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# DOMINANT LIMB ASYMMETRY ASSOCIATED WITH PROSPECTIVE INJURY OCCURRENCE

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***ABSTRACT***

*The purpose of the study was to identify associations between dominant lower limb asymmetry in unanticipated agility performance and prospective injury occurrence. Female netball players (N=24) performed unanticipated 180° turn agility sprints on both the dominant and non-dominant legs interspersed with an additional straight running (no turn) task (5 trials per task), which were cued randomly using a visual monitor in the gait laboratory. A symmetry index was calculated for turn performance time over 2m for each netballer. Netball players were contacted regularly throughout the following six-month period for verification of any lower extremity injury experienced during their netball season. Pearson correlation coefficients with 90% confidence intervals were used to identify any associations between dominant limb asymmetry of greater than 10% for unanticipated agility performance and injury occurrence. Lower limb injury occurred in 37.5% (n=9/24) of the netball players. All injuries (100%) occurred in the netballer's dominant leg. A dominant limb asymmetry of greater than 10% in performance was identified for 57% (4/7) of the injured netball players and 14% (1/7) of the non-injured netball players. A moderate association of r=0.45 (90% CI: -0.01 to 0.75) was identified between dominant limb asymmetry of greater than 10% and injury occurrence.*

**Key words:** Limb dominance; Turning performance; Prospective design; Netball.

## INTRODUCTION

In New Zealand and Australia, netball is considered the primary team sport played both recreationally and competitively by females (McManus *et al.*, 2006). Netball is a high-strategy sport that requires the precise execution of technical motor skills with and without the ball, as well as the application of tactical knowledge when making decisions during many explosive sprints, abrupt stops, change of direction and landing movements (McManus *et al.*, 2006; Bock-Jonathan *et al.*, 2007). Given the physical demands of netball, there is a heightened risk of injury (Hume & Steele, 2000) and thus a need to better appreciate the risk factors involved.

Limb dominance is considered a risk factor for lower extremity injury because most athletes place a greater demand on their dominant limb (Beynnon *et al.*, 2002). Thus an increase in unilateral demand may lead to a functional asymmetry in motor ability (Haaland & Hoff, 2003). The presence of functional asymmetry due to limb dominance may be one of the factors responsible for mechanical overload affecting movement technique (Maupas *et al.*, 2002). Additionally, the dependence on the dominant limb can increase stress on the joints of that extremity (Murphy *et al.*, 2003), because it is preferentially used for jumping, landing or pushing-off tasks (Murphy *et al.*, 2003; Negrete *et al.*, 2007). This can lead to an increased strength level, which may correspond to an increased frequency and magnitude of forces about the knee and ankle, particularly during high-demand activities (Beynnon *et al.*, 2002), which may increase the likelihood of injury (Negrete *et al.*, 2007). Research has identified an association between limb dominance and injury (Ekstrand & Gillquist, 1983; Chomiak *et al.*, 2000; Orchard, 2001), particularly for ankle and knee related injury occurrences. Such injuries are common in court sport, such as netball (Hume, 1993; Hume & Steele, 2000), and are also more likely to occur in females compared to males (Hutchinson & Ireland, 1995; Ireland, 1999; Griffin *et al.*, 2000).

With regard to a functional difference threshold between limbs, it is empirically unknown what an acceptable difference is for an individual to exhibit in motor function. Epidemiological studies have speculated that side-to-side (e.g. dominant to non-dominant) functional asymmetries greater than 10% may further heighten the risk of injury (Burkett, 1970; Knapik *et al.*, 1991). However, to date there is no published research that has validated the surpassing of such a threshold (>10%) in relation to injury occurrence prospectively.

## PURPOSE OF THE STUDY

The purpose of this study was to identify an association between dominant lower limb asymmetry of greater than 10% in unanticipated agility performance and prospective injury occurrence. In accordance with the literature reviewed, it was hypothesised that players exhibiting a dominant lower limb asymmetry of greater than 10% would be more likely to obtain a lower extremity injury.

