A Kinematic and Kinetic Case Study of a Netball Shoulder Pass

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ABSTRACT

Int J Exerc Sci 2(4): 243-253, 2009. The majority of studies analysing netball skills using force platforms have focused on reducing the risk of injury from compression and torsion forces on the knee and ankle joints during landing and pivoting. In this preliminary case study our aim was to investigate the efficacy of a combination of tools to describe the kinematic and kinetic mechanisms underlying the netball shoulder pass. The segmental movements of the netball shoulder pass were analysed from video and force platform data in order to develop a suitable methodology for use in a larger study. Peak vertical ground reaction force of 850 N was found to coincide with the point of maximum velocity of the centre of pressure, occurring 40 ms before ball release. The participant's centre of pressure continued anteriorly for 40 ms after ball release. The wrist traveled in a linear path during the propulsion phases, maximising impulse to the ball. A large shear force also occurred in the anterior posterior direction coinciding with ball release due to friction between the left shoe and the force platform, resisting the forward momentum of the body. Negative acceleration of the upper limb following the propulsion phase reached a peak of 68.6 rad/s-2 for the arm and 82.4 rad/s-2 for the forearm. Peak shoulder deceleration torque was calculated at 4.1 Nm which was greater than during acceleration (1.6 Nm). The combination of kinematic and kinetic tools yielded a comprehensive analysis of the investigated skill. Future biomechanical studies may determine differences in skill execution between novice and professional players or variability in movement within a population of skilled netball players.

KEY WORDS: Biomechanics, video analysis, force platform

INTRODUCTION

Netball is one of the most popular team sports in the world played by an estimated 20 million people in over 70 countries (8). In Australia it is the second most popular organized recreational activity, behind organised fitness classes, played by an estimated 3% of the population (1). However, to date there has been little biomechanical analysis of the discrete skills that comprise the sport (6). Those studies that have used kinematic or kinetic analysis to characterise netball skills have predominantly focused on explaining and attempting to minimize the high injury rate, commonly tears to the anterior cruciate ligament in the knee and lateral ankle ligaments (5, 7, 12, 16). Few descriptions of the upper limb biomechanics of this sport have been published (6). The shoulder pass in netball is a high, linear pass performed using one hand that can cover maximum allowable distances and which allows for fast disposal of the ball during play (20). Maximum allowable distance is less than

one third of the court which is about 10 m (18). The purpose of the shoulder pass is to elude defenders of the opposing team that may be in the way of the player's own receiving team members (3, 11). The netball shoulder pass can be classified as being a discrete skill, which is performed in an open environment in the game situation (4). A discrete skill is not cyclical in nature, having a definite beginning and end, even though it may be repeated many times during game play. For the purposes of analysis the shoulder pass can be divided into three movement phases, preparation, wind up, and propulsion. The division of skills into phases is a technique often used by sports coaches that allows for more accurate observation of errors in skill execution (4). In this preliminary case study our aim was to investigate the efficacy of a combination of tools to describe the kinematic and kinetic mechanisms underlying the netball shoulder pass. Video analysis provided kinematic data including outcome variables of displacement, velocity, and acceleration, while force platform analysis provided kinetic data, including the magnitude of reaction forces and analysis of the centre of pressure excursion.

METHOD

Participants

One female participant, aged 25 years, volunteered to take part in the study and the informed consent was obtained. She had 15 years experience playing netball competitively, 10 of those years playing at state level. Her team position at the time of the study was goalkeeper and in this position she employed the shoulder pass frequently to clear the ball from the goal area. The participant was 1.78 m tall and

weighed 68 kg. Her arm length, measured from the acromion process to the radial styloid process, was 0.59 m. Her leg length, from anterior superior iliac spine to medial malleolus, was 0.97 m. This project was exempt from ethical review on the basis that it was conducted within the University for teaching and learning purposes.

Data Collection

The participant was instructed to stand so that the entire surface area of both feet were in contact with the force platform. This is a narrower stance than would be adopted in game play but was deemed satisfactory as the object of the study was to assess the capabilities of the technologies to characterise this skill. The participant's performance of three successive shoulder passes was recorded at 50 frames a second in the sagittal plane using a Panasonic digital video camera (Model NV-MX7, Japan). Emphasis for each pass was on correct execution rather than maximum power. The participant's ground reaction forces were recorded using an ATMI force platform (Accugait PJB 101, Massachusetts) linked to a Pentium PC running Netforce (Version 2.2) software. Seven markers were placed on the participant for subsequent tracking using Siliconcoach digitiser software (Version 6.1, Siliconcoach, Dunedin, New Zealand). These markers were placed on the right temporo-mandibular joint, the greater tubercle of the humerus, the lateral epicondyle of the humerus, the capitate, the greater trochanter of the femur, the lateral epicondyle of the femur and the lateral maleolus of the fibula (see Figure 1).

