RISK FACTORS FOR RUNNING RELATED INJURIES IN A GROUP OF HIGH SCHOOL CROSS COUNTRY RUNNERS

By

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ABSTRACT

There is a high incidence of running related injuries (RRI) among runners; however there is a lack of consensus regarding risk factors of RRI. The goal of the current study was to identify potential risk factors for common running injuries. Specifically, the purpose was to examine the relationship of measurements of hip mechanics during running and a step down test in high school cross country athletes prior to their fall 2012 season to any RRI that occurred during the fall cross country season. Additionally, this study sought to analyze the reliability of using the step down test to predict running form. Subjects (15 female, 16 male, age 15.6 ± 1.2) were all members of a high school cross country running team in Eugene. Subjects had hip range of motion (ROM), strength of hip extension and knee extension, and kinematic gait analysis tested before the beginning of the season. Injuries were reported throughout the fall cross country season. In total there were seven RRI occurrences. The results and discussion of this study focus on a case study of one of these runners who developed low back pain. This case study suggests that limited hip ROM, specifically limited hip extension, is a potential risk factor for low back pain in runners. Additionally results from this case study suggest that the step down test may be an accurate predictor of hip mechanics while running. The results from this study serve as a base for future research with a larger sample size on risk factors for RRI in high school cross country runners.

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INTRODUCTION

Running Related Injuries in the General Population:

The occurrence of running related injuries (RRI) among the running population is a frequent problem. A study done at the Diet Pepsi 10,000 meter National Championships found that 210 out of 451 runners (47%) had suffered from a running related injury in the last 2 years (Jacobs & Berson, 1986). Another study found that 21% of novice runners training for a four-mile run during a 13-week training period suffered from RRI (Buist, Bredeweg, Lemmink, van Mechelen, & Diercks, 2010). A systematic review of the incidence and determinants of lower extremity running injuries in long distance runners found an incidence of injuries that varied from 19% to 92% (van Gent et al., 2007). These studies along with much additional research show that RRI are a frequent issue among the running population.

There are various RRI; however, many studies have concluded that **patellofemoral pain**[1] (PFP) is the most common. A systematic review of the incidence and determinants of lower extremity running injuries found knee injuries to have a location specific incidence ranging from 7% to 50% (van Gent et al., 2007). There are many possible risk factors for PFP. Ireland, Willson, Ballantyne, and Davis (2003) found that the **isometric** strength values were lower for both hip **abduction** and external rotation for subjects with PFP when compared to the healthy aged-matched control group. These isometric muscle strength tests were done on 15 subjects with PFP and fifteen age-matched control subjects (average age ± SD = 15.7± 2.7 y/o) using hand-held dynamometers and stabilization straps. Specifically, PFP subjects were 26%

[1] Terms found in the glossary are found in **bold** at their first appearance.

weaker in hip abduction ($p<0.001$) and 36% weaker in hip external rotation ($p<0.001$) (Ireland et al., 2003). Based on the results, it was concluded that that hip abduction and external rotation strengthening could benefit those with PFP by increasing frontal and transverse stability during running (Ireland et al., 2003).

Similarly, a study done by Cichanowski, Schmitt, Johnson, and Niemuth (2007) analyzed hip strength of Division III collegiate female athletes with PFP. Hip strength in subjects' legs with PFP was compared to hip strength in subjects' uninjured legs as well as to the hip strength of an uninjured aged-matched control group. The study found that female athletes with PFP had more hip muscle weakness than the control group, with the abductors and external rotators being especially weak (Cichanowski et al., 2007). Specifically, the mean force produced by injured hip abductor muscle group and the injured external rotator were significantly lower as compared to the mean force produced by the non-injured hip abductor group and the non-injured external rotator group (Cichanowski et al., 2007). These findings also support a connection between PFP and hip abduction and external rotation weakness. However, this finding is not universally accepted.

Conversely, Cowan, Crossley, and Bennell (2009) found that hip abductor and external rotator strength was not different between subjects with PFP and controls. The purpose of that study was to examine the effect of hip muscles in relation to PFP through **neuromotor control**, strength, and range of motion of hip muscles. Although the study concluded that trunk side flexion strength and neuromotor control of the gluteus medius are affected in people with PFP there were no significant results to

suggest strength of hip abductor and external rotator muscles affect people with PFP (Cowan et al., 2009).

In addition to strength of the hip muscles, PFP could be affected by differences in Q angle. The Q angle is the angle formed by a line drawn from the **anterior superior iliac spine** (ASIS) to central **patella** and a second line drawn from the central patella to the **tibial tubercle**. Powers (2003) suggested that both structural deformities and abnormal motions of the lower extremity are influencers of the Q angle. Structural deformities include **femoral anteversion, coxa vara**, and laterally displaced **tibial tuberosity**; lower limb motions include tibial rotation, femoral rotation, and knee **valgus** (Powers, 2003). However, the relationship between Q angle and PFP is still unclear. Nguyen, Boling, Levine, and Shultz (2009) found that Q angle is a poor predictor of knee injury, since it depends mostly on frontal plane measurement while knee injuries depend on both frontal and transverse motions. Additionally, rotational alignments may be important in understanding knee injury and are not accounted for by the Q angle (Nguyen et al., 2009). Many other RRI exist in addition to PFP.

In a retrospective case-control analysis of running injuries, it was found that **iliotibial band friction syndrome** (ITBFS), **plantar faciitis**, **meniscal** injuries, and patellar **tendinopathy** also ranked within the five most common running injuries (Taunton et al., 2002). One risk factor cited in this study was that patients of both genders were 2.5 times more likely to have tibial stress syndrome if they had an activity history (time spent participating in physical activity) of less than 8.5 years (Taunton et al., 2002). It was also reported that women had increased risk of tibial stress fractures and spinal injuries if their BMI was under 21 kg/m^2 (Taunton et al., 2002). They

concluded that some risk factors had a high correlation to certain injuries, but in order to increase the validity of these results, additional research is needed in which the control group is non-injured and weekly running distance and running experience are more adequately measured.

