The effect of external ankle support on knee and ankle joint movement and loading in netball players.

Final Report to NSW Sporting Injury Committee

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ABSTRACT

Purpose The aim of this study was to investigate the effect of external ankle support (braces and high top shoes) on the ankle and the knee joint loading.

Methods Twelve high performance netball players with no previously diagnosed severe ankle or knee injuries were recruited from the NSW Institute of Sport. A 3-D Motion Analysis System was used to collect kinematic data for the right lower limb and a Kistler force plate was used to simultaneously record the ground reaction forces at right foot contact. Single leg landing and cutting manoeuvres were performed under four conditions: (1) standard netball shoe; (2) standard netball shoe with brace; (3) hybrid netball / running shoe; (4) high top shoe.

Results During the single leg landing, the ankle rotation (inversion/eversion) was significantly larger when wearing the standard netball shoes compared to these shoes whilst wearing a brace (20.44 ± 3.37 vs 13.73 ± 2.68, p=0.01) and the high top shoes (16.84 ± 3.92, p=0.014). During side step cutting, the ankle flexion is significantly reduced when wearing the standard netball shoes compared to the shoes with brace (44.84 ± 6.80 vs 40.72 ± 6.20, p=0.045). None of the moments were significantly different during single leg landing and sidestepping.

Conclusions This study showed that prophylactic ankle brace and high top shoes restrict ankle eversion during single leg landing and sidestepping. Although movement at the ankle was restricted no changes in ankle and knee joint loading were observed

INTRODUCTION

About 430,900 adult females play netball on a regular basis making netball the most popular team sport in Australia (Australian Bureau of Statistics, Participation in sport and physical activity. 2005). Netball is a physically demanding sport that requires a high degree of speed, strength, fitness and flexibility. In netball, the incidence of injury is about 14 injuries per 1000 player hours (5). The most common site of injury in netball is the lower extremity with ankle injuries accounting for about 31% of these. Injuries to the knee are the second most common but the most significant in terms of costs and disability. Greater than 40% of ankle sprains can potentially progress to chronic problems and are therefore a major concern for physicians, physical therapists, and athletic trainers. With almost half a million netballers regularly competing in Australia, the development of effective injury prevention strategies has the potential to significantly decrease the number of injuries sustained.

Due to the lack of bony congruence and the inability of the static restraints to handle the forces generated during functional tasks, ankle and knee joints are forced to rely on the dynamic restraints (e.g. ligaments and muscles) to maintain joint stability. Determining factors for ankle sprain injury are the joint position at the time of injury, the magnitude, direction and rate of applied forces, and the resistance of the joint structures such as ligaments and muscles. Therefore, executing an incorrect jumping and landing technique will increase the load on the lateral ankle structures, resulting in injury. During landing, the ankle can be forced into supination, leading to injury to the ankle. During cutting manoeuvres with a quick change in direction ankles as well as knees sustain large forces with if not compensated by dynamic structures will lead to injury. Biomechanically, ankle sprains and knee injuries are caused by large ankle eversion torques and large valgus torques during dynamic movements (Figure 1).

Figure 1: Inversion of the foot while landing will damage the lateral structures of the ankle

External ankle support has been found to significantly reduce the occurrence of ankle sprains especially in people with previous ankle injuries (8). A systematic review by Quinn et al established a significant reduction in the number of ankle sprains in people allocated external ankle support (Peto odds ratio 0.49; 95% confidence interval 0.37 to 0.66). This reduction was greater for those with a previous history of ankle sprain, but still possible for those without prior sprain. There were no apparent differences in the degree of severity of the ankle sprain prevented or any change to the incidence of other leg injuries. The same systematic review concluded that the protective effect of 'high-top' shoes remains to be established.

Historically, ankle taping is the athletic trainers' preferred method to attempt to prevent ankle sprains. Ankle taping is effective in restricting the motion of the ankle and has also been proven to decrease the incidence of ankle sprains (9). It has been demonstrated that the stabilizing effect of ankle tape will decrease up to a 50% after as little as 10 min of exercise (7). Due to this deterioration in support, and the cost of tape, removable and reusable ankle braces were designed as an alternative to taping.