## METHODOLOGY

### Participants

Twenty-four female netball players (mean±SD: age 21.6±3.2 years; height 1.75±0.07m; mass 74.4±11.6kg) volunteered to participate in this study. All netball players had at least 9 years of netball playing experience (13.1±2.6 years) and were in their pre-competition phase, which consisted of 1 to 7 (5.4±1.5) training sessions at a total of 2 to 10 training hours (8.8±2.3 hours) per week during data collection. The players recruited for this study were of national and regional representative level. All netball players had no history of a significant lower extremity injury 6 months prior to testing and were injury free at the time of data collection. Each netballer gave informed consent in writing to participate in this study prior to testing. Ethical approval was obtained for all testing procedures from the University Ethics Committee. All netball players wore spandex shorts or pants and ASICS (Gel-Rocket) court shoes during the data collection.

### Netball player limb dominance

Limb dominance was determined via verbal questions and practical tests. The netball players were asked which leg was preferred for kicking a ball, and hopping on, with the preferred leg being considered the dominant leg (Maulder & Cronin, 2005). Furthermore, additional tests were used to identify which limb moved first, namely walking from a stationary position and stepping off a 0.3m high step from a stationary position. The limb that moved first was considered the dominant limb. This information in conjunction with the question data allowed for a comprehensive decision to be made on limb dominance. The dominant limb was determined as the limb on the side of the body that was identified in the four assessments the majority of the time.

**Unanticipated straight-run task and unanticipated 180°-turn tasks**

All testing was performed in a motion analysis laboratory. The netball players performed three tasks from a 10m approach that utilised a self-selected start stance: a left leg plant and 180°-turn; a straight ahead run; and a right leg plant and 180°-turn. The tasks were presented as options in order to obtain an unanticipated/decision made movement response, which have been demonstrated to elicit up to 2 times greater knee varus/valgus and internal/external rotation joint moments than anticipated movements (Besier *et al.*, 2001). Unanticipated movements may offer a better reflection of the loads experienced around lower extremity joints during a sporting scenario, as movements during game situations are generally not always anticipated due to an external stimulus (Besier *et al.*, 2001). Therefore, a visual cue was displayed on a 22-inch computer screen (Phillips 220BW, Phillips, China), which was triggered manually when the netballer was approximately 1m away from the target area. The screen was placed 0.5m to the right side of the target area. Testing tasks were assigned a colour consisting of green, yellow and red, which represented the 180° left leg plant and turn, straight ahead, and 180° right leg plant and turn respectively. Visual cues were created and presented using PowerPoint (Microsoft, Office, version 2003, California) slides.

Following a standardised warm-up that included 5 minutes of treadmill running and dynamic stretches of the lower extremity, several pre-planned and unanticipated trials of each task were performed before data collection started in order to provide the netball players with the opportunity to familiarise themselves with the testing tasks. Each netballer completed all 3 tasks randomly, as cued by the computer monitor. A total of 5 successful trials per turning task were needed for data analysis. A maximum of 30 trials were completed by the participants to acquire the required data set for 5 left leg plant and 180°-turns and 5 right leg plant and 180°-turns. No feedback on trials performed previously in the testing session was provided to the participants so as to avoid the possibility of the trials becoming planned.

A 180° left (or right) leg plant and turn trial was deemed successful if: (a) the approach speed fell between 3.5 and 5 $m.s^{-1}$; (b) the left (or right) foot came in contact with the turn area; and (c) the exit speed was between 2.5 and 3.5 $m.s^{-1}$. The turning tasks were utilised in this study due to the use of the movement in field test assessment for the sport of netball. Specifically, the 505-assessment (180°-turn) was utilised to assess an individual's change of direction ability. Furthermore, anecdotally this type of turn is frequently utilised in netball. The approach and exit speeds were based on unpublished field-testing scores typical in sprint and agility assessment of New Zealand netball players. Each netballer was given approximately 45-90 seconds of rest between trials so as to reduce the potential effects of fatigue.

A two gate SWIFT® speed timing light system (SL-OPT180, SWIFT, Australia) was used to measure/monitor approach, performance and exit velocities. One timing light gate consisted of a dual beam modulated visible RED light sensor/reflector set up collecting at 4MHz

±80Hz. The timing lights were set at a height of 1.1m and placed parallel to the approach runway with 1 gate located 3m prior to the target area and the other located 1m prior. Thus 2m turning time was utilised as the turning performance outcome. Performance scores for left and right turns were then normalised to represent the participant's dominant or non-dominant limb.