A sports medicine article focused on low back pain in young athletes found that low back pain is one of the most challenging athletic injuries for a sports physician to diagnose and treat even though low back pain only accounts for a small percent of all injuries (Harvey & Tanner, 1991). Many factors can play a role in back injury in the young athlete including: growth spurt, abrupt increases in training intensity or frequency, improper technique, unsuitable sports equipment, and leg-length inequality, poor strength of the back extensor and abdominal musculature, and inflexibility of the lumbar spine, hamstrings and hip flexor muscles (Harvey & Tanner, 1991). When running, the lumbar spine must deal with loads around 2.7–5.7 times bodyweight after footstrike (Schache, Blanch, Rath, Wrigley, & Bennell, 2002). Given the amount that some runners train per week this would put a very large load on the lumbar spine. However predicting factors for low back injury during running still have not been conclusively determined.

As can be seen by these cited studies, there are many hypotheses of risk factors such as alignment differences, muscle weakness, and poor flexibility that could lead to different RRI. The lack of consensus regarding risk factors of running related injuries calls for further research.

Running Related Injuries in High School Cross Country Runners

High school cross country runners provide a good group to research for RRI. This sport is gaining popularity, has a high rate of injury among participants, and represents a group from which many will become lifelong runners. In high school athletics, cross country participation increased to 460,756 participants in the 2011-12 school year, according to the National Federation of State High School Associations (National Federation of State High School Associations [NFSH], 2012). This is up from 451,601 in 2010-11, 441,576 in 2009-10, and 429,651 in 2008-09 (NFSH, 2012). These statistics show that high school cross country is gaining popularity and growing in participation every year. Just as seen in the general population of runners, high school cross country runners are also prone to high incidence of RRI. In a study examining injury rate of high school cross country runners in Seattle, 162 out of 316 total runners had some form of RRI during the 11 week session, with girls having a higher overall rate of injury than boys (Rauh, Koepsell, Rivara, Margherita, & Rice, 2006).

A 21-year tracking study by Telama et al. (2005) investigated how well childhood physical activity can predict long-term physical activity throughout adulthood. Cohorts of boys and girls at 3, 6, 9, 12, 15, and 18 years of age (2,309 total subjects) were measured for physical activity in the years 1980, 1983, 1986, 1992, and 2001. Physical activity was measured using a short self-report questionnaire and medical examination that were used to calculate a physical activity index. Based on the results, it was concluded that physical activity during the ages of 9 to 18 significantly predicts adult physical activity (Telama et al., 2005). These results support the possibility that high school students who participate in cross country running are

expected to stay active into adulthood, likely becoming long-term runners. The case of Stillwater Area High School in Minnesota is an example, where many of the high school cross country runners went on to run in college and post-college (Ferstle, 2012).

Development of running patterns and muscular and flexibility training programs starts for many runners in high school. A study on impact and overuse injuries in runners found that runners who have developed low impact force and rapid **pronation** rate stride patterns have a reduced risk of developing overuse running injuries (Hreljac, 2004). If predictors of RRI could be determined among high school runners and these factors could be addressed early on, then the occurrence of running injury may be reduced, not only among cross country runners in high school, but also for many runners throughout adulthood.

Step Down Test and Hip Projection Angle

There are many methods of assessing functionality and ability to return to sport in a clinical setting. The step-down test, designed to mimic stepping down stairs, is used to test the knee in anyone with a healthy knee or with knee pain to determine level of function. The test is done by standing with the leg to be tested on a standard height stair and then lowering the body to touch the heel of the opposite leg on the floor in front of the step. Loudon, Wiesner, Goist-Foley, Asjes, and Loudon (2002) conducted a study to assess intra-rater reliability of five different performance tests, including the step down test, for PFP patients. The results showed intra-rater reliability to be fair to high, ranging from 0.79 to 0.94 with the highest reliability occurring with the step down test (Loudon et al., 2002). They concluded the step down test could have good intra-rater reliability in a clinical setting as long as the clinician follows standard protocol.

Although it has been shown that the step down test can be easily administered in different settings, further research is needed on the true predictability of the step down test in determining functionality. Willson and Davis (2008) analyzed three-dimensional **kinematics** during single-leg squats, running, and single-leg jumps using anatomical markers for tracking. They found that patients with PFP had more negative **frontal plane projection angle** (FPPA) values during a single-leg squat and that this correlated with greater knee external rotation and hip **adduction** during dynamic activities (Willson & Davis, 2008). This suggests that the FPPA during single-leg squats may be a useful clinical measure in determining lower extremity kinematics associated with PFP. More research is needed to determine if the FPPA during a step down test can also help predict lower extremity kinematics.

PURPOSE

As seen by the background of RRI, it is likely that injury is a result of poor hip mechanics and lack of hip strength. The purpose of this study is to measure hip range of motion, hip strength, and hip kinematics during running and a step down test in high school cross country athletes prior to their fall 2012 season and to examine the relationship between these measurements and any RRI that occurred during the fall cross country season. In addition, this study will analyze the use of the step down test to predict running form. The following questions will be answered: Are there correlations between hip joint motion, strength, and kinematics and the occurrence of RRI? Is the step down test an accurate predictor of running form? I hypothesize that correlations will exist between hip weakness and RRI as well as between alignment during the step down test and alignment in running. No evaluation method has been found to date that

allows a clinician or coach to predict RRI among cross country runners. Thus, the present study seeks to analyze the relationship between strength, range of motion, and kinematic measurements taken and RRI with the ultimate goal of finding a way to predict the occurrence of RRI. This would allow for future research in which a preventative program could be developed based on risk of RRI. In addition, assessment of the reliability of the step down test in predicting running form will provide clinicians with the knowledge of whether this test is an accurate way of determining when patients are ready to return to running after occurrence of injury.

METHODS

Subject Selection

Subjects were recruited from a local high school cross country team in Eugene. Data collection was done at the Biokinesiology Laboratory at Tensegrity Physical Therapy in Eugene, Oregon. Subjects were asked to come in to the laboratory one time during which all testing was completed. Upon arrival, subjects filled out a consent form (Appendix B) and short questionnaire (Appendix C) asking about height, weight, age, gender, dominant leg, other physical activities, and history of previous injury. Then subjects did a five minute warm up on a Whirlwind upright exercise bike.

