THREE DIMENSIONAL PELVIS AND HIP INTERACTION DURING PUNT KICKING: SKILLED VERSUS NOVICE PLAYERS

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The purpose of this study was to examine the interrelationships between pelvis and hip kinematics and punt kicking proficiency during a series of kicks for maximum distance/velocity. Three dimensional data (500 Hz) were collected during punt kicks for maximum velocity performed by 15 semi professional (S-Pro) Rugby Union players and 15 male recreational (Rec) kicking sport athletes. Results showed that the punt kicking technique of the S-Pro group involved complex multiplanar pelvis movements, with greater emphasis on axial pelvis rotation than the Rec group. These movement patterns have the potential to increase the stretch-shorten cycle in the kicking leg. Conversely, the punt kicking technique of the Rec group involved simple flexion-extension pelvis and hip movement patterns, a strategy that appears to limit punt kicking ball velocity.

KEY WORDS: kinematics, punt kicking, pelvis and hip.

INTRODUCTION: Most research publications on kicking have focused on examining striking a soccer ball from the ground (Lees, Asai, Andersen, Nunome, & Sterzing, 2010), with proportionally few studies reporting punt kicking biomechanics (Ball, 2008, 2009, 2011; Dichiera, Webster, Kuilboer, Morris, Back, & Feller, 2006; Orchard, McIntosh, Savage, & Beatty, 2007). Typically, researchers have concentrated on sagittal plane kinematics and have not examined the skill in three dimensions (3D), or the contribution of other segments to performance. This lacuna of 3D data on punt kicking is surprising given that research on soccer kicking has indicated that segmental movements in all three planes contribute to ball velocity for kicks off the ground (Lees and Nolan, 2002; Lees, Steward, Rahnama, & Barton, 2009). Ball (2008) hypothesised that pelvic rotation about a vertical axis may be an important contributor to punt kicking proficiency, although scientific literature on this topic is extremely limited.

Similarly, biomechanical investigations that have reported differences between skilled and novice kickers are rare. Kawamoto, et al. (2007) indicated that skilled soccer players had greater peak knee extension, hip flexion and hip external rotation velocities than inexperience players. While the applicability of this research to punt kicking may be questionable, the significant increases reported in transverse plane hip movements within the skilled kickers reinforces the importance of 3D methodologies for kicking research. Similarly, Ball (2011) examined differences in punt kicking kinematics for kicks with the preferred and non-preferred foot in a group of high performance Australian Football players. This study found greater knee and shank angular velocities at ball contact, and larger sagittal plane pelvis range of motion (ROM) for kicks on the preferred side, while thigh angular velocity at ball contact and hip range of motion were significantly larger for kicks from the non-preferred leg. The reported shift from a thigh and hip dominant movement pattern (non-preferred side) to a pelvis, knee, and shank strategy (preferred side) may be representative of an increase in punt kicking skill. However, the absence of data from less capable kickers means that care should be taken to avoid generalising these findings across all skill levels.

There is limited data on both the 3D movements of the pelvis during punt kicking and how these movements interact distally with the hip and thigh in skilled and novice kickers. Accordingly, the aim of this study was to examine for differences in pelvis and hip kinematics between highly skilled and novice punt kickers during a series of kicks for maximum velocity.

METHODS: Fifteen semi professional (S-Pro) male Rugby Union players (23.5 ±4.9 y, 91.7 ±12.3 kg, 1.79 ±0.06 m) and 15 male recreational (Rec) kicking sport athletes (23.7 ±7.9 y, 80.9 ±12.2 kg, 1.81 ±0.05 m) volunteered to participate in this study. All S-Pro participants were chosen from playing positions that are required to kick regularly during normal game play. Data were collected at 500 Hz using a seven camera motion capture system (Qualisys AB, Gothenburg, Sweden). This system tracked the position of 14 mm retro-reflective markers that were attached bilaterally over the anterior and posterior superior iliac spines, greater trochanters, and on the medial and lateral condyles. Four additional markers were also placed on a standard Rugby ball (Gilbert Barbarian, size 5). Following a structured warm-up, participants were instructed to perform six punt kicks for maximum velocity. To reduce the effects of fatigue, there was a 2 min rest between each kick.

Captured marker trajectories were modelled in 3D using standard biomechanical software (Visual3D, C-Motion, Inc., USA) and smoothed using a digital fourth order 12 Hz filter (Ball, 2008, 2011) prior to the construction of a 7 segment rigid body model of the pelvis and thighs. A global reference system was established with the positive y-axis in the intended direction of ball travel, the x-axis perpendicular to the intended direction of ball travel (positive direction to the right) and the positive z-axis pointing vertically. Pelvis kinematics were calculated relative to the global reference system with anterior–posterior tilt, lateral tilt and axial rotations defined using Euler angle calculations as angular rotation about each segment's x, y and z-axes. Thighs were modelled using standard procedures (Wu, Siegler, Allard, Kirtley, Leardini, Rosenbaum, Whittle, D'Lima, Cristofolini, Witte, Schmid, & Stokes, 2002) with the orientation of the thigh in relation to the pelvis used to define hip motion. Hip flexion, adduction and medial rotation were defined as positive rotations of the distal segment about the joint's respective x, y and z axes. Resultant ball velocity was calculated from the mean of the first three frames after the ball left the foot.