In order to determine differences between limbs, a symmetry index score was calculated utilising the 2m turning performance on the dominant limb and the 2m turning performance on the non-dominant limb. Specifically the following turning performance symmetry calculation was utilised:

$$\% \text{ difference} = ((\text{Dominant} - \text{Non-dominant}) \div (\text{Non-dominant})) \times 100$$

**Injury data collection and analyses**

The prospective nature of the study involved all netball players being monitored for 6 months (1 competitive season) for the occurrence of lower limb injury. Prospective study designs are considered powerful for determining the risk factors of injury (Hagglund *et al.*, 2005). Injury was defined as that which interfered with performance and required professional treatment, causing the player to miss training and/or game time (McKay *et al.*, 2001). A training session was defined as any coach-directed scheduled physical activity carried out with the team, whereas a game was considered friendly or competitive (Hagglund *et al.*, 2006).

Netball players were contacted regularly (fortnightly), via email and telephone to enquire if a lower limb injury had occurred. If an injury had occurred, information about the injury type and location (Hagglund *et al.*, 2005), was recorded by the principal researcher, as communicated by the netballer. Clinicians that were not part of the research team diagnosed the injury. For reasons, such as clinician-client confidentiality, verification of the injury from the clinician was unable to be obtained by the principal researcher. It was presumed that the information that the netball players were communicating was accurate. For analyses purposes, injured player data were grouped into an injured group with all remaining participant data being grouped into the non-injured group category. Data classification allowed comparisons in symmetry index score to be made.

**Statistical analyses**

The assessment of data uniformity (normal distribution) and the calculation of Pearson correlation coefficients were performed utilising Statistical Package for Social Sciences (SPSS) version 18 for Windows (SPSS, Inc., USA). Specifically, a critical appraisal approach was used to determine if each netballer's data were normally distributed following the criteria recommended by Peat and Barton (2005) for each measure. If the difference between the mean and median was within 10% of the mean, then normality was assumed. However, if this initial criterion was breached, an additional 2 of 4 criteria would also have to be breached for the data to be described as exhibiting non-normal characteristics. These criteria were: (1) mean and standard deviation test (2×SD >mean); (2) Shapiro-Wilks statistics ($p<0.05$); (3) skewness and kurtosis statistics (within 1); and (4) skewness or kurtosis/standard error (within 1.96). These procedures were used recently by Bradshaw *et al.* (2007). In the event that data were non-normally distributed, it would be naturally log transformed to allow for parametric statistical approaches to be utilised. The data collected in this study was normally distributed and thus the following procedures were utilised.

Pearson correlation coefficients were calculated to identify associations between dominant limb asymmetry of greater than 10% for unanticipated agility performance and injury occurrence. The magnitude of the associations was qualitatively interpreted utilising the following criteria: 0.0–0.1 poor; 0.1–0.3 small; 0.3–0.5 moderate; and >0.5 large (Cohen, 1990). Confidence intervals (90% CI) were processed for these correlations to show the likely range of the true correlation using the methodical MS excel spread sheet (Microsoft, Office, version 2007, California) of Hopkins (2007). Furthermore, clinical inferences were also provided on the likelihood these relationships were clinically substantial or more precisely positively true (Hopkins, 2007).

## RESULTS

Lower limb injury occurred in 37.5% (n=9/24), of the netball players, which required them to miss either training and/or game time. The injuries included a variety of lower extremity ailments that can be observed in Table 1. All injuries (100%) occurred in the netballer's dominant leg (Table 1). Notably, 78% (7/9), of the injured netball players and 47% (7/15), of the non-injured netball players performed faster unanticipated turns on their dominant leg compared to the non-dominant leg. Performance times and symmetry index scores for these cases can be observed in Table 2 and Table 3 respectively. A dominant limb asymmetry of greater than 10% in performance was identified for 57% (4/7), of the injured netball players and 14% (1/7), of the non-injured netball players (Table 3). Pearson correlation coefficient analyses presented a moderate association of r=0.45 (90% Confidence interval: -0.01 to 0.75), between dominant limb asymmetry of greater than 10% and injury occurrence. There was an 89.9% likely probable chance that the association (Pearson correlation r-value), was positively true according to the analytical methods of Hopkins (2007).

