KINETICS OF THE WINDMILL SOFTBALL PITCH FOR WOMEN

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ABSTRACT: Three-dimensional (3D) high-speed cinematography and dynamometry were used to analyse the windmill pitching action of 10 high performance female pitchers. Mean ground reaction forces of 0.3BW (vertically) and 1.7 BW (horizontally) were recorded from the 'driving-leg'. A mean peak sagittal plane flexion torque of 45.7 Nm and a mean peak extensor torque of –134.9 Nm were recorded for the shoulder joint. These forces show that windmill pitching is a high force activity where specific physical preparation is required, particularly at the shoulder joint, to protect the body from injury.

KEY WORDS: softball, windmill pitch

INTRODUCTION: Fastpitch softball is an Olympic sport played by millions of people throughout the world. The pitcher, an integral part of a team at all levels of performance generally uses the windmill action to produce the highest speed pitch, the fastball (Woo and Brown, 1997). Despite the high incidence of upper limb injuries to elite pitchers (Loosli, Requa, Garrick and Hanley, 1992) few data have been reported on the role of the lower limbs and trunk in the pitching action or on pitching kinetics (Werner, 1994; Werner et al., 1996; Woo and Brown, 1997). The majority of research has involved kinematic analyses of the pitching limb (Alexander and Haddow, 1982; Dillman, Fleisig and Andrews, 1993; Olsen and Hunter, 1987; Wilson, McDonald & Neal, 1985).
Appropriate pitching mechanics that produce a high release speed, over repeated trials without undue risk of injury will only be achieved through the coordinated sequencing of lower limb, trunk and upper limb movements (Fleisig and Barrentine, 1995; Olsen and Hunter, 1987; Werner, 1993). Forces produced from the lower limb drive against the plate are transferred via the trunk to the pitching-limb (Werner, 1993).
The purpose of this study was therefore to investigate ground reaction force, two-dimensional (2D) sagittal plane shoulder torque and joint reaction forces, and selected kinematic parameters in the windmill softball pitch.

METHODS AND PROCEDLIRES: The best 10 windmill style female pitchers, as identified by the Western Australian state coach, acted as subjects for this study. Two phase-locked Photosonics high speed cameras, operating at a nominal rate of 200 Hz, filmed three successful trials from each pitcher. A successful pitch was deemed when the ball passed through the strike zone over a distance of 12.44 m, as required in the competitive environment. The Direct Linear Transformation (DLT) method of motion analysis for 3D space reconstruction of eight anatomical landmarks (central estimate of wrist, elbow, shoulder, and non-stride limb knee joint, both acromion processes and both anterior-superior Iliac spines) from the 2D film images was used (Marzan and Karara 1975). This procedure involved initially filming a reference structure, containing markers of known coordinates in space, which encompassed the field of the pitching action.
All pitching actions began with both the stride and the non-stride foot on a pitching rubber, which was firmly attached to a Kistler (9821) force platform, such that half of the rubber was located over the platform. Only the drive foot contacted the platform, with the stride-limb stepping to its side. This ensured that only drive-limb ground reaction force (GRF) data were recorded. Activation of an infra-red timing light, positioned in the view of both cameras, commenced the collection of force data thus permitting the synchronisation of kinetic and kinematic data. Digitising of the highest velocity trial, as measured from film, commenced from the point when the pitching-limb had been rotated forward 90° such that it was parallel with the ground during the backswing. Digitising continued until five frames beyond ball

release to account for filtering error.

