THE INFLUENCE OF SIDE DOMINANCE ON UPPER BODY KINEMATICS DURING RUGBY PASSES FROM THE GROUND

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This study described rugby passing technique in a group of 13 highly proficient players. Upper body kinematics (500 Hz) were assessed during six passes at a target positioned 8 m away from both dominant and non-dominant sides, with pass accuracy recorded subjectively using a 5-point scale. Passes to the *preferred side* were faster (P=0.02) and more accurate (P=0.001) than those to the *non-preferred* side. Variability analysis (NoRMS) showed greater shoulder and elbow movement variability, with greater standard deviation values at ball release for passes to the non-dominant side. Maximum shoulder flexion (lead) and adduction (trailing) velocities were *moderately* correlated with pass velocity (r=0.41 to r=0.48). Results suggest that despite displaying a high level of passing proficiency, participants presented with a bias when passing towards their dominant side.

KEY WORDS: rugby union, passing, technique analysis.

INTRODUCTION: Passing is a fundamental skill in rugby union (rugby) and all of the associated rugby codes including rugby 7's, rugby league, touch football, etc. There are nearly 300 passes per international rugby game, with the ball being passed at least once for every 8 s of match play (International Rugby Board, 2014). Passing ability has been linked to line breaks (den Hollander, Brown, Lambert, Treu, & Hendricks, 2016) and point scoring in elite rugby matches (Barkell, O'Connor, & Cotton, 2016; Higham, Hopkins, Pyne, & Anson, 2014). Approximately half of all passes are initiated with the ball on the ground (International Rugby Board, 2013), with the typical technique for these passes involving the ball being "swept" off the ground in a dynamic across body action whilst being spun rapidly about its longitudinal axis (Hooper, James, Jones, Lee, & Gál, 2008; Worsfold & Page, 2014). Players are expected to show equal proficiency when passing to both their dominant and non-dominant sides (Pavely, Adams, Di Francesco, Larkham, & Maher, 2009), delivering the ball rapidly and accurately over distances ranging from less than 1 m to over 15 m (i.e. for a right-handed player the dominant side is a pass to their left). The importance of a consistent, fast and accurate pass in rugby has resulted in the development of several "field based" skills tests, which have been used to assess both high performance (Pavely, et al., 2009) and developing players (Spamer & Hattingh, 2004).

Surprisingly, there are limited scientific research papers on the biomechanics of rugby passing technique. The few studies in this domain report only gross measures such as ball velocity, distance and/or accuracy, with no data on upper body kinematics and/or the potential influence of side dominance on passing technique. Accordingly, the aims of the study were to describe the biomechanical determinants of passing velocity in a group of highly proficient players. In addition, analysis included assessment of whether players altered passing technique when passing to their dominant or non-dominant sides.

METHODS: Thirteen semi-professional rugby union players volunteered to participate in this study (age 22.7 ±3.2 years, body mass 90.3 ±11.5 kg, height 1.784 ± 0.057 m). Participants were informed of the risks and experimental procedures and all provided their informed consent. This research was approved by the institutional Human Research Ethics Committee.

Prior to testing 12 mm retro-reflective markers were attached to the skin adjacent to key upper limb anatomical landmarks (Reid, Elliott, Alderson, Lloyd, & Elliott, 2010). Single markers were attached adjacent to the manubrium, xiphoid process and the spinous processes of the 7th and 12 thoracic vertebra. Three marker clusters were attached to the mid-point of both upper arms and forearms, with three additional markers attached to a match rugby ball (Gilbert, Virtuo). Static trials were then collected with the participants standing in the anatomical position.

Following a structured 10 min warm-up, which included standard locomotor activities and passes over varying distances, the players completed six passes to the left and right at a target positioned 8 m away. Participant were instructed to pass with high velocity, but to still try and hit the target (i.e. pass as they would in a game). Pass accuracy was determined using a 5-point scale. Marker trajectories were tracked at 500 Hz using an eight-camera motion capture system (Qualysis AB, Gothenburg, Sweden). Problems with tracking of the wrist and hand markers meant that both hand segments were not included in any further analyses. Data were smoothed using a 4th order low-pass digital filter (12 Hz), with kinematic data modelled in three-dimensions (3D) using standard biomechanical software (Visual3D, C-Motion, Inc., USA) to construct a 7 segment rigid body model of the pelvis, torso and upper limbs. A global reference system (GRS) was defined with the positive Y-axis was directed anteriorly, the X-axis laterally (positive direction to the right) and the positive Z-axis pointing vertically. Segment coordinate systems for upper limb segments were constructed according to standard biomechanics principles (Wu et al., 2005), with subsequent shoulder and elbow kinematics defined by angular movements of the distal segment in relation to the proximal, with flexion (and shoulder horizontal flexion), adduction and internal rotation were defined as positive rotations about each segment's X, Y and Z-axes respectively. All segment orientations were normalized as 0 deg using mean angles from the static trial.

