MOVEMENT VARIABILITY IN RUGBY UNION PUNT KICKING

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The purpose of this study is to look at the differences in Rugby Union punt kicking kinematics as well as the variability of movement patterns between two different skill levels. Three dimensional data (500 Hz) were collected during punt kicks for maximum velocity performed by 12 semi-professional Rugby Union players and 12 male recreational kicking sport athletes. The normalised root mean square values were used to determine intra-individual movement variability. Results showed that the semi-professional kickers had greater range of motion (ROM) at the pelvis and knee than the recreational group. The recreational group showed less movement variability than the semi-professional however, it was not significant. The higher movement variability shown by the semi-professionals combined with the greater (ROM) shows a higher level of functional movement variability.

KEY WORDS: kinematics, punt kicking, movement variability

INTRODUCTION: Kicking is one of the fundamental skills in the game of Rugby Union (Rugby). There is an average of 39 kicks per game of international Rugby, with the majority of these kicks being punt kicks (World Rugby, 2016). Despite the tactical importance of punt kicking in Rugby, there has been very little research completed on the technique of the punt kick.

One of the most accepted theories of skill behaviour development is the reorganisation of motor systems degrees of freedom (Bernstein, 1967). It has been suggested that a learner will often control the degrees of freedom around a joint by reducing joint movements which can be seen as rigid and awkward coordination patterns. As a person becomes more skilled, the constraints imposed on the degrees of freedom are gradually released and the movements become much more fluid (Bernstein, 1967). Evidence to support Bernstein's ideas can be found in the differences in joint Range of Motion (ROM), angular velocities and coordination patterns between skilled and less skilled athletes. In Rugby punt kicking, semi-professional players showed significantly greater ROM of the pelvis about the vertical axis and angular velocities across all lower extremity joints compared to recreational players (Sayers & Morris, 2012).

Another indicator used to differentiate between skill levels is the intra-individual movement pattern variability. Recent research suggests the movement pattern variability is a sign of expert performance (Bartlett, Wheat, & Robins, 2007; Seifert, Button, & Davids, 2012). Higher level athletes show functional levels of variability allows them to be more adaptable in unexpected situations (Carson, Collins, & Richards, 2013). Novice athletes will show less variability in their movements due to the more rigid movement patterns (Bernstein, 1967; Seifert et al., 2012). This study will look at the differences in kinematics as well as the variability of movement patterns between two different skill levels.

METHODS: Two participant groups were used in this study. The first group was comprised of 12 semi-professional male Rugby players (age 22.9 y ± 4.1, mass 90.0 kg ± 13.8, and height 1.77 m ± 0.04). The second group consisted of 12 males who participate in a kicking sport, but only at a recreational level (age 24.9 y ± 9.1, weight 83.3 kg ± 14.9, and height 1.82 m ± 0.06). This research was approved by the University of the Sunshine Coast Human Research Ethics Committee (HREC: S/10/266).

The study was conducted in the Motion Analysis Laboratory at the University of the Sunshine Coast. Data was collected at 500 Hz using a seven camera Qualysis Motion Capture System (Qualysis AB, Gothenburg, Sweden). The cameras tracked light that was reflected off low mass, retro-reflective markers (14mm) located on key pelvis and lower limb landmarks. These landmarks included both iliac crests, the anterior and posterior superior iliac spines, left and right femoral greater trochanters, medial and lateral femoral epicondyles, medial and lateral

malleolus, and clusters on the left and right thighs and shanks. Three additional markers were also placed on a standard size 5 Rugby ball (Gilbert Barbarian).

A 7 segment 3D model of the trunk and lower limbs was created from the calculated joint centres using standard biomechanical modelling software (Visual3D, C-Motion, Inc. Maryland, USA.) An automatic time frequency algorithm adapted from Nunome et al (2006) was used to smooth the data prior to it being processed to compute linear and angular velocities for each segment and the whole body centre of mass.

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. Segmental local coordinate systems were defined with reference to the proximal joint such that movements in the sagittal plane (e.g. knee flexion) were labelled so that they occurred about the X-axis. Movements in the frontal plane (e.g. hip abduction) were labelled so that they occurred about the Y-axis, while movements in the transverse plane (e.g. pelvis axial rotation) were labelled so that they occurred about the Z-axis. All joint orientations were normalised using mean angles from the static trial as 0° (Kawamoto, Miyagi, Ohashi, & Fukashiro, 2007). All rotations were defined using the right hand orthogonal rule.