Hip Range of Motion

After warm up, subjects had **hip extension** measured on both left and right hips. This range of motion (ROM) was measured using a digital inclinometer. A digital inclinometer is an instrument used to measure angles (Figure 1).

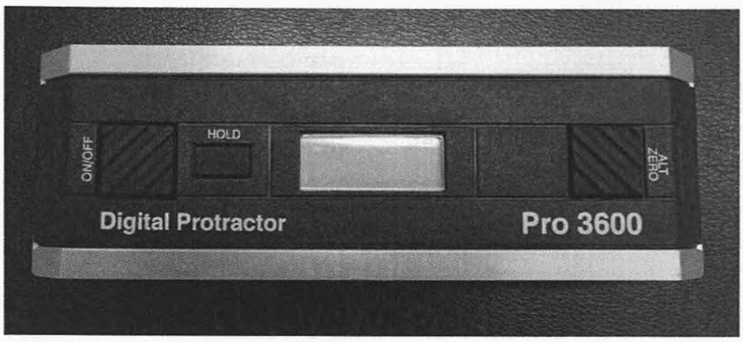


Figure 1. Image of digital inclinometer

To measure hip extension, the subject lay supine (on back) on a medical table and a Modified Thomas test was performed (Figure 2). This was done with the subject pulling the leg of the hip not being measured into his/her chest while the leg of the hip being measured hung over the end of the treatment table. The inclinometer was positioned so that it was at the middle of the **greater trochanter** and the **lateral epicondyle of the femur**.

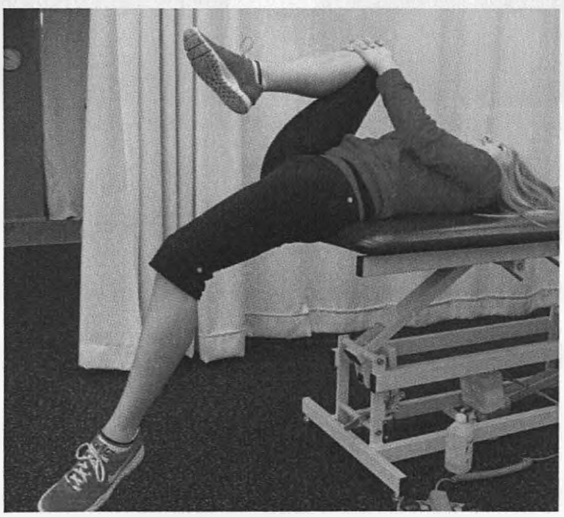


Figure 2. Positioning for modified Thomas Test

The measurements for hip extension, on both right and left legs, were taken three times. An average was calculated for data analysis. The order of testing (right or left) was randomized.

Isometric Strength Testing

Subjects then underwent an isometric strength testing using a **Biodex System 3 Isokinetic dynamometer (Biodex, Shirley, NY)**. Hip extension and knee extension were measured on both legs for each subject (Figure 3). The order of testing was randomized (hip extension vs. knee extension and right vs. left sides).

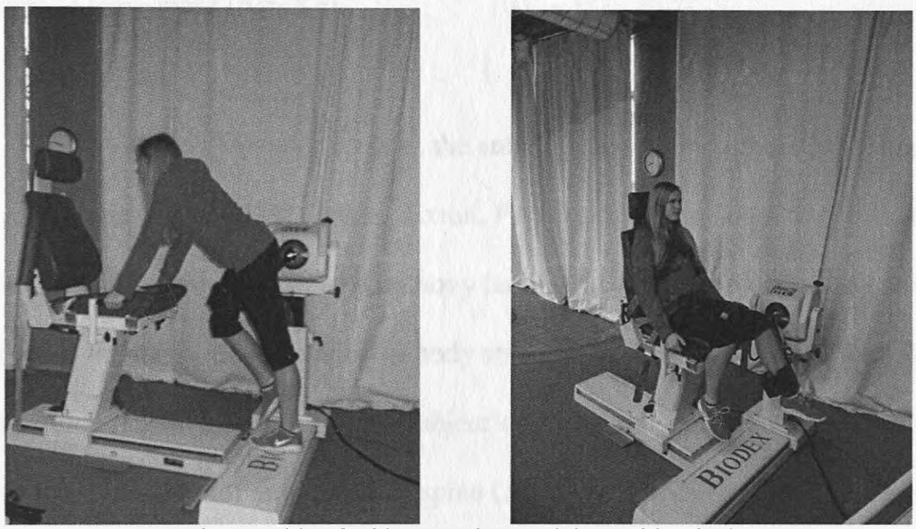


Figure 3. Biodex testing. Position for hip extension on right, position for knee extension on left

In each position, subjects performed a maximum voluntary isometric contraction (MVIC). A MVIC represents the peak force produced by a muscle as it contracts when pushing or pulling against an object that does not move. Using this MVIC, torque measurements were made by the dynamometer. Torque is the rotational equivalent of force and is calculated using the following equation:

$$\mathbf{T = F \times MA}$$

T= torque

F= force

MA= moment arm (perpendicular distance to axis of rotation)

The average peak torque was calculated for each subject in Newton-meters (Nm). In order to normalize the torque across subjects, the average peak torque was divided by the subject's body mass (Nm/Kg).

Kinematic Analysis

In the last step of data collection, the subject's motion was recorded using two high speed cameras at 120 Hz (Basler, Exton, PA) during a step down test and running on a treadmill. Markers were placed on bony landmarks on the subject's body so that angles could be measured in relation to body structures. The markers used were light emitting diode (LED) markers. On the subject's front, these markers were placed on the manubrium, right anterior superior iliac spine (ASIS), left ASIS, left tibial tuberosity, and left mid-ankle joint (Figure 4). Sagittally (on the subject's side), the markers were placed on the left acromion, left greater trochanter, left lateral epicondyle, left lateral calcaneus, and left head of the fifth metatarsal (Figure 4). While the Simi Motion (Simi, Unterschleissheim, Germany) program was running, the subject performed three step downs on each leg and ran on the treadmill for two minutes at a speed of 4.5 m/s for males and 3.6 m/s for females. A step down test was performed by having the subject stand on a 30.5 cm step stool and directing them to tap their right heel on the ground while keeping the left leg as the stance (Figure 4).