The participant performed several warm up shots and was then instructed to throw a series of three shoulder passes naturally.

During each of these three passes data was simultaneously recorded by the video camera and force platform software. The third execution of the shoulder pass was selected for analysis. Video data from the camera had to be converted to an AVI file to allow importation into Siliconcoach. This conversion to AVI resulted in a drop in frame rate to 25 frames per second. The total footage available for analysis was 80 frames spanning 3.2 seconds of action. This footage was imported into Siliconcoach digitiser and on every second frame the anatomical landmarks were highlighted for digitisation by the software. The resultant file thus contained 40 (x, y) coordinates for each anatomical landmark and this file was imported into Microsoft Excel for kinematic analysis. Synchronisation between the video and force platform data was achieved by identifying the first frame in which posterior movement of the body began and aligning this in the Excel spreadsheet with the first change in anterior posterior shear force (Fy). The accuracy of this alignment is limited to the frame rate of the camera which was lower than the sampling rate of the force platform. This point of synchronisation is consistent with, but more accurate than, the verbal cueing used on the video to indicate the start of force platform data acquisition.

Data Analysis

For the purposes of analysis the shoulder pass was divided into three movement phases, preparation, wind up, and propulsion (see Figure 2) adapted from a phase schema previously described by Derbyshire (6). Preparation phase is a stationary phase where the ball is held in both hands in front of the body. Wind up is from where the ball starts to move in a posterior direction until it reaches the most posterior aspect of travel. Propulsion phase starts as the ball begins to move anteriorly and concludes when the wrist is at its most anterior aspect. The frames comprising each phase were located in the quantised data file and the (x, y) coordinate data was used to calculate displacement for the wrist and elbow and joint angles in the sagittal plane. Joint angles in other planes were measured using a goniometer in static poses following filming. For the purposes of this study, 180° indicated full elbow extension and 30° full elbow flexion. The term neutral refers to limbs in the participant's natural standing posture. During analysis the body segments were treated as a series of rigid rotors moving in the (x, y) plane. Angular velocity and acceleration of the body segments was calculated from the (x, y) coordinate data generated from Siliconcoach. Torques were calculated using segment weight estimates from Plagenhoef, Evans, and Abdelnour (13) and the previously generated acceleration data. Calculations of the radius of gyration was based on data from Winter (19).

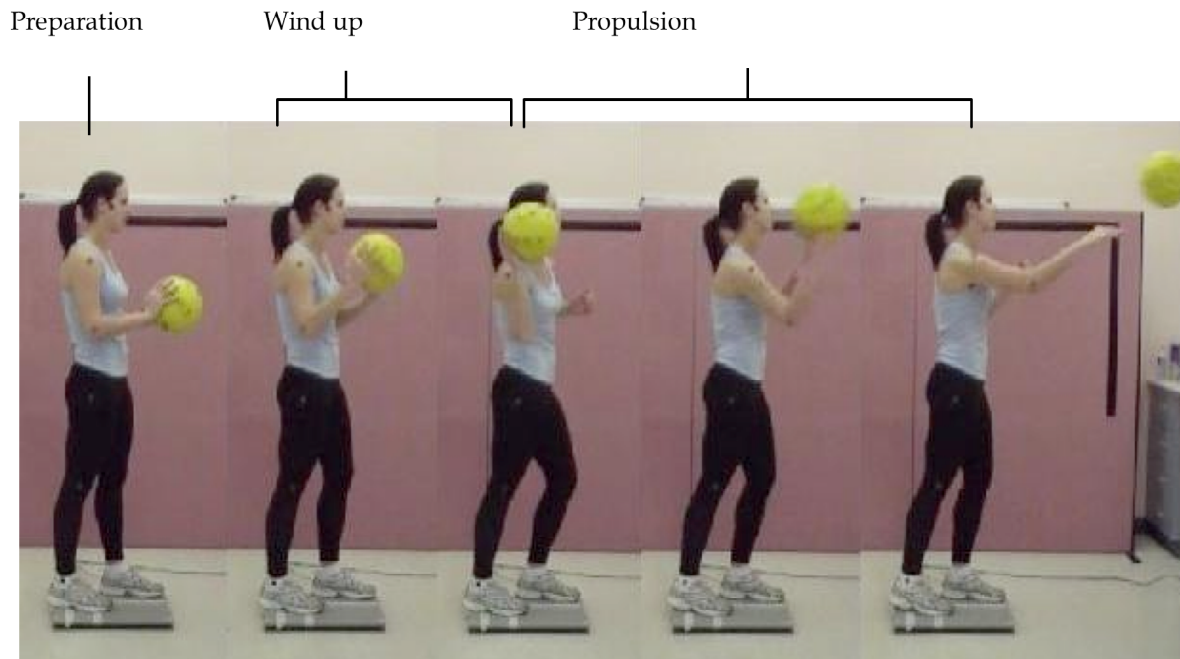Figure 1. Screenshot from captured video footage showing major landmark indicators.

