IS INJURY OCCURRENCE ASSOCIATED WITH JOINT COUPLING VARIABILITY DURING UNANTICIPATED MOVEMENT TASKS PERFORMED BY NETBALLERS?

Peter Maulder [1,2], Patria Hume [2] and Elizabeth Bradshaw[3]

School of Sport & Exercise Science, Wintec, Hamilton, New Zealand[1]
Sport Performance Research Institute New Zealand (SPRINZ), AUT University, Auckland, New Zealand[2]
School of Exercise Science, Australian Catholic University, Melbourne, Australia[3]

This study determined whether lower extremity joint coupling variability (JCV) measures during unanticipated change of direction movements were associated with prospective lower limb injury occurrence in netballers. Twelve elite injury-free female netballers performed five trials of unanticipated sprinting tasks (straight sprints and sprints with a 180° turn on their dominant and non-dominant legs) in the motion analysis laboratory from a 10 m approach. Lower extremity JCV measures were calculated for all movement tasks from 3D data. All netballers were monitored prospectively for a period of six months for the occurrence of lower limb injury. Five (42%) netballers sustained an injury with all injuries on their dominant leg. Low joint coupling variability was associated with injury occurrence in elite female netballers (r = 0.66).

KEY WORDS: straight speed, agility, vector coding.

INTRODUCTION: Netball is a high-strategy sport requiring many explosive sprints, abrupt stops, changes of direction and landing movements (McManus, Stevenson & Finch, 2006). Given the physical demands of netball there is a heightened risk of injury (Hume & Steele, 2000). Potential injury mechanisms of interest to researchers are the concepts of intra-limb coupling variability within a movement pattern (Hamill, Van Emmerik, Heiderscheit & Li, 1999; Heiderscheit, Hamill & Van Emmerik, 1999; Pollard, Heiderscheit, Van Emmerik & Hamill, 2005). Variability in joint coupling can be an essential component, providing the necessary flexibility for successful task execution. A more flexible repertoire (more variability) of coupling strategies may be associated with better performance and reduced injury risk (Hamill et al., 1999; Pollard et al., 2005). Researchers interested in the relationship between joint/segment coupling variability and injuries have used a dynamic systems approach to examine lower extremity injuries (retrospectively) in relation to running tasks. Various studies have provided information that moderately supports the notion that low joint coupling variability is associated with lower extremity injury (Hamill et al., 1999; Heiderscheit, Hamill & Van Emmerik, 2002). Though these studies have reported low intra-limb joint coupling variability to indicate the presence of injury, they do not determine the cause of injury due to the case-cohort study designs incorporated. Information pertaining to whether or not the reduced variability identified in the injured individual's system was observed as a result of pain, or possibly existed prior to the onset of pain placing them at greater risk of injury, warrants further investigation. Studies with a prospective design assessing lower extremity joint coupling variability patterns may offer a better insight into the causation of lower extremity injury occurrence. This study aimed to determine whether during unanticipated change of direction movements performed by netballers, lower extremity joint coupling variability measures were associated with prospective lower limb injury occurrence.

METHODS: Twelve elite level female netballers (mean ±SD: Age 22.3 ±3.8 y; Height 1.79 ±0.08 m; Mass 79.2 ±11.6 kg; Playing history 13.0 ±2.8 y; Training load 8.8 ±1.6 hours/week; Training load 5.5 ±0.8 sessions/week) volunteered to participate in the study. All netballers had no history of significant lower extremity injury six months prior to testing and were injury free at the time of data collection. Ethical approval was obtained for all testing procedures from the University's Ethics Committee.

All netballers wore spandex shorts or pants and ASICS (Gel-Rocket) court shoes during the data collection. Limb dominance was determined via questions and practical tests (Maulder & Cronin, 2005). The netballers performed three tasks from a 10 m approach that utilised a self-selected start stance: Left leg plant and 180° turn; Straight ahead run (left or right foot placement); Right leg plant and 180° turn. The tasks were presented as options in order to obtain an unanticipated/decision made movement response. A visual cue was displayed on a 19" computer screen which was triggered manually when the netballer was approximately 1 m away from the force platform. 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. Each netballer completed all four tasks randomly, as cued by the computer monitor. To enable the five successful trials (where the player landed on the force plate completely) for data analysis to be collected for each task, a total of 20 to 30 trials were performed. Each netballer was given approximately 45 - 90 s of rest between trials.