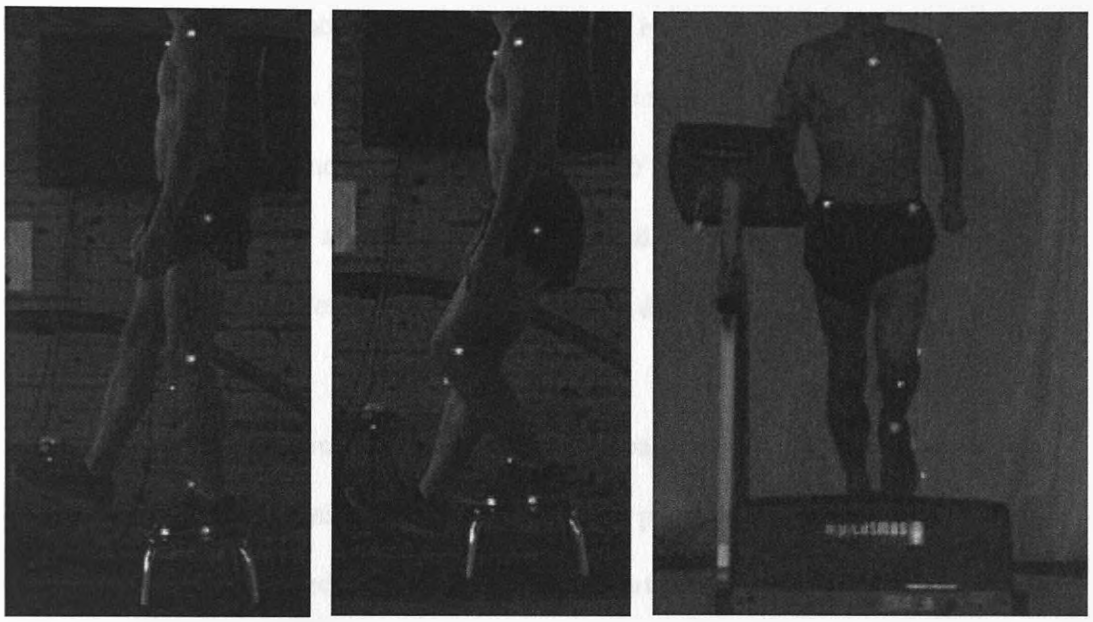
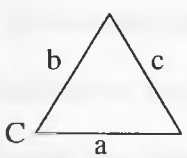


Figure 4. Left: starting position step down. Middle: mid step down. Right: frontal view running.

The Simi Motion and a customized LabView program were used to analyze the recorded video. All videos were calibrated and marker positions were assigned. Marker data was edited using "fill: spline" and "smooth: medium". Data was then exported to Microsoft Excel where the x and y coordinates for all markers were given. Based on these x and y coordinates, joint and movement angles were calculated using the law of cosines:

$$cosC = \frac{a^2+b^2-c^2}{2ab}$$



Using the x and y coordinates **initial contact** and **toe off** were calculated. Calculations for toe off were based on research that compared five kinematic methods of analyzing gait using a **force plate** to check for accuracy (Fellin, Rose, Royer, & Davis, 2010). It was found that peak knee extension was the most error free method for calculating toe off for treadmill running (Fellin et al., 2010). Toe off for the cross

country runners was found using second peak knee extension which occurs shortly after first peak knee extension. Heel strike was found using troughs in a vertical velocity curve of the lateral calcaneus marker. As done by O' Connor et al., a constraint was set at 35% of heel heights to avoid the trough in vertical velocity that occurs during the swing phase of gait (O'Connor, Thorpe, O'Malley, & Vaughan, 2007).

Injury Reports

Throughout the cross country season, the coaches were asked to report daily injury (Appendix D). Limitations or absences from participation in practice or meets due to injury were also recorded. Additionally, a certified athletic trainer or a licensed physical therapist evaluated the injury and recorded an evaluation report once a week.

All summary statistics report mean ± standard deviation.

RESULTS

There were 31 subjects (15 female, 16 male, age 15.6 ± 1.20) that successfully completed the requirements of the study. Seven out of the 31 subjects sustained injuries over the course of the cross country season. These seven injuries included: low back pain, pain and inflammation in the back of the knees at the insertion of the hamstrings, stress fracture of the second metatarsal on the left foot, shin splints, tibial stress fracture, and knee pain. Although measurements were taken for both knee and hip, the analysis of this report will focus on the hip measurements and the relation to low back pain. Subject number one who developed lower back pain over the course of the cross country season will be analyzed as a case study.

The torque produced during the isometric strength testing for hip extension using the Biodex machine for all subjects was 237 ± 39 Nm/Kg. The average hip extension in degrees measured using the digital inclinometer during the modified Thomas test on the right leg was 7.7 ± 8.7 degrees and on the left leg was 6.5 ± 7.5 degrees. Figure 5 shows the difference between average percent peak torque per body weight for subject one compared to the group average for both left and right legs. Subject one had an average torque of 25.4 Nm/kg higher than the average of the group on the right leg and 73.9 Nm/Kg higher than the average on the left leg. Figure 6 shows the differences in degrees of hip flexion of subject one compared to the group average. On the right leg, subject one had an average flexion of -16.4 degrees while the group had an average flexion of 7.7 degrees, a difference of 24.1 degrees for subject one from the average hip flexion on the right leg. On the left leg, subject one had an average of -10.7 degrees flexion while the group had an average of 6.6 degrees flexion, a difference of 17.3 between subject one and the group for hip flexion.