Differences in kinematic variables between the groups were determined using independent samples t-Tests. Pearson Product Moment correlation coefficients were used to determine the inter-relationships between ball velocity and pelvis and hip displacements, ROM and maximum angular velocities. Statistical analysis of the data was performed using the statistics package SPSS for Windows (version 19), with an alpha level of $p<0.05$.

RESULTS: Table 1 indicates significant differences between groups in ball velocity and pelvis and hip segmental kinematics. There were no other significant differences in either the orientation of the pelvis or the hip during the key phases of the kick, or segmental peak velocities during the leg swing phase. Both groups posteriorly tilted the pelvis through approximately 40 deg during the kick while also tilting the pelvis up laterally on the kicking leg side (ROM S-Pro 5 ±4°, Rec 7 ±5°). Within the Rec group the only variables that correlated significantly with ball velocity were both the ROM ($r=0.57$, $p=0.028$) and maximum velocity of posterior pelvic tilt ($r=0.79$, $p=0.001$). Conversely, in the S-Pro group significant correlations were recorded only between ball velocity and both ROM ($r=0.63$, $p=0.012$) and maximum velocity of axial pelvic rotation ($r=0.81$, $p<0.001$).

Representative pelvis and hip data from a participant from each group have been included in Figure 1. Typically, in the S-Pro group the peak posterior pelvic tilt velocity occurred prior to the peak in pelvic axial rotation velocity, with the latter corresponding to a reduction in hip flexion velocity just prior to ball contact. In nearly half of the S-Pro kicks the hip was extending briefly (relative to the pelvis) just prior to a rapid increase in hip flexion velocity at ball contact. Conversely, in the Rec group maximum posterior pelvic tilt velocity occurred relatively later in the kick, closer to the point of ball contact. None of the kicks performed by the Rec group presented with relative hip extension prior to ball contact.

DISCUSSION: Significant differences in maximum ball velocity between S-Pro and Rec were expected, with the values for S-Pro being slightly slower than those recorded previously for elite Australian Rules Football players (Ball, 2008, 2011). These differences may have been influenced by the punt kicking skill levels of the participants, as punt kicking in AFL is arguably a more important part of the game than it is in Rugby.

A key finding concerned differences in the pelvic movement strategies between groups. The ROM in pelvis posterior tilt for both S-Pro and Rec kickers were similar to that reported for AFL players when kicking using their preferred (47 ±9°) or non-preferred legs (40 ±8°) (Ball, 2011). Similarly, the pattern of tilting the pelvis laterally during the swing phase of a punt kick is similar to research on soccer kicking that has indicated the pelvis is raised 10 deg towards the kicking leg side at ball contact (Lees et al., 2009). While pelvic movements about the x and y axes appear to be important aspects in punt kicking, the skilled punt kickers (S-Pro group) also utilised pronounced pelvis axial rotation movement patterns during the forward swing of their kicking leg. These complex multiplanar pelvis movements have the potential to increase the relative distance through which the kicking foot can be accelerated during the forward swing. While this may influence the foot speed at ball contact, there are many other factors such as strength and inter-segmental coordination patterns that are known to contribute to kicking velocity (Dörge, Anderson, Sorensen, & Simonsen, 2002; Nunome, IkegamI, Kozakai, Apriantono, & Sano, 2006).

Table 1: Significant differences in pelvis and hip kinematic variables between S-Pro and Rec groups.

Variable	Mean (±SD)		*p*
	Rec	S-Pr^{o}	
Maximum Ball Velocity (m/s)	15.61 ±2.61	22.44 ±2.31	<0.001
Hip Flexion Angle at the end of the Backswing (deg)	-17 ±8	-26 ±7	0.003
Hip Flexion Angle at Ball Contact (deg)	24 ±8	15 ±7	0.007
Minimum Hip Flexion Velocity during Forward Swing (deg/s)	56 ±88	-54 ±105	0.004
Range of Motion in Pelvis Axial Rotation (deg)	12 ±15	21 ±10	0.047
Maximum Pelvis Anterior Tilt Velocity (deg/s)	289 ±67	393 ±80	0.001
Maximum Pelvis Axial Rotation Velocity (deg/s)	166 ±100	246 ±63	0.013