All displacement data were smoothed using a Butterworth digital filter (cutoff 18 Hz) prior to calculation of velocity and acceleration values. Sagittal and transverse plane data were structured from the 3D coordinates using procedures outlined by Wood (1977). The resultant torques about the shoulder joint in the plane of the pitch, (sagittal plane) were calculated using an inverse dynamics approach, where $\sum T = I a$ (T = segment torque, I = moment of inertia and a = segment angular acceleration of the hand, forearm and upper arm sequentially). Data for segment centres of mass and radii of gyration used in the calculation of segment I_{CG} values were taken from Dempster (1955) and Plagenhoef (1971). The forces of the ball were introduced at the hand segment during the inverse dynamics procedure which progressed from the open end of the pitching chain (the hand). These values were calculated from the 2D sagittal plane kinematic coordinate data file of the ball and introduced as external forces acting on the hand during the period the arm swing was digitised, where $\sum F_x = m.a$ and $\sum F_y = m.\ a + W$ (weight of the ball).

RESULTS AND DISCUSSION: The mean physical characteristics of the subjects and ball velocity at release are recorded in Table 1. The variability in mass suggests that windmill pitchers are not represented by narrow ranges in physical characteristics. This variability required force and torque data to be normalised if valid comparisons were to be made. Reaction force data were normalised by body weight (BW), while torque data were divided by the product of height and weight, as suggested for baseball pitching by Campbell (1993).

Table 1 Mean Subject Characteristics and Horizontal Ball Release Velocity (n = 10)

CHARACTERISTIC	MEAN (± SD)
Age (years)	19.0 ± 2.1
Height (m)	1.69 ± 0.05
Mass (kg)	69.6 ± 13.1
Release Velocity (ms^{-1})	24.0 ± 2.1

The range of horizontal velocities (21.0 – 26.7 ms^{-1}) was greater than reported for Australian national representatives (23.3 – 26.5 ms^{-1}; Wilson et al., 1985) and for high performance American pitchers (25.9 – 27.7 ms^{-1}; Werner, 1994). The mean horizontal velocity for 24 pitchers representing eight countries at the 1996 Atlanta Olympic Games was 26.7 ms^{-1}(Werner, Murray, Levy, Smith, Plancher & Hawkins, 1996). These mean release velocities, when compared to the literature, show that the five best pitchers in this sample (≥ 25.5 ms^{-1}) can be classified as elite calibre.

GRF Data: A negative horizontal impulse was initially recorded at the commencement of the action as body weight was moved backwards onto the stride-limb (points 1-2: Figure 1). At point 3, as the glove hand reaches its lowest point, the pitcher was balanced with minimal force applied horizontally (points 3-4). The stride limb then applied a force (not recorded) to begin the forward movement of the body over the support limb. A mean 1.7 BW peak horizontal GRF was then applied by the drive-limb to continue the forward movement of the body. This level was similar to the 1.4 BW reported by Woo and Brown (1997) and both these values are higher than the 0.55 BW reported in baseball (Elliott, Grove & Gibson, 1988). The higher mound in baseball and less vigorous backwards movement of the throwing-limb may be the reason for this lower force.

Trunk Rotation: Shoulder and hip rotation were calculated from the line joining the two acromion processes and the line joining the two anterior-superior iliac spines. A value of 0° indicated that the hips or shoulders were perpendicular with the line of the pitch (chest facing the catcher), with 90° indicating that the hips and shoulders are in line with the direction of the pitch (facing third base). Mean peak hip and shoulder rotations were 56.7" and 81.3° respectively. A mean separation angle (shoulder minus hip rotation) of 27.5° (±15.6°) shows that the hip alignment was rotated less than the shoulders at the completion of the backswing phase of the pitch for all subjects. A mean hip release alignment angle of 24 ° is well short of the 53 ° reported by Werner et al. (1996) suggesting that subjects in this study may have under-rotated the hips in preparation for the pitch.