Overall, braces have been demonstrated to be biomechanically effective in preventing, decreasing, or slowing motions that cause injury to the lateral ankle ligaments (9). One cadaveric study has shown that braces were not as effective as freshly applied tape (10). However, unlike tape, braces offer the advantage of being easily adjusted if and when support is compromised. Clinically, braces appear to be at least as effective as tape in the prevention of lateral ankle sprains. The injury rate in one study by Sitler et al. (1994)

reported that the ankle injury rate was more than triple in the nonbraced players as compared with braced players during intramural basketball at West Point.

A previous study found significantly reduced activity in the gastrocnemius but no effect of bracing or taping on rearfoot motion or ground reaction force during landing in netball players (3). However, the sample size was small and the subjects were not wearing shoes during this landing task which doesn't simulate the natural conditions. Some recent studies have indicated that there could be an effect of external ankle support on the knee joint torques (6, 11). Both studies observed an increased knee external rotation moment using a brace (11) or a foot orthoses. A decreased range of motion in the ankle may increase the loads at the knee and therefore the risk of injury.

In summary, external ankle support has been successfully used to prevent ankle sprains. However, the exact mechanics of this protective effect is not fully understood. Some recent studies have indicated that reducing the range of motion at the ankle will place larger loads to the knee and increase the risk of knee injuries.

AIMS AND HYPOTHESIS

The aim of this study is to investigate the effect of external ankle support on the ankle and the knee joint loading. A better understanding of the causes of those injuries will lead to better prevention and rehabilitation strategies in the context of netball and any fast paced sports in general.

The hypotheses of this study are

1) External ankle support will reduce the range of motion at the rear foot during side stepping and single leg landing compared to commonly worn footwear in netball players.
2) External ankle support will increase the loading on the knee joint during side stepping and single leg landing compared to commonly worn footwear in netball players.

METHOD AND PROCEDURE

Participants

This study recruited netball players within the New South Wales Institute of Sport (NSWIS). The standard of these players ranged from National team members to high performance U18 developmental squad members. Eligible subjects were older then 16 and had no previously diagnosed severe ankle (grade III ankle sprains) or no knee or ankle injury during the last 6 months. We recruited subjects for this study from the NSW Institute of Sport netball programme. An injury is defined as an incident that requires medical attention, limited physical activity, or resulted in oedema or swelling for more than a 24-hour period.

Screening procedure

All netball players were contacted via email and asked to fill in a pre-participation screening questionnaire that incorporated the Cumberland Ankle Instability Tool (2) and information about previous and current injuries. The self-administered questionnaire sought information about ankle and knee pain and / or diagnosed injuries (1) at any stage during the lifetime of the player; (2) specifically in the previous six months; and (3) at the time of completing the questionnaire (see Appendix 1). The questionnaire incorporated the Cumberland Ankle Instability Tool (CAIT) developed by Hiller et al., (2006) to assess the players' current perceptions of their ankle stability.

Each player in the testing phase of the study provided written consent prior to commencement. For those players under the age of 18, parental consent was also obtained. Players were assessed in an indoor biomechanics laboratory using a protocol that was approved by the Human Research Ethics Committee at the University of Sydney.

Outcome measurements

Biomechanical Analysis

A three-dimensional kinematic analysis was performed to track the position of all segments of the right lower limb (pelvis thigh, shank, rear foot and fore foot, respectively) in space at the Biomechanics Laboratory at the University of Sydney (Figure 2). The data were collected using 14-camera 3-D Motion Analysis System (200 Hz). Additionally, one Kistler force plate sampling at 1000 Hz was used to simultaneously measure ground reaction forces.

Figure 2: Markers attached to the shoe, and on the foot, shank, thigh and pelvis.

Figure 3: The rearfoot wand and the markers on the shoe.

Each subject had twenty reflective surface markers taped to specific anatomical landmarks on the thorax, pelvis, thigh, shank and foot using hypoallergenic tape (Figure 2). In-shoe motion of the rearfoot segment was determined using a wand device in which three retro-reflective markers were attached to a single rigid shaft mounted onto a flat stirrup (Figure 3). The stirrup provided a large area of contact around the heel and was attached firmly. The wand extended posteriorly through a 10 mm hole in the rear of the shoe counter.

It was ensured that the wand shaft did not contact the shoe during movement. Markers were also attached to the shoe, and on the shank, at the knee and at the ankle to calculate segment motion with six degrees of freedom and joint centre locations for the knee and ankle joint complex.