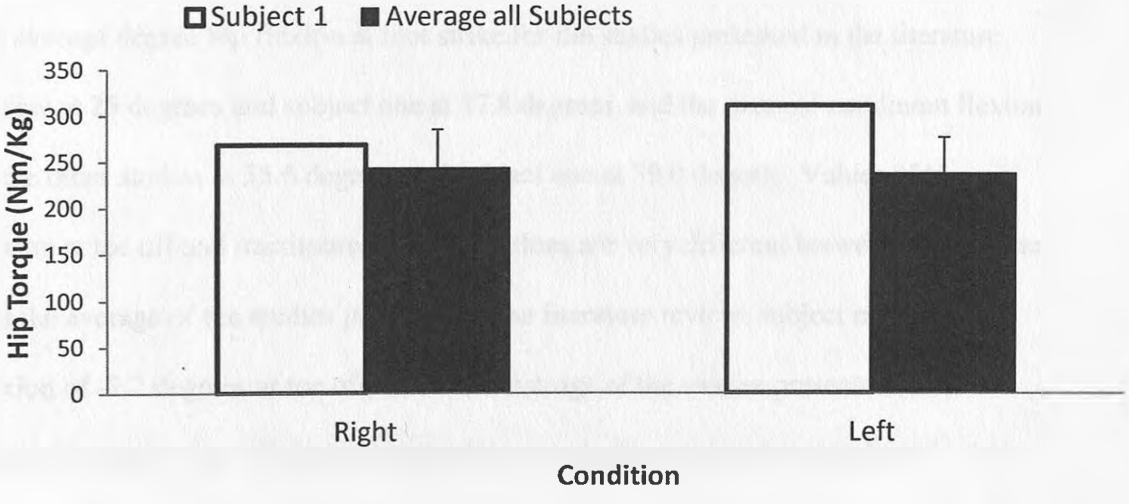


Figure 5. Average Peak Torque per Body Weight for Subject 1 Compared with Group Average

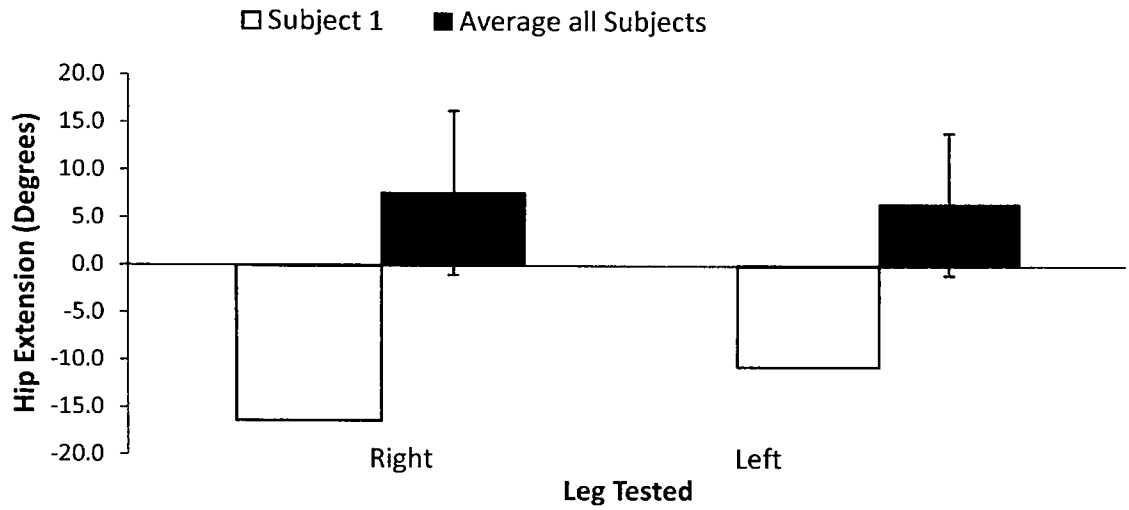


Figure 6. Hip Flexion in Degrees for Subject 1 Compared with Group Average

Figure 7 shows the angles of hip flexion, pelvic tilt, and lateral trunk lean for subject one over one **gait cycle**. Table 1 shows the difference in degrees hip flexion while running between subject one and averages compiled by Schache et al. (1999) in a literature review of the coordinated movement of the lumbo–pelvic–hip complex during running. Subject one has comparable values for foot strike and maximum flexion with the average degree hip flexion at foot strike for the studies presented in the literature review at 25 degrees and subject one at 17.8 degrees, and the average maximum flexion of the other studies at 35.6 degrees and subject one at 39.0 degrees. Values of hip flexion at toe off and maximum extension values are very different between subject one and the average of the studies presented in the literature review: subject one had a hip flexion of -2.2 degrees at toe off, while the average of the studies presented in the literature review was -26 degrees and subject one had a maximum extension of -14.1 degrees while the average of the studies in the literature review had an average of -27.6

degrees. Table 2 compares pelvic obliquity or lateral pelvic tilt from subject one and a study on the comparison of overground and treadmill running for measuring the three-dimensional kinematics of the lumbo–pelvic–hip complex (Schache et al., 2001). Subject one appears to have similar values for degree of pelvic obliquity as the average of the cohort of 10 able-bodied runners with an average age of 28.3 tested by Schache et al., (2001). Figure 8 shows the differences in maximum and minimum right pelvic tilt and lateral trunk lean between the step down test and treadmill running during the left stance phase. Values between the step down test and running are comparable with a 0.02 degree difference in maximum pelvic tilt, a 2.14 degree difference in minimum pelvic tilt, a 2.29 degree difference in maximum lateral trunk lean, and a 0.71 degree difference in minimum trunk lean.

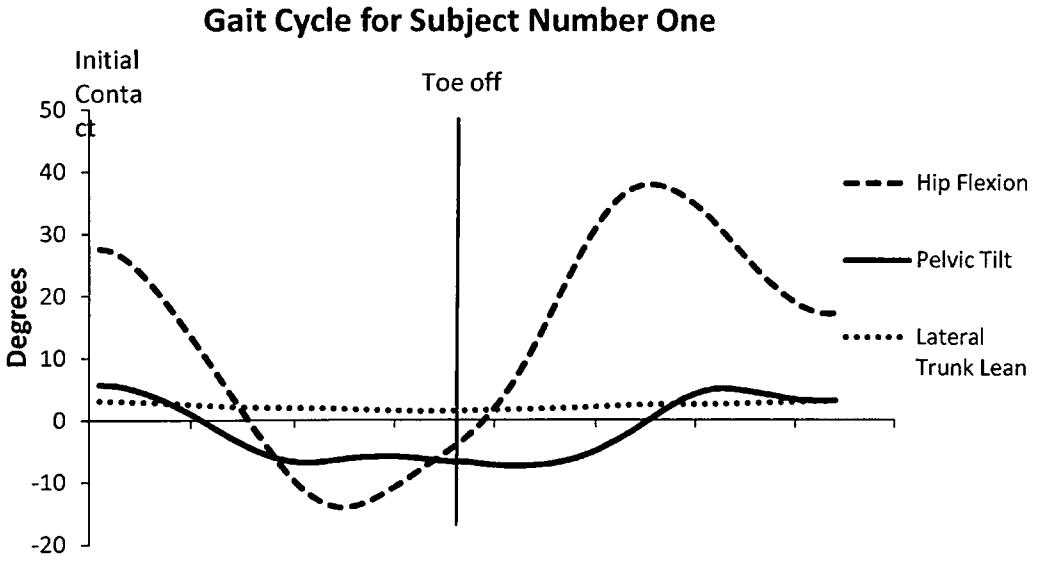


Figure 7. Gait Cycle for Subject One Showing Hip Flexion, Pelvic Tilt, and Lateral Trunk Lean