Preparation   Wind up   Propulsion

Figure 2. Sequence of phases in the netball shoulder pass.

RESULTS

Kinematic and kinetic results from trial three are presented in this section. Range of movement data for each phase is presented in tables 1 to 3, along with average and peak angular velocity, and peak acceleration. Additionally, peak acceleration and deceleration torques, at the shoulder and elbow, during the propulsion phase are shown in Table 3. (Note: In tables 2 and 3 "+" denotes a clockwise rotation of the segment and "–" a counterclockwise rotation.)

Kinematic Data

Instantaneous angular acceleration data were calculated and graphed for the arm and forearm. In figures 3a and 3b the acceleration of these segments during the propulsion phase can be seen. The peak acceleration during the propulsion phase was 26.9 and 47.8 rad/s^{-2} for the arm and forearm respectively. The negative acceleration after release of the ball was more rapid at 68.6 and 82.4 rad/s^{-2} respectively. At the shoulder a torque of 1.6 Nm was required to accelerate the arm whereas a decelerating torque of 4.1 Nm was required to arrest movement of the limb. Similarly, for forearm acceleration a torque of 1.1 Nm was required and the decelerating torque was 2.0 Nm. Functional strength ratios of 2.56 and 1.82 were calculated for the shoulder and elbow respectively. Figure 4 represents pictorially the displacement of the elbow and wrist in which the wrist trace can be seen to follow a near linear path.

Kinetic Data

Figure 5 depicts the movement of the centre of pressure (COP) of the body on the force platform during the shoulder pass, which

Table 1.   Preparation Phase

Duration   1.04 seconds

Segment	Avg ω (rad / s)	Peak ω (rad/s)	Peak α (rad/s/s)
Arm	-	-	-
Forearm	-	-	-

Key Elements with Movement Ranges	Joint Angle Range of Movement (ROM)
Shoulders near neutral anatomical position	6º flexion
Flexion of R. Elbow*	90º flexion
Extension of R. Wrist	55º extension

* Full extension of elbow being defined as 180 degrees

Table 2.   Wind up Phase

Duration   0.40 seconds

Segment	Avg ω (rad / s)	Peak ω (rad/s)	Peak α (rad/s/s)
Arm	0.12 +	1.18 +	20.2
Forearm	2.46 -	4.81 -	44.5

Key Elements with Movement Ranges	Joint Angle ROM
Extension of L. Shoulder (L. Hand removed from ball)	6º flexion to neutral
Flexion of R. Shoulder	6º flexion to 8º flexion
Abduction of R. Shoulder	6º abduction to 40º abduction
Lateral rotation of R. Shoulder	To full rotation
Retraction of R. Scapula	To end of range
Flexion of R. Elbow	90º to 30º

Table 3. Propulsion Phase

Duration   0.22 seconds

Segment	Avg ω (rad / s)	Peak ω (rad/s)	Peak α (rad/s/s)
Arm	3.09 -	5.67 -	26.9
Forearm	1.69 +	6.28 +	47.8