***TABLE 1*: INJURED LIMB WITH CORRESPONDING INJURY TYPE OF INJURED NETBALL PLAYERS**

| Injured Player | Injured limb | Injury type |
|---|---|---|
| 1 | Dominant | Ankle sprain |
| 2 | Dominant | Ankle sprain |
| 3 | Dominant | Calf strain |
| 4 | Dominant | Calf strain |
| 5 | Dominant | Patella tendonosis |
| 6 | Dominant | Patella tendonosis |
| 7 | Dominant | Achilles strain |
| 8 | Dominant | Adductor strain |
| 9 | Dominant | Shin splints |

***TABLE 2*: MEAN TURNING PERFORMANCE AND SYMMETRY INDEX DIFFERENCE SCORES FOR NETBALL PLAYERS WITH DOMINANT LEG ASYMMETRY**

| **Variables** | **Injured (n=7) Mean±SD** | **Non-Injured (n=7) Mean±SD** |
|---|---|---|
| Turn on dominant leg time (s) | 0.78±0.15 | 0.85±0.09 |
| Turn on non-dominant leg time (s) | 0.90±0.13 | 0.92±0.11 |
| Difference in time between limbs (%) | -13.80±10.40 | -7.00±4.60 |

***TABLE 3*: INDIVIDUAL SYMMETRY INDEX DIFFERENCE SCORES FOR NETBALL PLAYERS WITH DOMINANT LEG ASYMMETRY**

| **Case** | **Injured Netball players** | **Non-Injured Netball players** |
|---|---|---|
| 1 | -31.6% | -15.4% |
| 2 | -22.5% | -9.1% |
| 3 | -16.0% | -8.2% |
| 4 | -10.8% | -6.3% |
| 5 | -7.8% | -5.7% |
| 6 | -6.0% | -2.2% |
| 7 | -2.0% | -2.1% |

## DISCUSSION

Epidemiological studies have speculated that side-to-side (dominant to non-dominant) functional asymmetries greater than 10% can lead to injury occurrence (Burkett, 1970; Knapik *et al.*, 1991). The present study is the first to attempt to validate such an assumption utilising a prospective study design. A prospective study, which follows participants going forward in time can ascertain the aetiology of the injury and for this reason is generally viewed as a more meaningful study design compared to a retrospective study, which typically utilises injured participants and thus cannot determine the origin of the injury (Hamill & Davis, 2006).

Findings of this study indicated lower limb injury, as defined by McKay *et al.* (2001), occurred in ~38% of the netball players tested in the present study which required them to miss either training or game time. The ~22% of ankle sprains presented by the netball players were consistent with the frequency of ankle ligament sprains reported in the literature (Hume, 1993; Hopper *et al.*, 1995; Handoll *et al.*, 2001). Netball is a high-strategy sport requiring many explosive sprints, abrupt stops, change of direction and landing movements (McManus *et al.*, 2006; Bock-Jonathan *et al.*, 2007). Therefore, it is no surprise that the ankle complex would be the most commonly injured site due to the amount of stress it would encounter as a major pivot point in the kinetic link system during such movement tasks.

In the present study all injuries (100%), occurred in the netballer's dominant leg, which is consistent with the findings of others (Ekstrand & Gillquist, 1983; Chomiak *et al.*, 2000; Orchard, 2001). Limb dominance is considered a risk factor for lower extremity injury because most athletes place a greater demand on their dominant limb (Beynnon *et al.*, 2002). This can lead to an increased frequency and magnitude of moments about the knee and ankle, particularly during high-demand activities that place the ankle and knee at risk (Beynnon *et al.*, 2002). It must be acknowledged that the association between limb dominance and injury is controversial due to equivocal findings in the literature (Surve *et al.*, 1994; Seil *et al.*, 1998; Beynnon *et al.*, 2001; Matava *et al.*, 2002; Negrete *et al.*, 2007). The contrasting findings may have been the result of study designs, participant type and numbers, injury location or the methods used for data analysis. Nonetheless, the findings of this study advocate the link between limb dominance and prospective injury occurrence.