Table 1. Hip Flexion Values in Degrees for Subject One Compared with Hip Flexion Values from a Literature Review (Schache, Bennell, Blanch, & Wrigley, 1999).

Reference	Speed (m/s)	Foot strike	Toe off	Maximum extension	Maximum flexion
Subject One	4.5	17.78	-2.21	14.11	39.01
Elliot and Blanksby	3.5	21	–21	21	26
Williams	3.6	24	–25	26	34
Siler and Martin	3.6	NR	NR	26	41
Miller	3.8	27	–26	26	35
Cavanagh	4.2	30	–25	25	42
Williams	4.5	23	–33	35	37
Siler and Martin	4.7	NR	NR	34	34
Average	4.0	25	-26	27.6	35.6

Table 2. Pelvic obliquity/ Lateral Pelvic Tilt values in degrees for Subject One Compared with data from an assessment of lumbo-pelvic-hip kinematics while running (Schache et al., 2001).

Reference	Foot strike	Toe off	Minimum Pelvic Obliquity	Maximum Pelvic Obliquity
Schache et. al.	3.1	-5.8	-7.6	6.9
Subject One	3.41	-5.86	-7.4	7.88

Table 3. Degree of lateral trunk lean for Subject One.

	Foot strike	Toe off	Maximum Trunk Lean	Minimum Trunk Lean
Subject One	3.02	1.66	3.44	0.74

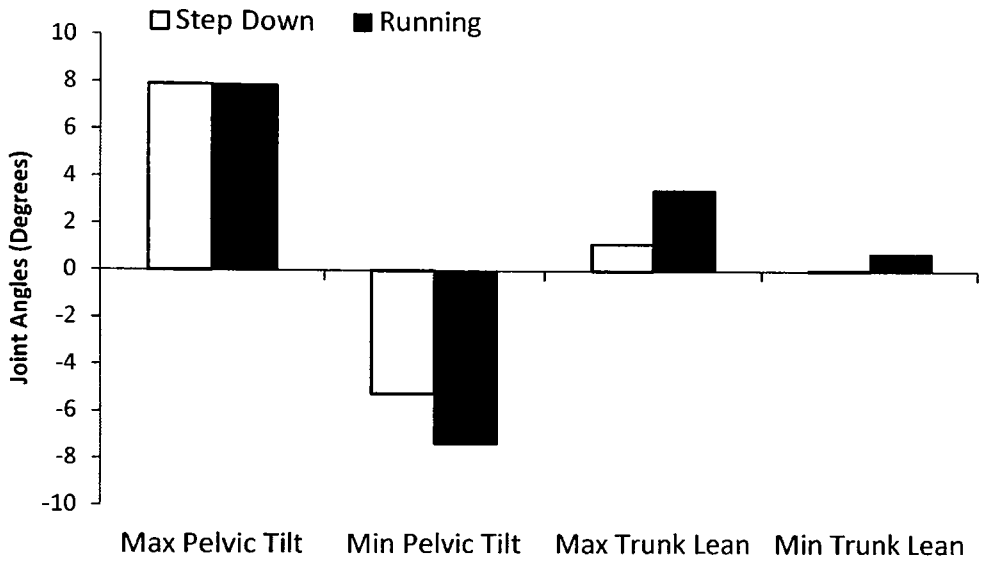


Figure 8. Maximum and minimum values for right pelvic tilt and lateral trunk lean compared between the step down test and treadmill running during the left stance phase.

DISCUSSION

Scientific studies show that RRI are often a result of problems occurring in hip and trunk mechanics (Bach, Green, Jensen, & Savinar-Nogue, 1985; Cichanowski et al., 2007; Cowan et al., 2009; Harvey & Tanner, 1991; Ireland et al., 2003; Van Dillen, McDonnell, Fleming, & Sahrmann, 2000). The purpose of this study was to measure hip range of motion, hip strength, and hip kinematics during running and a step down test in high school cross country athletes to examine the relationship between these measurements and any RRI suffered by the athletes. Injury reports returned showed that several RRI occurred in the high school cross country runners over the course of their season. One of these injuries was in subject number one who developed low back pain. Subject number one was then analyzed as a case study for the effects of hip and trunk mechanics on low back pain.

Results of this study reveal differences between subject one and normal control values for hip mechanics. Compared with the group average, subject one had a very limited degree of hip flexion during the Thomas test. In addition, when values of hip extension during running gait from subject one are compared to healthy controls, subject one shows deficiencies in hip extension. Specifically, subject one had much lower maximum hip extension and lower hip extension values during toe off compared with data of healthy control runners in seven other studies presented in a literature review (Schache et al., 1999). No difference was seen between normalized peak torque for subject one compared to the group average. Lateral pelvic tilt for subject one appears to be similar to lateral pelvic tilt values in healthy controls in a study done assessing lumbo-pelvic-hip kinematics while running (Schache et al., 1999). This would suggest that the main difference between subject one and healthy controls is limited hip flexibility, specifically limited hip extension.