A nine-camera motion capture system (Qualisys, Sweden) was used to record three dimensional (3D) kinematic data at a sampling rate of 240 Hz. The cameras encircled a force platform (~0.48m x ~0.51m) embedded within the floor (Advanced Mechanical Technology Inc., USA, 1200 Hz). A two gate SWIFT® timing light system (SWIFT, Australia) was used to measure/monitor approach, performance and exit velocities. Retro-reflective tracking markers and calibration markers were utilised based on the protocols used by others previously (Pollard et al., 2005). Q-Trac software (Qualisys, Sweden) was used to digitize the marker coordinates. Digitized coordinate data were then exported to Visual 3D™ software (C-Motion, Inc., Rockville, MD, USA) where they were low-pass filtered using a fourth-order Butterworth filter with an 8 Hz cut-off frequency. Ground reaction force data were low-pass filtered using a fourth-order Butterworth filter with a 50 Hz cut-off frequency (Pollard et al., 2005). Kinematic and ground reaction force data were then exported to a customised LabVIEW software (National Instruments, Austin, Texas, USA) where all angle data were linearly interpolated to 101 data points in order to normalize stance to 100%. Intra limb joint couplings of the stance leg for each task were generated using a vector coding method of Sparrow, Donovan, Van Emmerik, and Barry (1987). Reliability was established for these measures in pilot work with acceptable intraclass correlation coefficients ranging between 0.75 and 0.92. Whilst an unanticipated 180° turn on the dominant leg was utilised as a movement task in this study, no joint coupling variability measures were assessed due to a lack of reliability calculated during pilot work.

Angle–angle plots were constructed for each coupling of interest with the distal motion on the vertical axis and the proximal motion on the horizontal axis. Coupling angles were then calculated using the orientation of the resultant vector to the right horizontal between two adjacent data points in the stance phase. The standard deviation of the coupling angles across the five trials for a task was calculated for each percent of stance, providing a measure of between-trial, within-participant variability. Joint coupling variability was averaged within one period of stance based on discrete events in the vertical ground reaction force . The period was defined from foot-strike to the maximum vertical ground reaction force. These procedures were repeated for each intra-limb coupling within each movement task for each netballer. Data were then categorised/reallocated based upon limb dominance.

The prospective nature of the study involved all netballers being monitored for six months (one competitive season) for the occurrence of lower limb injury. Injury was defined as that which interfered with performance and required professional treatment, causing the player to miss training and/or game time (McKay, Goldie, Payne, Oakes & Watson, 2001). 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 was recorded by the principal researcher, as communicated by the netballer.

SPSS version 18 was used to calculate Pearson correlation coefficients to identify associations between joint coupling variability measures 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; >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 methods of Hopkins (2007). Furthermore, clinical inferences were also provided on the likelihood these relationships were clinically substantial.

RESULTS: Lower limb injury occurred in ~42% (N = 5/12) of the netballers which required them to miss either training and/or game time. Injuries included two ankle sprains, two cases of patella tendonosis, and a calf strain. All injuries (100%; N = 5/5) occurred on the netballer's dominant leg (Table 1). Due to all injury occurrences presenting on the dominant leg, the following information focuses on the straight dominant leg only. Joint coupling variability magnitudes are presented in Table 1. A large correlation (r>0.50) existed between low rearfoot$_{(eversion/inversion)}$–knee$_{(rotation)}$ coupling variability and injury occurrence for elite female netballers. Based on the clinical inference criteria such an outcome was very likely. Small correlations existed between injury occurrence and the remainder of coupling variability measures when considering all netballers that participated in this study. All associations between coupling variability measures during the straight dominant leg task and dominant leg injury occurrences are presented in Table 2.