| Key Elements with Movement Ranges	Joint Angle ROM
Flexion of R. Shoulder (acceleration torque 1.6 Nm peak) (deceleration torque 4.1 Nm peak)	8º flexion to 73º flexion
Adduction of R. Shoulder	40º abduction to 10º abduction
Medial rotation of R. Shoulder	To 50% of range
Protraction of R. Scapula	Full protraction
Extension of R. elbow (acceleration torque 1.1 Nm peak) (deceleration torque 2.0 Nm peak)	30º to 105º
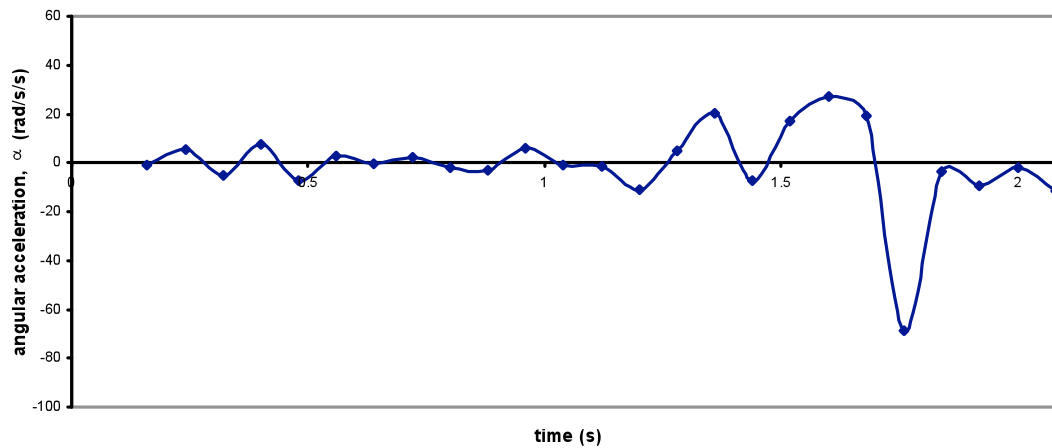
Figure 3a. Instantaneous arm segment acceleration during the 3 phases of a netball
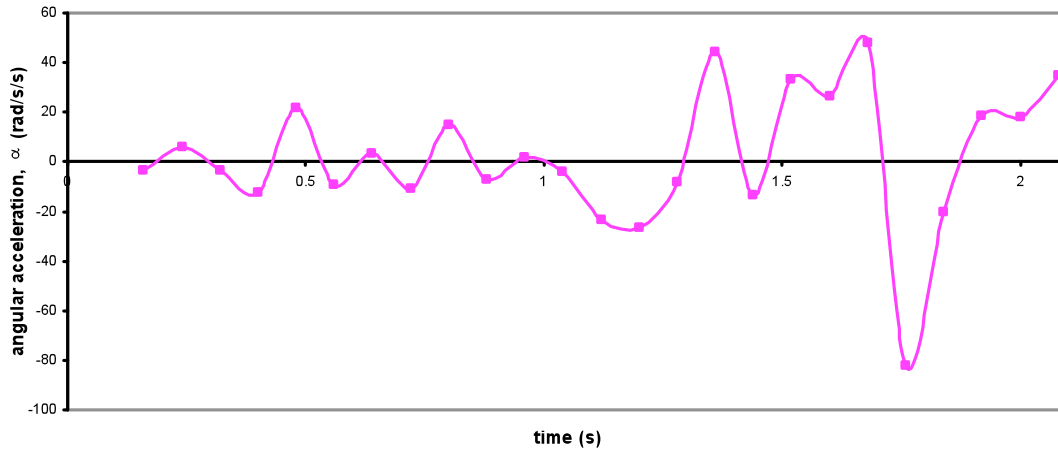
Figure 3b. Instantaneous forearm segment acceleration during the 3 phases of a netball shoulder pass
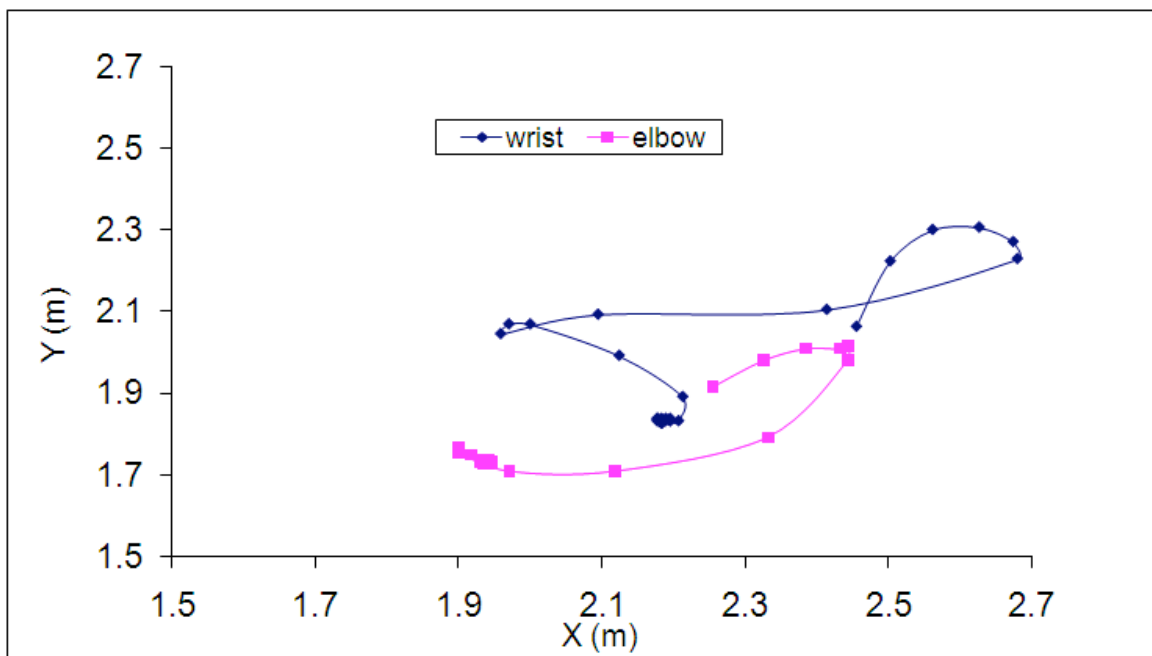