Other studies have shown a connection between restricted hip flexibility and low back pain. It is suggested that with lack of hip flexibility, the hip flexor muscles are shortened, limiting hip extension and causing anterior pelvic tilt. This position of anterior pelvic tilt creates increased low back **lordosis**, putting increased strain on the lumbar spine, thus increasing risk of low back injury (Bach et al., 1985). People who suffer from low back pain commonly have decreased hip flexibility as found in a study done by Van Dillen et al. (2000). This study compared 35 controls with healthy backs to 10 subjects with low back pain. Passive length of the hip flexors was measured in four different positions. It was found that subjects with low back pain had less passive hip extension, -5.6°± 4.3°, than control subjects, -2.6°±4.2° (Van Dillen et al., 2000). In a

review of low back pain in adolescents several studies are cited that connect low back pain and hip flexibility. One of these studies examined 446 adolescents (age 12-18 years) and found a significant association between back pain and decreased mobility of the hips and knees (Balagué, Troussier, & Salminen, 1999). However another study also included in the review found no correlation between lumbar spine flexion-extension and low back pain (Balagué et al., 1999).

It can be seen that the findings of other studies suggest low back pain has a relation to hip flexibility. Additionally, the results of this study show that subject one has decreased hip extension compared to controls both during the Thomas test and during running gait. Thus it can be suggested by this case study, however not significantly proven, that one risk factor for low back pain in runners is lack of hip flexibility.

An additional purpose of the current study was to assess the reliability of using the step down test to predict running form. Previous studies, such as a study done by Zaino, Marchese, and Westcott (2004), have found that an up and down stair test is a simple measure of functional mobility and balance that is easily performed in varied settings. These results were found when assessing the use of a step up and down test in children with and without cerebral palsy (Zaino et al., 2004). In the case of subject one in the current study, the step down test demonstrated similar mechanics to running. Specifically, maximum pelvic tilt, minimum pelvic tilt, maximum trunk lean, and minimum trunk lean were all similar between the step down test and running trial for subject one. As demonstrated by Figure 8, values differed from running to step down by 0.02 degrees for maximum pelvic tilt, 2.14 degrees for minimum pelvic tilt, 2.29

degrees for maximum trunk lean, and 0.71 degrees for minimum trunk lean. This suggests that when a physical therapist, athletic trainer, doctor, or other professional wishes to assess hip mechanics while running, the step down test could serve as a predictor for these values. This eliminates the need for the equipment, space, and time required for a running assessment.

There are several limitations to this study. Primarily, the small sample size resulted in insufficient data to show significant values. With more subjects, more injuries would likely occur and then correlations could be looked for among the larger group of runners. An additional limitation is the lack of control over other activities than running that the subjects take part in. This could result in an injury being attributed to running when it was actually caused by a different activity. One way to address this problem would be to have subjects keep a log of other activities they complete during the cross country season that could be used for reference.

Overall, based on the results shown in the case study of subject one, this study suggests that there is a connection between decreased hip flexibility and occurrence of low back pain. Further research should be done with a larger sample size to support this conclusion with significant results. Additionally, further research should address predictors for other injuries such as knee pain and stress fractures. Goals for future research include a similarly designed study that involves all the cross country runners from several high schools in Eugene. This would provide a large sample size within which risk factors for many running related injuries could be examined.

APPENDIX A: GLOSSARY

Abduction: moving away from the midline of the body.

Adduction: moving towards the midline of the body.

Anterior superior iliac spine: a bony projection on the front of the pelvis.

Biodex System 3 Isokinetic dynamometer: used for performance testing and rehabilitation methods and provides measurements of force and torque.

Coxa vara: the hip curves inward and the angle between the upper femur and ball joint is reduced making the femoral neck shaft angle less than 120-135°. This can cause side effects such as pain, stiffness, and leg length discrepancy.

Femoral anteversion: a condition where the femoral neck leans forward with respect to the femur.

Force plate: often used in research and clinical settings to measure ground reaction forces.

Frontal plane projection angle: measure of knee alignment.

Gait cycle: time interval between the exact same repetitive events of walking.

Greater trochanter: a large projection of the femur.

Hip extension: occurs when the leg is moved backwards.

Iliotibial band friction syndrome: occurs when the iliotibial band which runs along the outside of the thigh becomes inflamed.

Initial contact: the point in walking or running during which the foot first strikes the ground.

Isometric: during this contraction joint angle and muscle length do not change.

Kinematics: analysis of the motions of the body using points in space.

Lateral epicondyle of the femur: small eminence on the lateral aspect of the femur.

Lordosis: curvature of the spine in the lower back and neck.

Meniscal: cartilage that acts as a barrier between the bones that meet at the knee joint.

Neuromotor control: neural processes involved in controlling human motion.

Patella: anatomical term for the knee cap.

Patellofemoral pain: inflammation where the back of the kneecap meets the femur.

Plantar faciitis: inflammation of the plantar fascia (web-like structure on the bottom of the foot).

Pronation: position where the feet roll inwards.

Tendinopathy: painful conditions occurring in and around tendons in response to overuse.

Tibial tubercle/ tibial tuberosity: elevated section on the front of the tibia (shin bone) that provides attachment for several tendons.

Toe off: the point at which the foot leaves the ground during gait.

Valgus: the distal segment of a bone or joint moves outwards.

APPENDIX B: CONSENT AND ASSENT FORMS

Informed Consent

Western Washington University
Consent to Take Part In a Research Study
Project: Pre-season evaluation in high school cross country runners

You are invited to participate in a research study conducted by Sean Roach, PhD, DPT, ATC, and Jun San Juan, PhD, ATC, from Tensegrity Physical Therapy, and David N. Suprak, PhD, ATC, CSCS, from the department of Physical Education, Health, and Recreation at the Western Washington University. The purpose of this investigation is to measure hip range of motion and strength of high school runners before the start of the season, and to examine the relationship of these measurements to the type of injury incurred at the end of the season. You were selected as a possible participant in this study because you have no history of surgery to the spine, hips or knee or any neurological issues.

If you decide to participate, you understand that the following things will be done to you. You will be asked to fill out a brief form to provide basic information such as age, height and weight. Non-invasive measurements will be made throughout the experiment. To perform these measurements, a goniometer will be used to measure joint angles. A strength testing device will be used to measure your knee and hip strength. Also, you will be asked to run on a treadmill.

There is no direct benefit to you by participating in this study. However, you understand that information gained in this study may help in the understanding of the function of the lower extremity, and may guide decisions made in preventing and prescribing strengthening and injury rehabilitation exercise.