Passes were divided into two phases, with the preparatory phase defined as occurring from the initial point of contact with the ball until the instant that the ball started moving in the direction of the pass, with the propulsive phase then ending at the point of ball release. The possible effect of side dominance on discrete variables was determined via paired t-tests or Mann-Whitney U tests. Normalised Root Mean Square (NoRMS) (Chow, Davids, Button, & Koh, 2008) were used to quantify the consistency in upper body movement patterns in the *lead* and *trail* shoulder and elbows (i.e. for passes to the left the *lead* side is the left). Pearson Product Moment and Spearman's Rank correlation coefficients tested the relationships between pass kinematics and ball release speed and pass accuracy. Results are presented as means ± one SD of the mean, with an alpha level of $P<0.05$ used throughout.

RESULTS: Results indicate a clear effect of side dominance on both pass velocity and accuracy, with passes to the player's dominant side being significantly faster (12.34 ±2.1 m/s, $P=0.02$) and more accurate (4.1 ±0.5, $P=0.04$) than passes to their non-dominant side (10.95 ±1.71 m/s and 3.2 ±0.7 respectively). Analyses of the upper body kinematics show that the shoulder and elbow kinematics involve extremely complex 3D movements that regardless of pass direction involves rapid flexion of both the lead (dominant 422 ±133 deg/s, non-dominant 414 ±139 deg/s, $P=0.88$) and rear (dominant 399 ±180 deg/s, non-dominant 409 ±183 deg/s, $P=0.89$) shoulders that is coupled with rapid abduction of the lead shoulder (dominant 363 ±108 deg/s, non-dominant 353 ±118 deg/s, $P=0.82$) and adduction of the rear shoulder (dominant 508 ±104 deg/s, non-dominant 504 ±134 deg/s, $P=0.93$). These movements are also linked with a moderately rapid extension of the lead (dominant 199 ±98 deg/s, non-dominant 210 ±122 deg/s, $P=0.80$) and trailing elbows (dominant 317 ±124 deg/s, non-dominant 375 ±264 deg/s, $P=0.48$). However, there were no significant differences in shoulder or elbow orientations between dominant or non-dominant sides at each of the discrete points in the passing action ($P=0.31$ – 0.97).

Shoulder/elbow angle-angle data show similar movement patterns in the rear arm, but slight differences in the lead arm – particularly approaching the point of ball release (Figure 1). Results also show larger SD values for shoulder and elbow angular displacement data at ball release when passing to the non-dominant side. NoRMS analyses of sagittal shoulder-elbow angle/angle data indicates that the players had more consistent movement patterns in their trail arm when passing towards their dominant side (6.1 ±2.3) rather their non-dominant side (12.9 ±3.1, $P<0.001$). However, there were no significant differences in NoRMS values for the equivalent data on the lead arm (dominant 8.9 ±2.9, non-dominant 10.0 ±3.1, $P=0.34$).