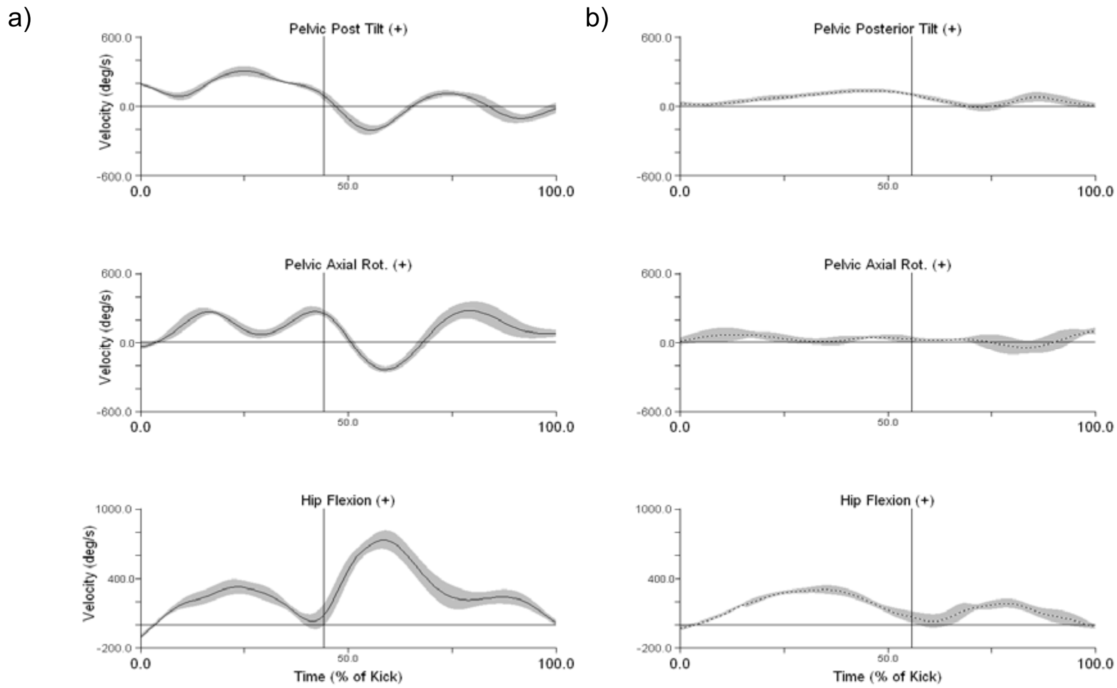

Figure 1: Representative pelvis anterior-posterior tilt (top), axial rotation (middle) and hip flexion-extension velocity data for individual players from the S-Pro (a) and Rec (b) groups. Data starts at the plant of the non-kicking leg (0%) and ends at the point of maximum hip flexion (100%). The vertical line represents ball contact.

The ROM in pelvic axial rotation reported for the S-Pro punt kickers was still less than for kicking a soccer ball from the ground although this may have been influenced by the angled approach, relative ball height, and medial foot ball contact typical in soccer kicking (Lees, et al., 2009). Similarly, the task constraints imposed by striking a moving ball in punt kicking may limit the role of pelvic axial rotation. Another key finding was the inter-relationships between pelvis movements and the patterning of the forward thigh movement during the kick. Previous research has suggested that a rapid posterior pelvic tilt has an important role in generating a stretch-shorten cycle on the front of the hip and hence increase the rate of hip flexion during the kick (Ball, 2008; Lees, et al., 2009). In addition to this movement, the rapid pelvic axial rotation present in the S-Pro actually resulted in relative hip extension in many of the kicks – an action that would dramatically increase the magnitude of the tension arc across the front of the kicking leg (Shan & Westerhoff, 2005). The increased hip extension at the end of the backswing present in the S-Pro group also has the potential to increase the elastic energy stored in the kick leg hip flexors prior to the forward swing. Interestingly, the use of the stretch-shorten cycle in kicking a soccer ball from the ground has been thought to account for the 43% of the difference in ball speeds between novice and elite players (Shan & Westerhoff, 2005). Although open for further investigation, the complex pelvis and hip movement patterns used by the S-Pro group have the potential to dramatically increase the effectiveness of the stretch-shorten cycle on the kicking leg, possibly suggesting that this ability is a characteristic of skilled punt kicking performance.

CONCLUSION: The S-Pro kickers in this study presented with more complex pelvis movement strategies than the Rec kickers. In addition, rapid axial pelvis rotation velocities were key determinants of the high punt kicking ball velocities developed by the S-Pro group. Conversely, less skilled punt kickers placed greater emphasis on simple flexion/extension movement patterns, a strategy that possibly limited punt kicking ball velocity. Results suggest that the skilled kickers may be using these movements to generate a stretch-shorten cycle in the kicking hip flexors, although this area needs to be investigated further.

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