Before trial, an anatomical reference position was obtained with the subject standing motionless in the capture area. The three-dimensional external moments and intersegmental joint forces were calculate using inverse dynamics and by modelling the leg as a collection of rigid links or segments.

The primary outcome for this study was the external valgus moment. Secondary outcomes included knee extensor/flexor moments and rearfoot inversion/eversion.

There were three shoe types. The first was specifically marketed as a standard netball shoe (Ignite 3, ASICS), the second was marketed as a hybrid netball / running shoe (Netburner, ASICS), and the third was a high top basketball shoe (Nike). Each of these shoe types formed one condition. The fourth condition involved the Ignite 3 shoes in association with a semi-rigid ankle brace (EProfessional). The order of these conditions was randomised.

The two movement patterns that were assessed were a single leg landing whilst receiving a pass and an anticipated side-step cutting manoeuvre.

For the single leg landing trials each player was instructed to use a straight line approach to the landing area (designated by the border of the force plate) at a self-selected speed that simulated that required to effectively beat an opponent and receive a pass in a game situation. The player 'leapt' from her left leg and landed on her right leg on the force plate. As the player was about to land she received a chest pass distributed with a flat trajectory by a tester who was positioned at approximately 5 metres from the landing area and at a 5° angle relative to the approach direction. After receiving the pass the player was permitted to step forward with her left leg but had to pass the ball back to the tester before violating the stepping rule. This has been described as a run-on landing technique in previous literature {Otago, 2004 #139}. A standard netball (Gilbert) was used and the same tester distributed the pass for all players.

For the side-step cutting manoeuvre trials each player was instructed to once again use a straight line approach to the landing area at a self-selected speed that simulated that required to effectively beat an opponent. The player contacted the force plate with the right foot and changed direction to the left to avoid an imaginary opponent that was positioned at the far end of the force plate. A designated space was positioned 35-55 degrees from the original line of progression so that players cut an angle of approximately 45 degrees.

Players were allowed as many practice trials as necessary to become familiar with the requirements of the task and the testing environment. In order to ensure a realistic landing was performed the player was told not be concerned about the placement of her right foot on the surface of the force plate. If a trial was unsuccessful due to the foot landing outside the border of the force plate the player was instructed to alter her starting position or the leg on which the approach was initiated. The trials continued until # successful trials were collected.

Statitistics

Histograms of all variables were inspected for normality visually, and expressed as mean and standard deviation or median and range, as appropriate. Comparisons between groups were made using a paired t-test for normally distributed continuous data. The Kruskal-Wallace test was used for non-normally distributed continuous data. Comparisons between the brace and the standard shoes; and the high top shoes and the standard shoes were made using paired t-test for normally distributed continuous data. The Kruskal-Wallace test was used for non-normally distributed continuous data. SPSS (Release 17.0 for Windows, 2004, Chicago: SPSS Inc) was used for all data analysis. All *p* values of less than 0.05 were considered statistically significant.

RESULTS

Recruitment

From the 49 scholarship holder, 44 returned the screening questionnaire (Figure 4). The players had an average score of 26.2 ± 3.2 on the Cumberland Ankle Instability Tool. Twenty five players were eligible for testing but only 50% of those were able to attend a testing session. Most players of the green squad were aged under 18 and were therefore (1) attending school 9am-3pm five days per week, and (2) reliant upon parents to drive them to the university for testing. Other players couldn't attend the testing because of unrelated injuries or commitments with the national team.