Participants completed a structured warm-up then instructed to perform five punt kicks. To reduce fatigue, there was a 2 min rest between each kick. Kicking performance was determined from maximum ball velocity, which was calculated using the max ball velocity in the first five frames after ball contact with the foot (Kawamoto et al., 2007). Trials were excluded from analysis if they were not complete and clean trials. ROM data was calculated for each segment from maximum hip extension (BS) to ball contact (BC).

The variability between joint movement patterns was determined by using the normalised root mean squared error (NoRMs) technique (Sidway, Heise, and Scoenfelder-Zohdi (1995) The NoRMs indices were averaged for each subject, and each group, for sagittal hip-knee and hip-pelvis, as well as sagittal hip versus transverse pelvis angle-angle data. A lower NoRMs index indicates less variability in joint coordination (Chow, Davids, Button, & Koh, 2007; Sidway et al., 1995).

Descriptive statistics were calculated to find the mean movements for each participant, then for each participant group. A Shapiro-Wilk test of normality was used to determine normal distribution. The differences between the participant groups were determined using Independent samples t-Test for the variables found to have normal distribution, while those that were not were determined by using independent samples Mann-Whitney U test. Effect sizes were calculated for each of the variables and reported using standard descriptors (trivial: 0-0.2, small: 0.2-0.5, moderate: 0.5-0.8, large: >0.8 (Cohen, 1988).

RESULTS: The mean angles for the hip, pelvis and knee at BS and BC can be found in table 1. The Semi-Professional players had significantly faster ball velocities (22.9m/s ± 1.8) than the recreational participants (16.4m/s ± 2.7, t=7.11, p=0.00, d=2.90).

There was a moderate difference in movement variability for the hip-pelvis about the X axis (d=0.61), where the recreational group reported lower NoRMs values (3.9 ± 1.3) than the semi-professional group (4.8 ± 1.5, t = 1.49), the difference was not found to be significant (p=0.18). There was no difference in movement variability for the hip-pelvis about the Z axis (t=0.77, p=0.45, d=0.32), where the recreational group had slightly less variability (4.4 ± 1.6) than the semi-professionals (4.8 ± 1.9). The semi-professional kickers had slightly more movement variability for the hip-knee movement patterns (7.2 ± 2.2) than the recreational kickers (6.8 ± 2.7, t=0.34, p=0.74, d=0.14).

Figure 1 shows representative sagittal hip-knee and hip-pelvis angle-angle plots as well as transverse plane angle-angle plots for the hip-pelvis for both participant groups. The two graphs representing the sagittal plane movements show similar movement patterns between groups, with the magnitude being the difference. The hip-pelvis in the transvers plane angle-angle graph shows different movement patterns as well as different magnitudes. The angle-angle graphs also show the intra-trial variability for the represented individuals.

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Table 1: Mean (with SD) kinematic values for each group of key lower limb segments at crucial phases in the kick

	Semi-Pro		Recreational		Effect
	Mean(^{0})	SD	Mean(^{0})	SD	Size
Maximum Knee Flexion	95.0	7.3	87.0	11.4	0.837[a]
Knee Flexion at BC	56.7	8.3	51.5	8.5	0.614[b]
Hip Flexion at BS	-26.5	7.6	-22.0	12.7	-0.428
Hip Flexion at BC	13.8	8.0	25.7*	10.7	-1.262[a]
Hip Internal Rotation at BC	0.2	11.3	-2.5	10.2	0.248
Pelvic Flexion ROM	39.6	5.2	31.9	14.4	0.71[b]
Pelvis Internal Rotation at BC	5.4	6.5	-0.7*	5.7	0.996[a]
Pelvis Internal Rotation ROM	22.6	8.0	15.3*	7.8	0.924[a]