Figure 4. Displacement graph of the elbow and wrist during the shoulder pass. Arrows highlight the nature of the path traced by the wrist and elbow.

reached a maximum velocity of 0.2 m/s, 40 ms before the ball is released. The ground reaction force in each of three directions is presented in figure 6. The normal ground reaction force (F_z) rose to a peak value of 850 N during the propulsion phase of the movement and this peak value occured 40 ms before ball release. The peak anterior posterior shear force (F_y) of 62 N occurred at ball release. Medial lateral shear force (Fx) reached a maximum of 46 N, 4 ms after ball release.
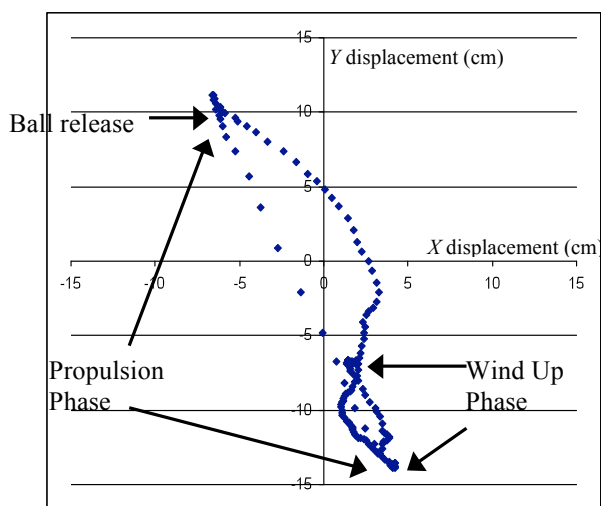

Figure 5. Centre of pressure path data (in cm) recorded by the force platform during the shoulder pass.

DISCUSSION

Kinematic analysis demonstrated stability in the trunk with the power for the shoulder pass being developed primarily in the muscles of the shoulder, arm and forearm. The torque required to accelerate the arm would be provided by the concentric contraction the shoulder flexors; whereas the decelerating torque required to arrest movement of the limb would come from eccentric contraction of the shoulder extensors. The deceleration torque was more than twice the recorded value for the

acceleration produced in the same segment yielding a high functional strength ratio of 2.51 for this athlete. Similarly for the forearm, acceleration torque would be achieved by the concentric contraction of the elbow extensors and the decelerating torque provided by the eccentric contraction of the elbow flexors. Functional strength ratio for this movement at the elbow was also high at 1.82. Low functional strength ratios (eccentric torque / concentric torque) have been suggested as indicators of joint injury risk (2, 14) and significant differences have been reported between injured and uninjured volleyball athletes (17). The analysis techniques used in this study proved an effective means of calculating functional strength ratios from video footage of the skill itself rather than using dynamometers.