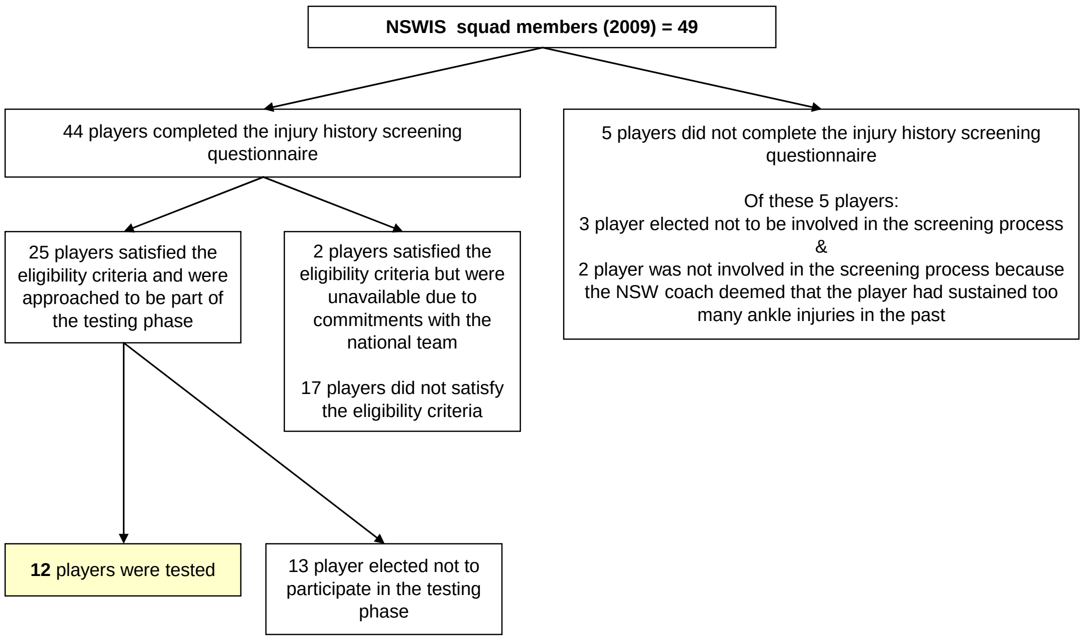

Figure 4: Flow chart of the recruitment process.

Baseline characteristics of the twelve elite netball players that participated in the study are presented in Table 1.

Table 1: Subject characteristics of the 12 elite netball players.

Variable	Mean ± SD
Height (cm)	178.5 ± 4.1
Weight (kg)	70.1 ± 8.2
Shoe size	10.2 ± 1.0
Preferred method of restriction (Strapping/braces)	10/2

Single Leg Landing

The range of motion of midfoot, ankle, knee and hip in all 3 planes are summarized in Table 2. During landing, the ankle rotation (inversion/eversion) was significantly larger when wearing the standard netball shoes compared to both the shoes with a brace (20.44 ± 3.37 vs 13.73 ± 2.68, $p=0.01$) and the high top shoes (16.84 ± 3.92, $p=0.014$). There was less ankle adduction range of motion in the high top shoes compared to the standard shoes. None of the other ranges of motion were significantly different.

Table 2: Midfoot, ankle and knee angle range of motion during landing.

Range of Motion (deg)	Standard shoe	Standard shoe with brace	p	High top shoe	p
Midfoot Sagittal plane	24.45 ± 12.20	23.77 ± 9.09	0.768	18.76 ± 7.54	0.224
Midfoot Transverse plane	9.14 ± 4.22	8.00 ± 2.07	0.384	7.89 ± 1.85	0.345
Midfoot Frontal plane	12.75 ± 4.60	11.78 ± 3.69	0.467	13.82 ± 6.05	0.341
Ankle Sagital plane	44.02 ± 8.31	43.87 ± 9.80	0.705	41.25 ± 10.35	0.652
Ankle Transverse plane	20.44 ± 3.37	13.73 ± 2.68	0.001	16.84 ± 3.92	0.014
Ankle Frontal plane	23.11 ± 7.14	19.09 ± 3.46	0.187	17.60 ± 4.05	0.039
Knee Sagital plane	29.05 ± 19.86	27.16 ± 20.67	0.763	34.60 ± 27.14	0.338
Knee Frontal plane	19.26 ± 9.90	17.48 ± 10.08	0.515	18.03 ± 10.53	0.471

During single leg landing, the netball players landed in a less inverted position (-7.52 ± 6.23 vs -4.54 ± 5.27, p=0.03) in the standard shoe with brace compared to the standard shoes (Figure 5). No significant differences were found between the high top shoe condition and the standard shoes.