* statistical significant difference ($p \leq 0.05$) between Recreational and Semi-Professional participants
[a] large effect size ($d > 0.8$)
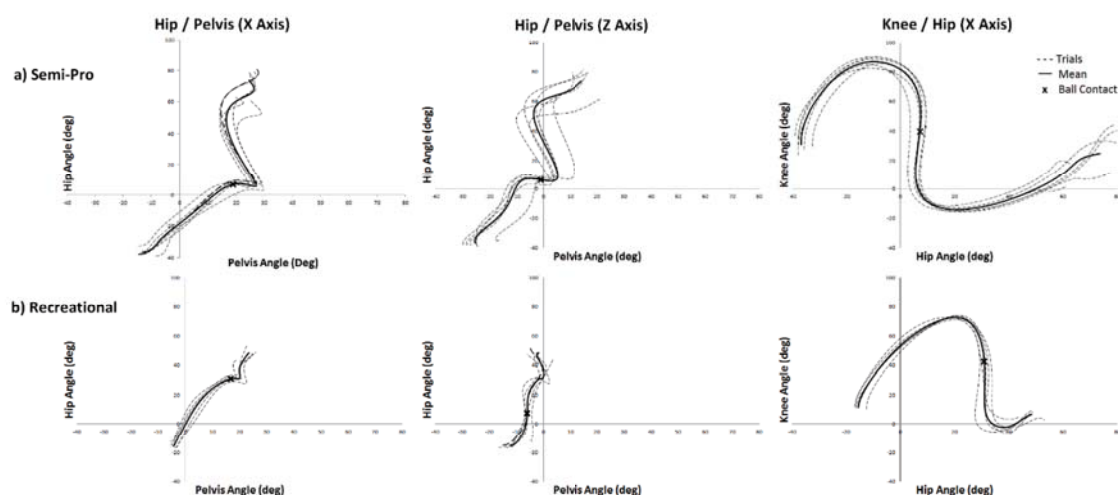[b] moderate effect size ($d = 0.5 - 0.8$)

Figure 1: A representative angle-angle graph of the Hip/Pelvis about X and Z axes and Knee/Hip about the X axis for both a) Semi-Professional group and b) Recreational group.

DISCUSSION: The semi-professional kickers had a larger pelvic anterior tilt, greater knee flexion and greater hip extension in the backswing than the recreational kickers. As illustrated in Figure 1, the movement patterns in the sagittal plane show similar shapes but the semi-professional group had a greater ROM. The recreational athletes showed similar hip ROM to the semi-professionals, due to the hip being more flexed at BC. The greater hip flexion at BC shows that the recreational athletes used a hip / thigh dominated movement pattern as the main generator of force and ball speed. There was greater ROM for semi-professionals from the pelvis about the z axis, as well as completely different movement patterns compared to the recreational kickers (Figure 1). Previously we have shown that these differences are important discriminators between skilled and less skilled Rugby Union punt kickers (Sayers & Morris, 2012). The notable differences in coordination patterns between the semi-professionals and recreational kickers may be, in part explained by original theories in skill acquisition (Bernstein, 1967). Our recreational kickers tended to restrict the degrees of freedom at the pelvis and knee to increase stability and success of the movement. Conversely, the more highly skill semi-professional kickers tended to relax constraints at the pelvis and knee, allowing the knee to make use of the velocity generated by the pelvis, hip and other proximal segments in the kinetic chain.

While the results were not significantly different, there was a trend of less intra-individual variability amongst the recreational kickers when compared to semi-professional kickers. This trend has been found previously in soccer kicking where novice players typically recorded the

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lowest NoRMs values for lower limb segments, while and expert players had higher NoRMs scores (Chow et al., 2007). Higher levels of variability can be indicative of a highly skilled participant's adaptation to task constraints. Functional variability is considered an important factor for highly skilled athletes, especially those in an invasive team sport such as Rugby Union, due to players needing to be able to adapt to deal with defensive pressures of the opposite team.(Bartlett et al., 2007)

Functional variability due to adaptation to task restraints is quite apparent in punt kicking due to the kick itself. In a punt kick the ball is dropped for the hand onto the foot. Kickers have to adapt the coordination pattern and timing to make sure the ball contact is clean. When looking at the NoRMs scores, the hip/pelvis patterns were quite consistent, whereas the hip knee had more variability. This was also found on a study looking at the variability of externally timed soccer kicks, and was thought to occur due to the need to make last minute adjustments to still achieve the desired outcome (Egan, Verheul, & Savelsbergh, 2007).

CONCLUSION: This studied explored the differences in lower limb kinematics and movement variability between recreational and semi-professional Rugby Union punt kickers. Results showed that the semi-professional players utilise a kicking technique that not only allows for greater ROM in the pelvis and knee, but also provides for greater movement variability than recreational level players. These findings highlight the role that functional variability plays in kicking. In light of these findings, the importance of using variations in training to encourage kickers to adopt non-robotic techniques has been emphasised. Providing athletes with differing environmental conditions, timeframes, space and game situations during training can help the athlete adopt a more adaptable punt kicking technique.

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