Participation in any research study carries with it possible risks. Because multiple trials will be performed, there is a risk of muscle soreness. However, precautions will be taken to minimize this risk. However, you may discontinue participation at any time during testing.
Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept confidential by coding the data with subject numbers, rather than names.

Your participation is voluntary. Your decision whether to participate will not affect your relationship with the Western Washington University or Tensegrity Physical Therapy. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions, please feel free to contact Dave Suprak, (360) 650-2586, Department of Physical Education, Health and Recreation, Western Washington University, Bellingham, WA, 98225. If you have questions regarding your rights as a research subject, contact the Ken Clark in the Office of Research and Sponsored Programs, Western Washington University, Bellingham, WA, 98225, (360) 650-4403. You have been offered a copy of this form to keep.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights or remedies.

Print Name_____

Signature_____

Date_____

Parental Consent/Child Assent Form
Pre-season evaluation in high school cross country runners

We are trying to learn about injury prevention by measuring hip range of motion and strength of high school runners before the start of the season, and to examine the relationship of these measurements to the type of injury incurred at the end of the season. There is no direct benefit to you by participating in this study. However, you understand that information gained in this study may help in the understanding of the function of the lower extremity, and may guide decisions made in preventing and prescribing strengthening and injury rehabilitation exercise.

If you decide you want to be in our study, you will be asked to fill out a brief form to provide basic information such as age, height and weight. Non-invasive measurements will be made throughout the experiment. To perform these measurements, a goniometer will be used to measure joint angles. A strength testing device will be used to measure your knee and hip strength. Also, you will be asked to run on a treadmill. We anticipate that completing these measures will take approximately 90 minutes.

You are assured of the following safeguards to protect your confidentiality. The files are coded so that your name and your child's name will not appear anywhere on the measures themselves. This signed consent form will be kept in a locked filing cabinet separate from the measures.

Participation in any research study carries with it possible risks. Because multiple trials will be performed, there is a risk of muscle soreness. However, precautions will be taken to minimize this risk. You may discontinue participation at any time during testing. You may withdraw from the study without any penalty. Your signature on this form does not waive your legal rights of protection.

If you have any questions about your participation or your rights as a research participant, you can contact the WWU Human Protections Administrator (HPA), (360) 650-3220. If during or after participation in this study you suffer from any adverse effects as a result of participation, please notify the Dave Suprak, (360) 650-2586, Department of Physical Education, Health and Recreation, Western Washington University, Bellingham, WA, 98225 or the WWU Human Protections Administrator.

****

I have read the above description and understand the expectations for my participation.
I __ agree to participate I___ do not agree to participate

_____ _____
Parent Participant's Signature Date

_____
Parent Participant's PRINTED NAME

I have read the above description and understand the expectations for my participation.
I __ agree to participate I___ do not agree to participate

_____ _____
Child Participant's Signature Date

_____
Child Participant's PRINTED NAME
I ___agree (___ do not agree) to permit my child to participate in this study

_____
Parent's Signature

NOTE: Please sign both copies of the form and retain the copy marked "Participant."
Researcher Participant
Copy Copy

APPENDIX C

High School Running Research Protocol/Data Sheet

Subject ID: _____ Dominant Leg: RIGHT / LEFT

	Check Off List	Comments
Date		Common Activities:
Time (Begun, Completed)		
Subject Number		
Height (in)		
Body Weight (lbs)		
Age (y/o)		
Gender	Male / Female	Injury History:
Consent Form Completed	Yes / No	
Mark Key Landmarks	Yes / No	
Prep Skin Sites	Yes / No	
Warm-Up Completed	Yes / No	
Collect Each Trial	Yes / No	

Station 2: Hip ROM

	Trial 1		Trial 2		Trial 3	
	L	R	L	R	L	R
Hip Extension						

Station 3: Biodex

	L	R
Hip Extension		
Knee Extension		

Station 4: Kinematics

Step Down	
Treadmill Running	

APPENDIX D: INJURY REPORT FORM

Injury report form

Injury details: *This report reflects an accurate record of the injured person's reported symptoms of injury*

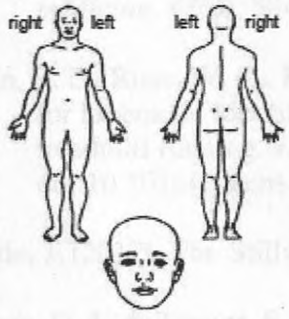
Name of person injured:	DOB: (Day/Month/Year) / /
Date when injury occurred: / /	Date when injury is evident: / /
Person injured: ☐ Athlete ☐ Coach ☐ Other:	Gender: ☐ M ☐ F
Supervising coach: _____ (Signature)	Witness: _____ (Signature)

First aid provided by: _____ (Signature)	Time of first aid: :	Initial treatment: ☐ No treatment required
Nature of injury: ☐ New injury ☐ Recurrent injury	☐ Aggravated injury ☐ Other:	☐ CPR ☐ RICER ☐ Crutches ☐ Sling/splint ☐ Dressing ☐ Strapping ☐ Massage ☐ Stretching
Did the injury occur during… ☐ Training ☐ Event ☐ Other:		

Symptoms of injury:

☐ Blisters	☐ Inflammation/swelling	☐ Spinal injury
☐ Bleeding nose	☐ Cramp	☐ Cardiac problem
☐ Bruising/contusion	☐ Suspected bone fracture/break	☐ Electrical shock
☐ Cut	☐ Dislocation	☐ Burn
☐ Graze/abrasion	☐ Concussion/head injury	☐ Insect bite/sting
☐ Sprain	☐ Loss of consciousness	☐ Poisoning
☐ Strain	☐ Respiratory problem	☐ Other:

Body part injured:



How did the injury occur?

☐ Collision with a fixed object	☐ Overbalance
☐ Collision/contact with another person	☐ Overstretch
☐ Fall from height/awkward landing	☐ Slip/trip
☐ Fall/stumble on same level	☐ Other:

Extra detail regarding how the injury occurred:

Was protective equipment worn on the injured body part? ☐ Yes ☐ No

Follow up action:

☐ None ☐ Medical practitioner/physiotherapist ☐ Hospital
☐ Ambulance ☐ Other:

Signature of person completing form: Date: / /

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