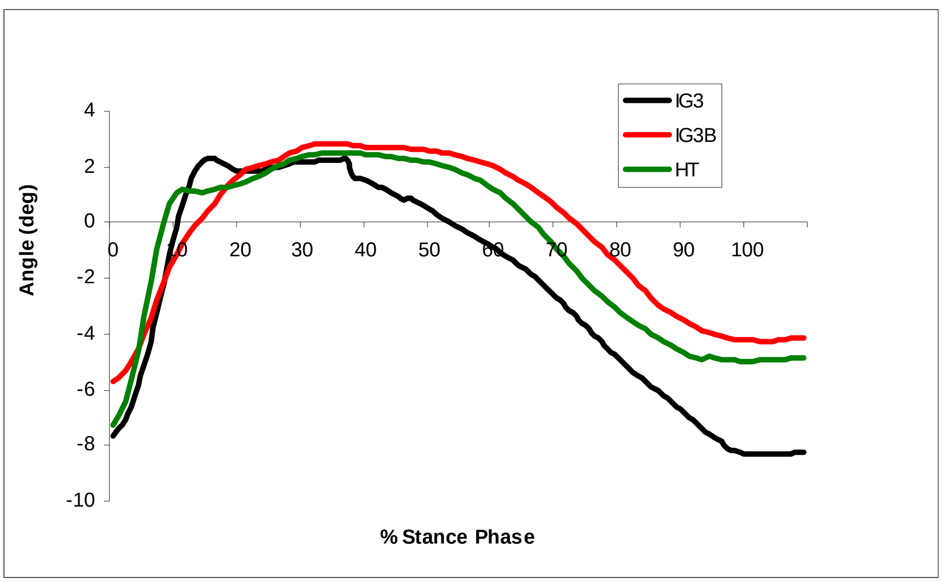

Figure 5: Inversion/Eversion angle during a single leg landing with standard shoes, standard shoes with brace and high top shoes.

Loading during landing

None of the moments were significantly different but there was a trend towards an increased ankle plantarflexion moment and hip flexor moment when wearing the shoes with the brace compared with the standard shoes (Table 3: Peak moments of the ankle and knee during a single leg landing..

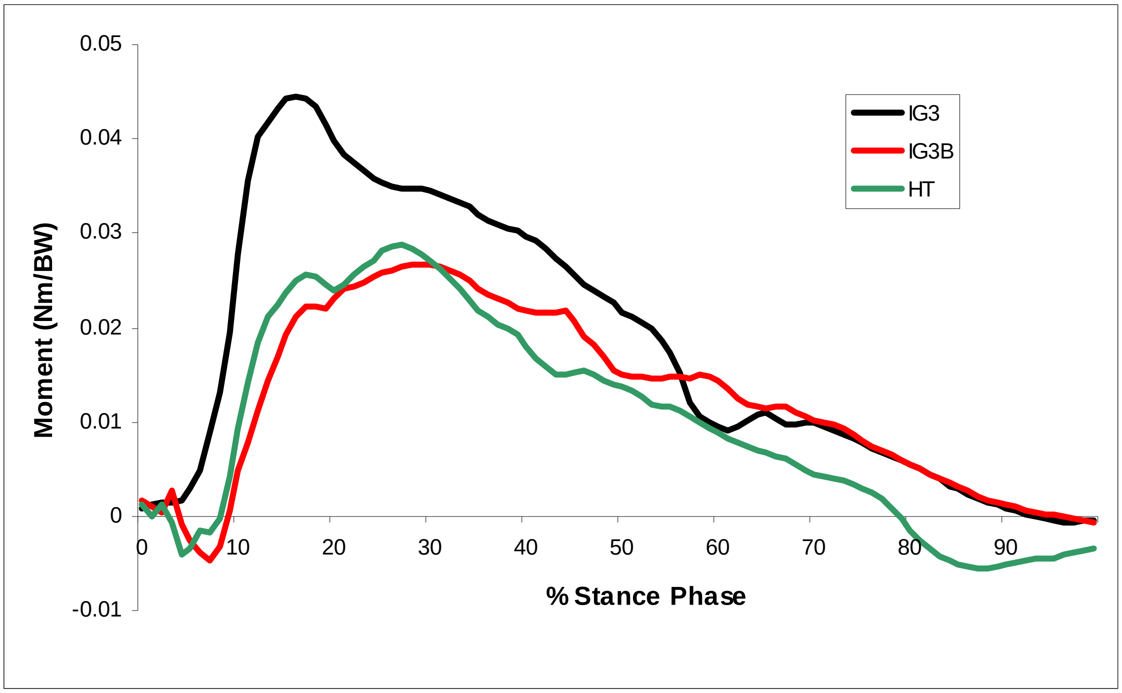

Figure 6: Time series of the ankle inversion/eversion moment during landing with standard shoes, standard shoes with brace and high top shoes.