Table 1: Mean coupling variability (°) from foot contact to peak active vertical ground reaction force for each coupling during unanticipated straight sprint tasks performed by injured (N=5) and non-injured (N=7) netballers.

	Injured Mean ±SD	Non-injured Mean ±SD
Rearfoot$_{(eversion/inversion)}$Knee$_{(flexion/extension)}$ (°)	24.9 ±16.5	25.2 ±17.3
Rearfoot$_{(eversion/inversion)}$–Knee$_{(rotation)}$ (°)	16.1 ±6.4	24.3 ±10.4
Tibial$_{(rotation)}$– Knee$_{(flexion/extension)}$ (°)	30.2 ±13.1	30.8 ±15.5

Table 2: Correlations between straight dominant leg coupling variability (°) and dominant leg injury occurrences presented by Elite female netballers (N=12).

	r (90%CL upper – lower)	Clinical inference
Rearfoot$_{(eversion/inversion)}$–Knee$_{(flexion/extension)}$ (°)	0.29 (-0.25 to 0.69)	Possibly may not be associated
Rearfoot$_{(eversion/inversion)}$–Knee$_{(rotation)}$ (°)	0.66 (0.24 to 0.87)	Association is very likely
Tibial$_{(rotation)}$– Knee$_{(flexion/extension)}$ (°)	0.12 (-0.40 to 0.58)	Possibly may not be associated

Key: r = correlation coefficient; CL = confidence limit

DISCUSSION: Lower limb injury which caused the athlete to miss either training or game time (McKay et al., 2001), occurred in ~42% of the netballers tested in the present study. All injuries (100%) occurred in the netballer's dominant leg which is consistent with the findings of others (Chomiak, Junge, Peterson & Dvorak, 2000). Due to the majority of injury occurrences occurring on the dominant leg in the present study, the following discussion will focus on the coupling variability measures during the straight dominant leg task. An expectation of the present study was that netballers who exhibited low coupling variability were likely to incur an injury to the lower extremity throughout the six month/competitive season period. A large correlation was observed between rearfoot$_{(eversion/inversion)}$–knee$_{(rotation)}$ coupling variability and injury occurrence for elite female netballers. These findings were indicative of an association between low coupling variability and injury. It must be acknowledged that the true values of the correlation could indicate anything between a trivial and very strong association between low coupling variability and injury occurrence as indicated by the 90% confidence limits.

Low coupling variability during straight running has been associated retrospectively with the presence of injury (Hamill et al., 1999; Heiderscheit et al., 2002). High amounts of coupling variability appears to be beneficial for avoiding injury which is confirmed prospectively utilising female netballers in the present study. Variability in joint coupling is considered an essential component, providing the necessary flexibility for successful task execution (Hamill et al., 1999). A more flexible repertoire (more variability) of coupling strategies an individual can exploit within the movement task allowing for changing task constraints may be beneficial for reducing injury risk (Hamill et al., 1999; Pollard et al., 2005). In fact, a lack of coupling variability within a movement pattern is thought to lead to less flexible movement strategies that can adapt inadequately to meet the needs of an environment change or perturbation, thus increasing the risk for the individual attaining injury (Hamill et al., 1999). If movement patterns are invariant (performed identically) the same tissues would be maximally loaded each time and thus high coupling variability may modify tissue loads between repetitions reducing injury risk. Dynamical systems theory supports this concept as it suggests that consistent high-level performance across a variety of situations and conditions can only be achieved with a variable coupling pattern that can be adapted to suit the demands of the task at hand (Hamill et al., 1999).

CONCLUSION: Low joint coupling variability for the lower limb segments was associated with lower limb injury occurrence in elite female netballers. More prospective studies are required to better understand the associations between joint coupling variability and injury occurrence in female athletes. Furthermore, research investigating training interventions aimed at adapting joint coupling variability is needed. The findings of this study suggest that an intervention program designed for females should be focused more on developing a greater repertoire of coupling strategies. Research that monitors changes in joint coupling variability post injury, then following treatment and rehabilitation would be of great worth to the joint coupling variability body of knowledge.

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