Overall 58% of the netball players assessed in this study demonstrated superior turning performance on the dominant leg relative to the non-dominant leg, which lead to the identification of dominant limb asymmetry. From an information processing theoretical perspective, the findings of the current study (the dominant limb demonstrating superior turning performance), may support the premise that participants can learn tasks more effectively with their dominant limb than with their non-dominant limb (Davidson & Wolpert, 2003), and thus increase the potential for enhanced performance. However, this unilateral demand will likely lead to functional asymmetry and differences in motor ability, especially strength and coordination (Kearns *et al.*, 2001; Haaland & Hoff, 2003). For example, Itoh *et al.* (1998), found healthy male participants had significantly more powerful (~5%; effect size=0.49), dominant leg performances when compared to the non-dominant leg during a horizontal counter-movement jump. The greater power output/performance capability in the dominant limb identified by Itoh *et al.* (1998), and the current study may be due to greater muscle mass of the dominant limb compared to non-dominant limb (Chhibber & Singh, 1970). Unfortunately girth and mass characteristics of the lower limbs were not determined in the current study to support the aforementioned premise.

It is fair to assume that in the majority of instances when comparing unilateral tasks, some magnitude of functional asymmetry will be present for an individual. The practitioner needs to be cognizant of a likely threshold at which injury risk is potentially heightened for the identified asymmetry and thus accommodate remediation intervention accordingly. As presented, earlier researchers have speculated that limb asymmetry should not exceed that of 10% (Burkett, 1970; Knapik *et al.*, 1991). However, it was uncertain if such a threshold was valid, thus the primary purpose of this study was to identify an association between dominant lower limb asymmetry of greater than 10% in unanticipated agility performance and prospective injury occurrence. It was hypothesised that players exhibiting a dominant lower limb asymmetry of greater than 10% would more likely obtain a lower extremity injury. Pearson correlation coefficient analyses presented a moderate association between dominant limb asymmetry of greater than 10% and injury occurrence, which supports this study's hypothesis. Furthermore, a number of injured netball players investigated in this study exceeded the 10% asymmetry threshold. These findings validate the assumption that an excessive over reliance on the dominant limb can lead to injury over time. Thus, the 10% limb functional asymmetry threshold appears appropriate for physical conditioners to implement in their pre-habilitative conditioning regimes with their athletes. If an excessive discrepancy exists, training strategies that minimise the functional difference are recommended. Additionally, research into such training interventions warrants future investigation.

It should be acknowledged that this study's findings are directly related to female netball players and their ability to perform unanticipated turning tasks. The reader is advised to be cautious when attempting to apply the findings to other forms of unilateral functional tasks and corresponding symmetry index scores. Further research is required that incorporates a prospective study design and investigates limb asymmetries in different motor tasks (vertical jumping, horizontal bounding) and the association with injury occurrence.

A number of methodological limitations were present in this study and thus the results need to be interpreted with caution. Firstly, the unanticipated sprint stimulus was simulated via computer software on a digital screen in a controlled laboratory environment. It is possible that limb functional asymmetry observations may be different with the addition of competitors and other possible environmental perturbations during a competitive field setting. Another, limitation to this study was the diagnosis of injury occurrence by clinicians that were not part of the research team. For reasons such as clinician-client confidentiality, verification of the injury from the clinician was unable to be obtained by the principal researcher. It was presumed that the information communicated by the netball players was accurate. The inclusion of a qualified clinician as part of the research team would have strengthened the validity of the reported injury occurrence data. A further limitation was the lack of monitoring training and playing loads of the netball players throughout the prospective portion of this study. This type of monitoring was not considered until after the completion of the study as initially this study was only interested in establishing whether or not dominant limb functional asymmetry would lead to injury occurrence in a given period. A final limitation to be acknowledged in this study is the sample size especially for the injured netball player cohort. It is recommended that future research incorporate a similar methodology to that utilised in this study with attention being given to rectifying the limitations outlined.

## CONCLUSION

In conclusion the study provides evidence indicative of a likely probable link between dominant limb asymmetry of greater than 10% in turning performance and lower limb injury occurrence in female netball players. Based on the present findings favouring a lower limb during performance may be unfavourable to an athlete's health prospectively. Thus, the conditioning specialist is advised to assess the functional differences between an athlete's limbs to determine if an excessive (>10%) asymmetry is present, especially for tasks that require the ability to utilise both sides of the body. If an excessive discrepancy exists, training strategies that minimise the functional difference are recommended. There is still a need for further research that incorporates a prospective study design and investigates limb asymmetries in different motor tasks (vertical jumping, horizontal bounding) and the association with injury occurrence.

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