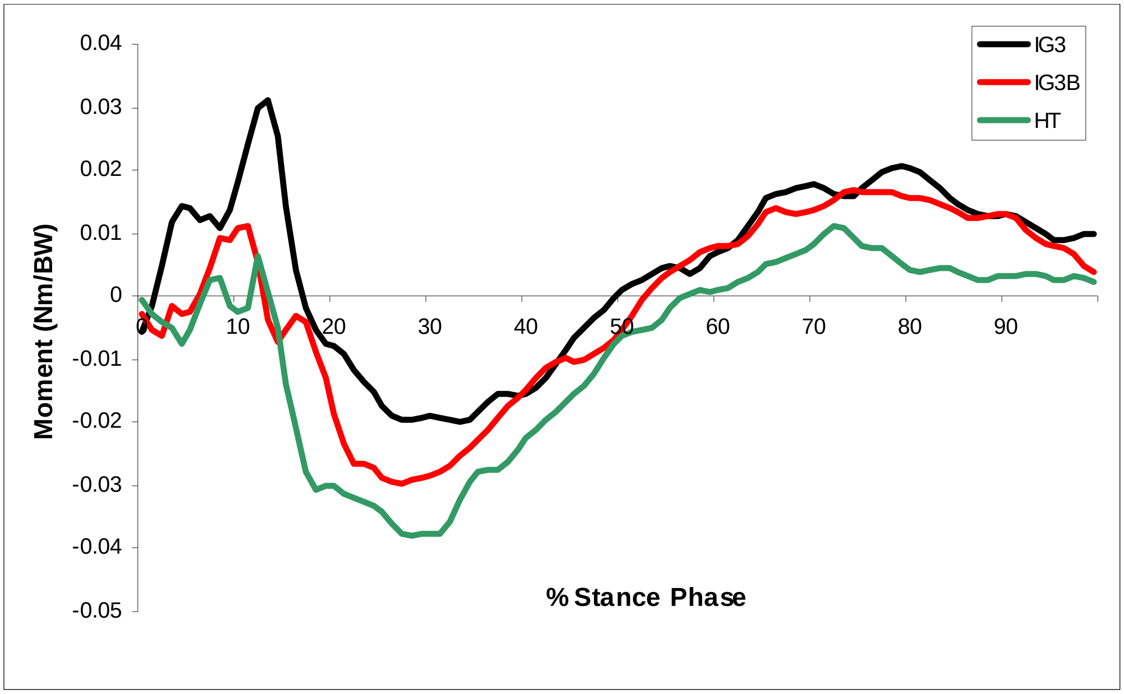

Figure 7: Knee ab/adduction moment during single leg landing with standard shoes, standard shoes with brace and high top shoes.

Table 3: Peak moments of the ankle and knee during a single leg landing.

Peak Moments (Nm/BW)	Standard shoe	Standard shoe with brace	p	High top shoe	p
Ankle inversion	0.0550 ±0.0559	0.0458 ± 0.0394	0.317	0.0449 ± 0.0344	0.427
Ankle plantarflexion	-0.2142 ± 0.0504	-0.2349 ± 0.0437	0.051	-0.2363 ± 0.0405	0.253
Knee abduction	-0.0627 ± 0.0286	-0.0667 ± 0.03432	0.180	-0.0715 ± 0.0396	0.098
Knee extension	0.2566 ± 0.0573	0.2718 ± 0.0417	0.429	0.2660 ± 0.0548	0.861
Knee external rotation	-0.023 ± 0.011	-0.018 ± 0.006	0.226	-0.0191 ± 0.0076	0.332
Hip abduction	0.5570 ± 0.1142	0.5739 ± 0.1263	0.482	0.5225 ± 0.0902	0.390
Hip flexion	0.1143 ± 0.0366	0.1159 ± 0.0495	0.063	0.1088 ± 0.0502	0.663

Sidestepping

The range of motion of midfoot, ankle, knee and hip in all 3 planes are summarized in Table 4. During side stepping, the ankle flexion was significantly reduced when wearing the standard netball shoes compared to the shoes with a brace (44.84 ± 6.80 vs 40.72 ± 6.20, p=0.045). There was increased ankle inversion/eversion range of motion in the high top shoes compared to the standard netball shoes. None of the other ranges of motion were significantly different.