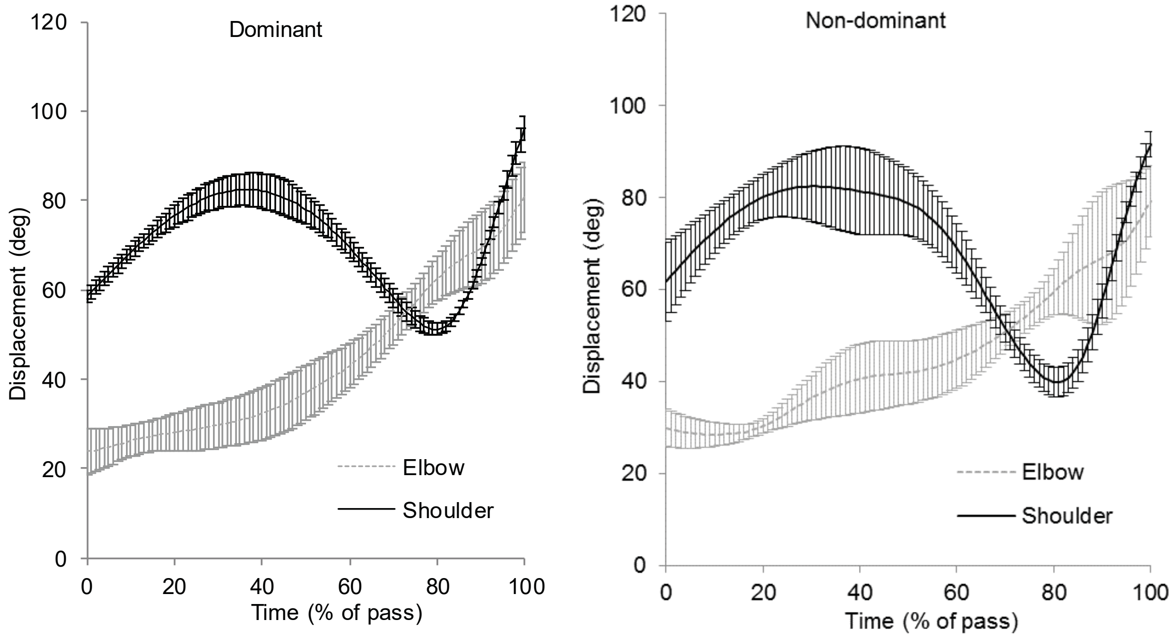

Figure 1: Mean lead sagittal shoulder (black) and elbow (grey) angular displacement time series data (i.e. joint flexion/extension) for passes to the player's dominant (left) and non-dominant (right) sides. Graphs start from the point of contact with the ball (0%) and end at the point of release (100%). Error bars represent ±1SD.

Maximum leading shoulder flexion velocities and maximum trailing shoulder adduction velocities were correlated significantly, albeit moderately with ball velocity for passes to both sides, whilst other significant correlates differed between sides (Table 1). None of the kinematic variables achieved better than weak or significant correlations with passing accuracy.

Table 1
Upper body correlates with pass velocity

Variable	Dominant	Non-dominant
Max lead shoulder flexion (deg/s)	*r=0.45, P=0.02*	*r=0.48, P=0.01*
Max lead shoulder abduction (deg/s)	*r=0.45, P=0.02*	*r=0.31, P=0.13*
Max lead shoulder external rotation (deg/s)	*r=0.28, P=0.17*	*r=0.61, P=0.01*
Max trail shoulder flexion (deg/s)	*r=0.31, P=0.13*	*r=0.09. P=0.65*
Max trail shoulder adduction (deg/s)	*r=0.41, P=0.04*	*r=0.46. P=0.02*
Max trail shoulder external rotation (deg/s)	*r*=0.21, *P*=0.30	*r*=0.25. *P*=0.22
Max lead elbow extension velocity (deg/s)	*r*=-0.35, *P*=0.08	*r*=-0.16, *P*=0.42
Max trail elbow extension velocity (deg/s)	*r*=-0.11, *P*=0.28	*r*=-0.30, *P*=0.13

DISCUSSION: A key finding from our study was that despite the high level of playing ability of our participants, side dominance had a clear effect on both maximum ball velocity and pass accuracy. This result appears at odds with both the requirements of the game and other research (Pavely, et al., 2009). Our results also support unpublished data cited by Pavely, et al. (2009) indicating that more tries are scored on the left side of the field, the side that favours passes by right-hand dominant players. However, these findings have clear performance limitations and so coaches need to emphasise the importance of bilateral passing ability from a young age.

Although our analyses were influenced by the relative magnitude of the SD values, there were no significant differences in any of the discrete data for passes to either the dominant or non-dominant sides, with no clear differences in velocities of the lead or trail arms. Accordingly, potential differences in wrist kinematics may account for the significant differences in ball velocities for passes to the dominant side, but further research on wrist kinematics during passing is required to confirm this hypothesis. However, as the most distal segment in the kinetic chain it is likely that the wrists have an important role in this skill.

Results from our NoRMS analyses indicated that all participants presented a certain degree of upper body movement variablity in their passing action, a phenomenon typically associated with skilled performance (Bartlett, 2008; Davids, Glazier, Araujo, & Bartlett, 2003). Additionally, trail arm movement patterns were more consistent for passes towards the dominant side (most accurate), while the movements of the lead arm were more variable regardless of pass direction. These data suggest that the lead arm has a role in controlling passing accuracy by performing compensatory movements (Bartlett, 2008; Davids, et al., 2003), particularly when passing to the dominant side. Conversely, the reduction in passing accuracy for passes to the non-dominant side might be a function of the lead arm being unable to compensate for the relatively inconsistent movement patterns of the trail arm. Accordingly, our results support the development of training drills that reduce excessive trail arm movement variability, whilst reinforcing the controlling role of the lead arm.

CONCLUSION: This study highlights the complex multiplanar nature of the upper body movement patterns associated with the rugby pass from the ground and shows that side dominance affects technique even in skilled players. Results also suggest that effective upper body technique when performing the rugby pass from the ground involves a certain degree of adaptive movement variability in the lead arm whilst minimising excessive movement variability in the trail arm.

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