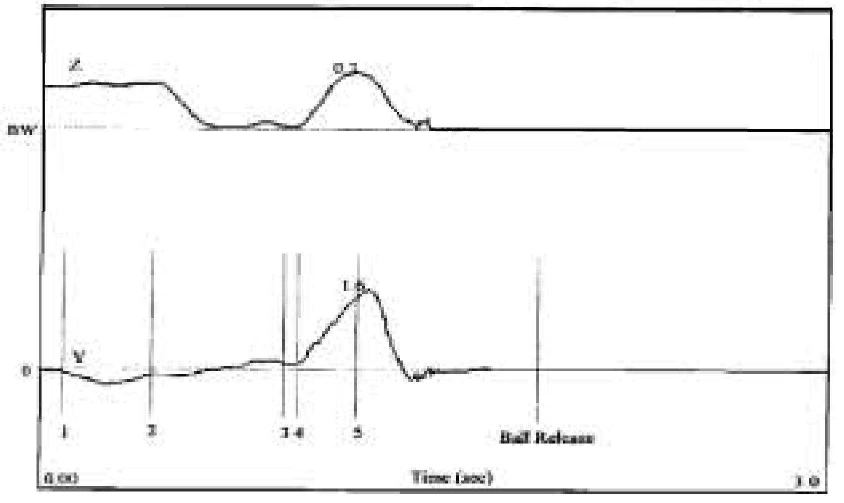

Figure 1 - Typical Vertical **(Z)** and Horizontal (Y) **GRF's** During the Windmill pitch

Shoulder Kinetics (Sagittal Plane): A mean peak sagittal plane flexion shoulder torque of 45.7 Nm (Table 2, Range: 31.6- 64.0 Nm) was less than the 75 Nm reported by Werner (1994), which may be due to the lower skill level of the subjects in this study or the fact that Werner reported a 3D value. Peak concentric muscle action which produced the flexion torque, changed direction immediately prior to release to produce a peak eccentric extensor torque of -134.9 Nm. Peak eccentric torque occurred between 0.02 sec and ball release for nine out of ten subjects. This is partially supported by data reported by Woo and Brown (1997), where the average torque for the entire forward-swing was a small extensor value (-7.4 Nm). This eccentric action may serve to protect the shoulder from injury, while also creating a stable structure from which forearm and hand segment may move effectively. While the absolute level of peak shoulder flexor torques show a range of values (45.7 ± 11.1 Nm), when peak values are normalised for height and mass, similar levels are produced across all subjects (0.035 ± 0.01 N Kg^{-1}).

TABLE 2: Mean 2D Sagittal Plane Shoulder Joint Torque and Force Data **(N=10)**

VARIABLE	RESULT
Peak Toque (Nm)*	45.7 (11.1)
Peak Torque (Nm/BW•H)	0.035 (0.007)
Ball release (BR) Torque (Nm)	-107.9 (64.6)
BR Toque (Nm/BW•H)	-0.08 (0.05)
BR Horizontal JRF(N/BW)	-0.27 (0.08)
BR Vertical JRF (N/BW)	0.73 (0.14)

* 2D shoulder joint torque is in the sagittal plane

The mean vertical and horizontal JRF's (Table 2) are accelerating the head of humerus upwards and backwards at ball release. The upper arm is almost aligned vertically with the trunk, suggesting the upper arm is being 'pulled' back into the joint for stabilisation, although further work is required to clarify this point. The mean vertical and horizontal JRF's of 0.73 BW and -0.27 BW at ball release were marginally larger than those reported for baseball pitching of approximately -0.4 BW and -0.1 BW respectively (Campbell, 1993). The results

suggest that marginally higher forces are apparent at the shoulder in windmill pitching, than in baseball and the potential for overuse injuries must be carefully monitored.
The high levels of peak eccentric torque evidenced in the last half of the forward swing prior to ball release suggest that the conditioning of shoulder extensors are an important consideration for the player, coach and trainer if shoulder injuries are to be prevented in windmill softball pitching. The results of this study also suggest that the pitcher should exhibit a greater degree of shoulder rotation compared with hip rotation prior to ball release.

CONCLUSION: The windmill softball pitch is a high velocity activity that is characterised by high levels of trunk rotation, shoulder torques and moderate ground reaction forces. The range of absolute shoulder torque values shows that torque must be normalised if comparisons are to be accurately made between subjects. While the ground reaction forces are not particularly high, the shoulder torque values show that the potential for overuse injuries is significant in the windmill softball action.

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