Table 4: Midfoot, ankle and knee angle range of motion during sidestepping

Range of Motion (deg)	Standard shoe	Standard shoe with brace	p	High top shoe	p
Midfoot Sagital plane	27.93 ± 6.03	29.88 ± 5.52	0.329	25.34 ± 4.68	0.238
Midfoot Transverse plane	16.45 ±4.62	17.43 ± 3.36	0.272	16.10 ± 3.42	0.809
Midfoot Frontal plane	14.97 ± 4.84	14.88 ± 3.32	0.955	16.19 ± 3.37	0.576
Ankle Sagital plane	44.84 ± 6.80	40.72 ± 6.20	0.045	42.58 ± 8.69	0.238
Ankle Transverse plane	14.70 ± 3.33	14.97 ± 3.69	0.752	14.77 ± 3.25	0.940
Ankle Frontal plane	13.07 ±4.64	13.54 ± 5.03	0.574	16.31 ± 4.47	0.021
Knee Sagital plane	15.72 ± 6.96	16.06 ± 8.59	0.856	15.55 ± 8.14	0.869
Knee Frontal plane	15.11 ±5.87	15.61 ± 5.61	0.603	13.81 ± 5.19	0.136

Angles at footstrike during sidestepping

During sidestepping, the netball players landed in less inverted position (-3.88 ± 6.26 vs -1.95 ± 5.22, p=0.05) in the standard shoes with a brace compared to the standard shoes (Figure 8). No significant differences were found between the high top shoe condition and the standard shoes.

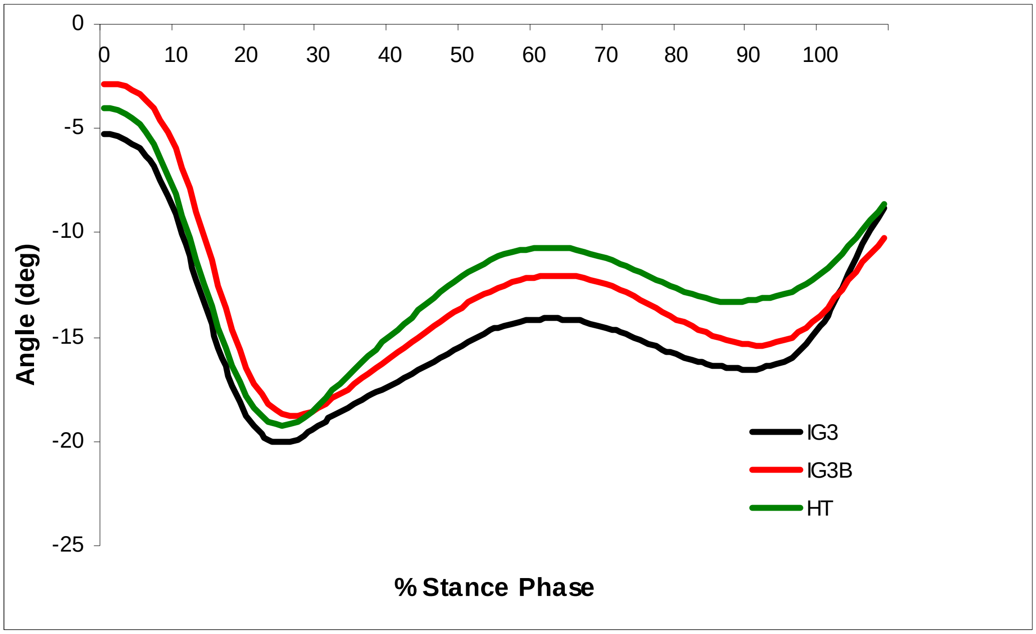

Figure 8: Ankle inversion/eversion during sidestepping with standard shoes, standard shoes with brace and high top shoes.

Moments during sidestepping

None of the moments were significantly different but there is a trend towards an increased ankle plantarflexion moment (p=0.063) when wearing the shoes with the braces compared with the standard shoes (Table 5).