During the propulsive phase the arm moved at high velocity in a counterclockwise arc about its pivot point as the shoulder flexed. At the same time the elbow extended and the combined result of these two movements was the near-linear path that the wrist travelled. This near-linear path maximised the impulse imparted to the netball.

At the beginning of the movement (preparation phase) the COP was located posterior to the midline of the body and over the right foot. The COP moved more posteriorly and to the right during the wind up phase and then rapidly anteriorly and to the left during the propulsion phase. Interestingly, the COP continued to move anteriorly after the ball was released due to forward momentum of the arm and trunk. Ball release did not occur at the point of maximum velocity of the COP but 40 ms after that point. The linearity of the COP
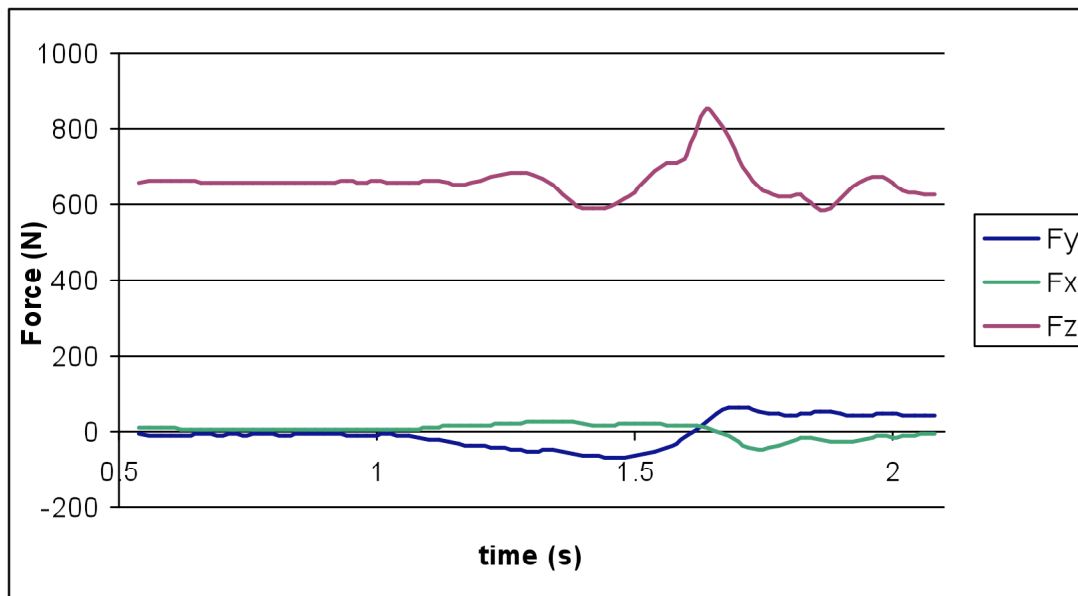
Figure 6. Force data (in N) in three planes recorded by the force platform during the shoulder pass. *Fx*: Medial lateral. *Fy*: Anterior posterior. *Fz*: Vertical.

trace during the wind up and propulsion phases indicated that the arm and forearm were travelling in a straight path which also added impulse to the ball in the desired direction of flight.

Peak ground reaction force of 850 N coincided with the point of maximum velocity of the COP, 40 ms before ball release, and hence was associated with weight transfer at the point where maximum impulse was imparted to the ball. Sixty-two Newtons of frictional force in the Fy direction resisted the forward momentum of the body at the point of contact between the left shoe and the force platform and this force was at maximum at ball release. This forward momentum was controlled intrinsically by the hamstring and gluteal muscles. The range of medial lateral shear force (F_x) was low during the movement and this provided an a posteriori justification for our assumption that the motion was essentially two-dimensional, with minimal upper body rotation, and hence we ignored the medial lateral kinematics of the performance. However, large medial lateral shear and torsion forces, on landing, have been the focus of other studies into netball knee injuries, particularly involving the anterior cruciate ligament, for example McManus, Stevenson, and Finch (10), Otego (12), Smith (15), and Steele (16).

Smith et al. (15) note that one of the most effective risk factor interventions for injury in netball include specific pre-season training and targeted exercises. In this context, this study provides useful information on the assessment of mechanics of the netball shoulder pass that could be used in a larger study to develop recommendations for exercises to reduce stress on the shoulder joint. Further, eccentric exercise has been reported to be an effective rehabilitation method, and may be important, especially when considering

the eccentric torque developed during this activity in the shoulder muscles(9). Targeted exercises may be most beneficial for those athletes with recognised hyper mobility (15). The biomechanical techniques outlined in this study may be used to measure variability in experienced players to further determine efficiency and technical skill in the shoulder pass.

