sd	
Hip			
Passive External rotation¹ (°)	59,1 ± 4,483	53,5 ± 6,117	0,039*
Passive External rotation² (°)	57,2 ± 5,652	49,75 ± 4,166	0,006**
Passive Internal rotation¹ (°)	45,3 ± 6,464	52,125 ± 5,026	0,026*
Passive Internal rotation² (°)	46,1 ± 6,226	49,875 ± 6,642	0,234
Passive flexion¹ (°)	117,7 ± 6,201	120,625 ± 7,424	0,376
Passive flexion² (°)	120,2 ± 5,613	125,625 ± 6,277	0,07
Passive extension¹ (°)	14,5 ± 6,240	16,125 ± 6,334	0,593
Passive extension² (°)	16,5 ± 5,359	15 ± 6,324	0,593
Passive abduction¹ (°)	44,9 ± 6,045	48,5 ± 6,023	0,226
Passive abduction² (°)	47,4 ± 6,186	45,375 ± 8,782	0,573
Passive adduction¹ (°)	21,2 ± 2,973	22,625 ± 3,777	0,383
Passive adduction² (°)	20 ± 2,981	18 ± 1,511	0,104
Spine			
Active Thoracolumbar rotation¹ (°)	73,7 ± 7,732	73,25 ± 10,02	0,915
Active Thoracolumbar rotation² (°)	73,2 ± 5,731	75 ± 4,898	0,49
Active Lateral flexion¹ (cm)	20,3 ± 2,740	21,9375 ± 2,744	0,226
Active Lateral flexion² (cm)	20,35 ± 1,944	22,4375 ± 4,858	0,23
Lower Extremities			
One leg CMJ¹ (cm)	18,325 ± 3,479	16,629 ± 2,246	0,251
One leg CMJ² (cm)	18,423 ± 3,408	17,025 ± 3,586	0,41
Circumference of thigh¹ (cm)	51,04 ± 3,810	57,5875 ± 3,815	0,002**
Circumference of thigh² (cm)	50,55 ± 4,206	57,7125 ± 3,839	0,001**

¹) Right leg/side

²) Left leg/side

* Statistically significant P <.05.

** Statistically significant P <.01

*** Statistically significant P <.001

Appendix 8

SNOWBOARDING PARTICIPATION*

Seven years of age and older, more than once, calendar year

	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
Total (in millions)	5.1	5.2	6.0	6.3	6.3	5.9	5.3	4.3	3.6	3.6
Percent of U. S. Population	1.9%	2.0%	2.3%	2.5%	2.5%	2.2%	2.1%	1.7%	1.4%	1.5%
Average Number of Days	10.0	9.1	9.0	8.8	8.3	8.9	7.2	7.7	9.3	8.4
Male	73.5%	72.9%	74.2%	73.4%	65.7%	77.0%	72.4%	74.1%	74.3%	76.4%
Female	26.5%	27.1%	25.8%	26.6%	34.3%	23.0%	27.6%	25.9%	25.7%	23.6%
HH Income of $50,000+	70.6%	66.7%	62.7%	66.3%	64.1%	65.1%	58.5%	54.6%	64.1%	55.0%
HH Income of $35-50,000	13.8%	15.8%	13.4%	14.6%	14.8%	15.4%	16.4%	17.0%	16.5%	16.2%
Median Age -- Male	21.6	20.3	21.3	21.3	19.4	22.0	20.1			
Median Age -- Female	18.8	22.7	23.0	26.2	19.6	23.5	22.1			
Age 24 or Younger	79.7%	75.7%	73.0%	77.3%	80.4%	67.6%	75.1%	80.8%	75.4%	74.1%
Frequent (10+ Days)	32.0%	30.6%	41.2%	39.6%	38.2%	36.4%	30.5%	34.6%	49.3%	38.9%
Occasional (2-9 Days)	68.0%	69.4%	58.8%	60.4%	61.8%	63.6%	69.5%	65.4%	50.7%	61.1%
Percent who Alpine Skied	13.9%	9.8%	13.0%	10.5%	12.3%	11.5%	na	8.2%	18.0%	23.5%

* Net of Snowboarding at resort and Snowboarding not at resort

Source: NATIONAL SKI & SNOWBOARD RETAILERS ASSOCIATION, Mt. Prospect IL 60056 Tel: 847.391.9825 Fax: 847.391.9827
info@nssra.com www.nssra.com

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About the Author

Tommy Danielsson is a former professional snowboarder and member of the Swedish National Team in Halfpipe and Snowboardcross. He has successful career with several national championship podiums and international results, and also performed as assistant coach for the Swedish Olympic Team in Snowboardcross in Turin 2006.

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