Table 5: Peak Moments (Nm/BW) during sidestepping

Peak Moments (Nm/BW)	Standard shoe	Standard shoe with brace	p	High top shoe	p
Ankle inversion	0.121 ± 0.080	0.106 ± 0.080	0.570	0.101 ± 0.057	0.492
Ankle plantar flexion	-0.29 ± 0.048	-0.312 ± 0.03	0.063	-0.308 ± 0.034	0.158
Knee internal rotation	-0.065 ± 0.037	-0.069 ± 0.035	0.539	-0.058 ± 0.034	0.208
Knee abduction	0.163 ±0.074	0.156 ± 0.066	0.626	0.148 ± 0.072	0.333
Knee extensor	0.370 ±0.066	0.387 ± 0.079	0.151	0.364 ± 0.064	0.622
Hip abduction	0.346 ± 0.095	0.369 ± 0.133	0.407	0.353 ± 0.096	0.698
Hip flexor	0.051 ±0.042	0.076 ± 0.061	0.208	0.073 ± 0.044	0.077
Hip extensor	-0.156±0.181	-0.152 ±0.196	0.705	-0.148 ± 0.203	0.500

BW=Body Weight, Nm = Newton meters

DISCUSSION

This study investigated the effect of external ankle support on the ankle and knee joint loading. The current study did not find any influence of bracing or high top shoes on the ankle or knee joint loading. We did observe a reduction in ankle rotation (inversion/eversion) when wearing the shoes with a brace and the high top shoes compared to the standard netball shoes during single leg landing. Ankle flexion range of motion was reduced when wearing a prophylactic brace during side stepping compared to the standard netball shoes alone.

Although the external ankle support decreased the ankle eversion/inversion range of motion, no changes in knee and ankle loading were found during single leg landing. This is in contrast to Venesky et al, who found that wearing prophylactic ankle braces increased the ankle eversion moment and the knee external rotation moment. However, in the study by Venesky et al. the subjects performed a drop landing onto a slanted board and this was different the protocol used in the current study. Rather than select a movement that passively forced the ankle into , we used a more functional movement which is used frequently during the netball game. Our movement probably didn't force the ankle into ankle eversion to the same extent and this may have made it harder to detect differences in moments.

This study is the first to measure the rearfoot motion inside the shoe during landing and sidestepping in netball players. This study found that ankle eversion/inversion range of motion is restricted when wearing a brace inside the standard netball shoe during single leg landing but not during side stepping. At foot strike, the ankle eversion was restricted when wearing a brace but not when wearing the high top shoes during landing and side stepping. Loading at the ankle and the knee wasn't influenced by bracing or high top shoes during single leg landing or sidestepping, except for an increase in plantar flexor moment when performing sidestepping in standard netball shoes with braces. Our results are in contrast to Hopper et al. (4) who did not find any restriction in ankle and knee range of motion during single leg landing. However, Hopper et al. measured the effect of the braces when landing from a jump rather then landing after a run. They also had the netball players wearing the brace without any shoes on. The reduction in ankle eversion range of motion was similar to what was found by Anderson et al (1). They observed a reduction in eversion angle of about 9 degrees during a drop landing which is similar to our reduction (7 degrees).

LIMITATION OF THE STUDY

Limitations of this study are the small sample size. We recruited 12 elite netball players from the same source in order to get a homogenous sample size. Although the markers were placed on the calcaneus bone inside the shoe, for the high top shoes the malleous markers had to be placed on the shoe. This might have influenced the calculation of the ankle joint centre for this shoe condition.

CONCLUSIONS AND FUTURE WORK

This study showed that prophylactic ankle brace and high top shoes restrict ankle eversion during single leg landing and sidestepping. Although movement at the ankle was restricted no changes in ankle and knee joint loading were observed.

Future work might look into the effect of prophylactic ankle brace and high top shoes on muscle activity patterns. Other movement pattern which force the ankle in more extreme position should also be included in future research.

ACKNOWLEDGEMENT

We would like to acknowledge all netball players who were willing to volunteer for this study and offer some of their very busy life to this research project. This research was funded by the Research and Injury Prevention Scheme of the NSW Sporting Injury Committee.

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