In future studies the use of two recessed force platforms would allow for a wider, more game-normal stance. Additionally, the use of electromyography could be a useful adjunct to accurately determine muscle activation during skill execution. The use of a single subject does not allow the current study to provide data about variations among netball players. The instructions provided to the subject also do not allow for expected variations in range of pass or power and variations in a game situation.

In this case study we analysed a netball shoulder pass using video analysis and force platform data with a view to utilising this method in a larger scale project with elite netball players. A large and rapid negative acceleration in the upper limb was found after the propulsion phase. Peak deceleration torque of the arm was calculated at 4.1 Nm indicating that forces on the shoulder joint during negative acceleration were much greater than during acceleration. The participant's COP continued anteriorly for 40 ms after ball release as the arm and forearm travel in a linear path during the wind up and propulsion phases to maximise impulse to the ball. Peak ground reaction force of 850 N in the F_z direction was found to coincide with the point of maximum velocity of the COP occurring 40 ms before ball release.

Future biomechanical studies of the netball shoulder pass could involve using larger participant groups to determine differences in skill execution between novice and professional players or variability in movement within a population of skilled netball players. The combination of kinematic and kinetic tools used in this study has yielded a comprehensive analysis of the investigated skill.

REFERENCES

1. Australian Bureau of Statistics, Participation in sports and recreation 2005-2006. 2007.

2. Bak K, Magnusson S. Shoulder strength and range of motion in symptomatic and pain- free elite swimmers. Am J Sports Med 25(4): 454-459, 1997.

3. BBC Sport. Netball: Shoulder pass. 2005 (cited 12 September 2007); Available from: http://news.bbc.co.uk/go/pr/fr/- /sport1/hi/other_sports/netball/4187668.stm.

4. Carr, G.A., Sport mechanics for coaches. Human Kinetics, Champaign, IL: 2nd ed. 2004.

5. Cowling E, Steele J. Is lower limb muscle synchrony during landing affected by gender? Implications for variations in ACL injury rates. J Electromyogr Kinesiol 11(4): 263-268, 2001.

6. Derbyshire D. Physical factors influencing the throwing action in netball and cricket players. Stellenbosch University, 2007.

7. Hopper D, McNair P, Elliot B. Landing in netball: Effects of taping and bracing the ankle. Br J Sports Med 33: 409-413, 1999.

8. International Federation of Netball Associations. 2009 (cited 23 March 2009); Available from: http://www.netball.org/ifna.aspx.

9. Langberg H, et al. Eccentric rehabilitation exercise increases peritendinous type I collagen synthesis in humans with Achilles tendinosis. Scand J Med Sci Sports 17: 61-66, 2007.

10. McManus A, Stevenson MR, Finch CF. Incidence and risk factors for injury in non-elite netball. J Sci Med Sport (9):119-124, 2006.

11. Netball Australia. Inside netball: Playing the game. 2007 (cited 1 September 2007); Available from: http://www.netball.asn.au/.

12. Otego L. Kinetic analysis of landing in netball: Is a footwork rule required to decrease ACL injuries? J Sci Med Sport 7(1): 85-95, 2004.

13. Plagenhoef S, Evans FG, Abdelnour T. Anatomical data for analysing human motion. Res Q Exerc Sport 54:169-178, 1983.

14. Sirota SC, et al. An eccentric- and concentric-strength profile of shoulder external and internal rotator muscles in professional baseball pitchers. Am J Sports Med 25(1): 59-64, 1997.

15. Smith R, et al. Hypermobility and sports injuries in junior netball players. Br J Sports Med 39: 628-631, 2005.

16. Steele JR. Biomechanical factors affecting performance in netball. Implications for improving performance and injury reduction. Sports Med 10(22): 88-102, 1990.

17. Stickley C, et al. Isokinetic peak torque ratios and shoulder injury history in adolescent female voleyball athletes. J Ath Train 43(6): 571-577, 2008.

18. The International Federation of Netball Associations (1997) Official rules of The International Federation of Netball Associations.

19. Winter DA. Biomechanics and motor control of human movement. NY: John Wiley, 1990.

20. Woodlands J. The netball handbook: Winning essentials for players and coaches. Champaign, IL: Human Kinetics, 2006.