ISSN 1750-9823 (print)
International Journal of Sports Science and Engineering
Vol. 07 (2013) No. 02, pp. 101-110

Upper Body Kinematic Predictors of Ball Velocity During Out of Hand Kicking in International Level Rugby League Kickers

Jonathan Sinclair [1], Paul John Taylor [2], Steve Atkins [1] and Sarah Jane Hobbs [1]

[1] Division of Sport Exercise and Nutritional Sciences, University of Central Lancashire
[2] School of Psychology, University of Central Lancashire

(*Received February 6, 2013, accepted March 9, 2013*)

Abstract. Out of hand punt kicking is integral the attacking and defensive elements of rugby league and a coveted aspect of any player's skill set is the ability to kick the ball with high linear velocity. This study aimed to identify the important technical aspects of kicking linked to the generation of ball velocity using regression analyses. Maximal out of hand kicks were obtained from six international standard rugby league kickers using a 3-D motion capture system sampling at 250Hz. Upper body 3-D kinematics were obtained. Regression analyses with ball velocity as criterion was used to identify the upper body kinematic parameters associated with the development of ball velocity. The regression model yielded an Adj R^2=0.81, p≤0.01. A single discrete variable: Sagittal plane torso rotation at ball impact. This suggests that upper body kicking mechanics have a strong influence on ball velocity and potentially overall kicking performance. Therefore it is recommended that players be exposed to coaching and strength techniques geared towards the modification of kicking mechanics specific to this study.

Keywords. rugby, kicking, kinematics, upper body, ball velocity.

1. Introduction

Rugby league is a popular and expanding sporting discipline in a number of countries. Effective out of hand punt kicking is essential to rugby league performance and is considered a desired element of any player's skill set. Lim et al., (2009) proposed following their examination of game actions contributing to performance that the ability to kick the rugby ball long distances is of greater importance than any of the set piece elements of rugby league.

In professional rugby league effective out of hand punt kicking is important for attacking play, typically in the form of a 40-20 where a player behind his side's 40 metre line kicks the ball over the side-lines of the field of play past the opponent's 20 metre line. A successful 40-20 typically gives the offensive side attacking possession by moving the team from their own 40 metre line to the position where the ball went out inside the opposing team's 20 metre area. Furthermore, kicking out of hand for maximal distance is also important for defensive play near the end of the tackle count, whereby a kicker will return possession of the ball to the opposing side in the most favorable position for his team by kicking as far down the opposite end of the field as possible. Thus ensuring the opposing team has to commence their attack in position as far from the defensive try line as possible.

It is well known that a greater projection velocity results in a greater kick distance (de Mestre, 1990). Whilst the importance of maximal distance kicking out of hand in professional rugby league has been well documented, there has been no examination of the technical elements pertinent to the development of kicking distance using international standard rugby league players. This study therefore aimed to aims to identify important technical aspects of the upper body linked to the generation of high ball velocity during out of hand punt kicking using regression analyses.

2. Methods

2.1. Participants

Six international standard male rugby league kickers volunteered to take part in this investigation (age 24.75 ± 4.11 years; height 178.25 ± 5.68 cm; body mass 82.75 ± 7.5 kg). The participants were contracted to a professional rugby league club in England. All were free from lower extremity pathology and provided written informed consent in accordance with the procedures outlined in the declaration of Helsinki. Ethical approval for this project was obtained from the School of Psychology ethics committee at the University of Central Lancashire.

2.2. Procedure

A ten camera motion analysis system (Qualisys^{TM} Medical AB, Goteburg, Sweden) captured kinematic data at 250 Hz from each participant performing maximal out of hand kicks with a 5 m run up. Dynamic calibration of the motion analysis system was performed before each data collection session in accordance with the Sinclair et al., (2012a) recommendations for this system.

The anatomical marker configuration utilized for this study was based on the calibrated anatomical systems technique (CAST) method (Cappozzo et al., 1995) allowing the thorax, left and right upper arms and left and right forearms to de defined. Retro-reflective markers were attached in the following locations; C7, T12, xiphoid process, medial and lateral elbow, medial and lateral wrists, right and left acromion process, right and left iliac crest, right and left anterior superior iliac spines (ASIS), and right and left posterior superior iliac spines (PSIS) with tracking clusters positioned bilaterally onto the upper arm and forearms.

The tracking clusters which were comprised of four 19mm spherical reflective markers mounted to a thin sheath of lightweight carbon fiber with a length to width ratios of 1.5:1 and 2.05:1, in accordance with the previously established guidelines (Cappozzo et al., 2005). A static trial was captured to define the torso, right and left upper arms, right and left forearms and the pelvis, following which markers not used for tracking the segments during motion, were removed prior to the collection of dynamic information.

2.3. Data processing

Trials were processed in Qualisys Track Manager in order to identify anatomical and tracking markers and then exported as C3D files. Kinematic parameters were quantified using Visual 3-D (C-Motion, Germantown, MD, USA) after marker data was filtered using a low-pass Butterworth 4th-order zero-lag filter at a cutoff frequency of 15 Hz which was selected as being the frequency at which 95% of the signal power was below. Five trials of maximal out of hand kicking were averaged for each participant. Kicking trials were defined by the instances of kicking limb take off and ball contact, with an intermediary event defined as stance limb contact with the force platform (Sinclair et al., 2011). Ball contact was determined using a retro-reflective markers attached to the ball. With the exception of the shoulder all angles were created about an XYZ cardan sequence (Sinclair et al., 2012b) referenced to co-ordinate systems created about the proximal end of the segment, where X = sagittal plane rotations; Y = coronal plane rotations and Z = transverse plane rotations. Shoulder rotations were quantified using a ZYZ sequence of rotations in accordance with the recommendations of Wu et al., (2005). 3-D kinematic measures from the torso and right/left shoulder and elbow joints which were extracted for statistical analysis were 1) angle at footstrike, 2) angle at toe-off, 3) angle at ball impact, 4) range of motion during stance, 5) peak angle during stance, 6) relative range of motion from footstrike to peak angle, 7) angular velocity at footstrike, 7) angular velocity at toe-off, 8) angular velocity at ball impact and 9) peak angular velocity.

2.4. Statistical analyses

Descriptive statistics (means and standard deviations) for 3-D kinematic parameters and ball velocity were calculated. A multiple regression analysis with ball velocity as the dependent/criterion measure and the upper 3-D kinematic parameters as predictor variables was carried out using a forward stepwise procedure with significance accepted at the $p \leq 0.05$ level. The independent variables were examined for co-linearity prior to entry into the main regression model using a Pearsons correlation coefficient matrix. Those exhibiting high co-linearity $R > 0.7$ were removed. All statistical procedures were conducted using SPSS 20.0 (SPSS Inc, Chicago, USA).

3. Results

Figures 1-5 present the mean ± standard deviation 3-D kinematic parameters from both the torso and left and right arms. The overall regression model yielded an $R = 0.94$, $R^2 = 0.88$ and Adj $R^2 = 0.81$, $p \leq 0.01$. A single discrete biomechanical parameter was obtained as significant predictor of ball velocity. Sagittal plane torso angle at ball contact was found to be the strongest significant predictor of ball velocity.

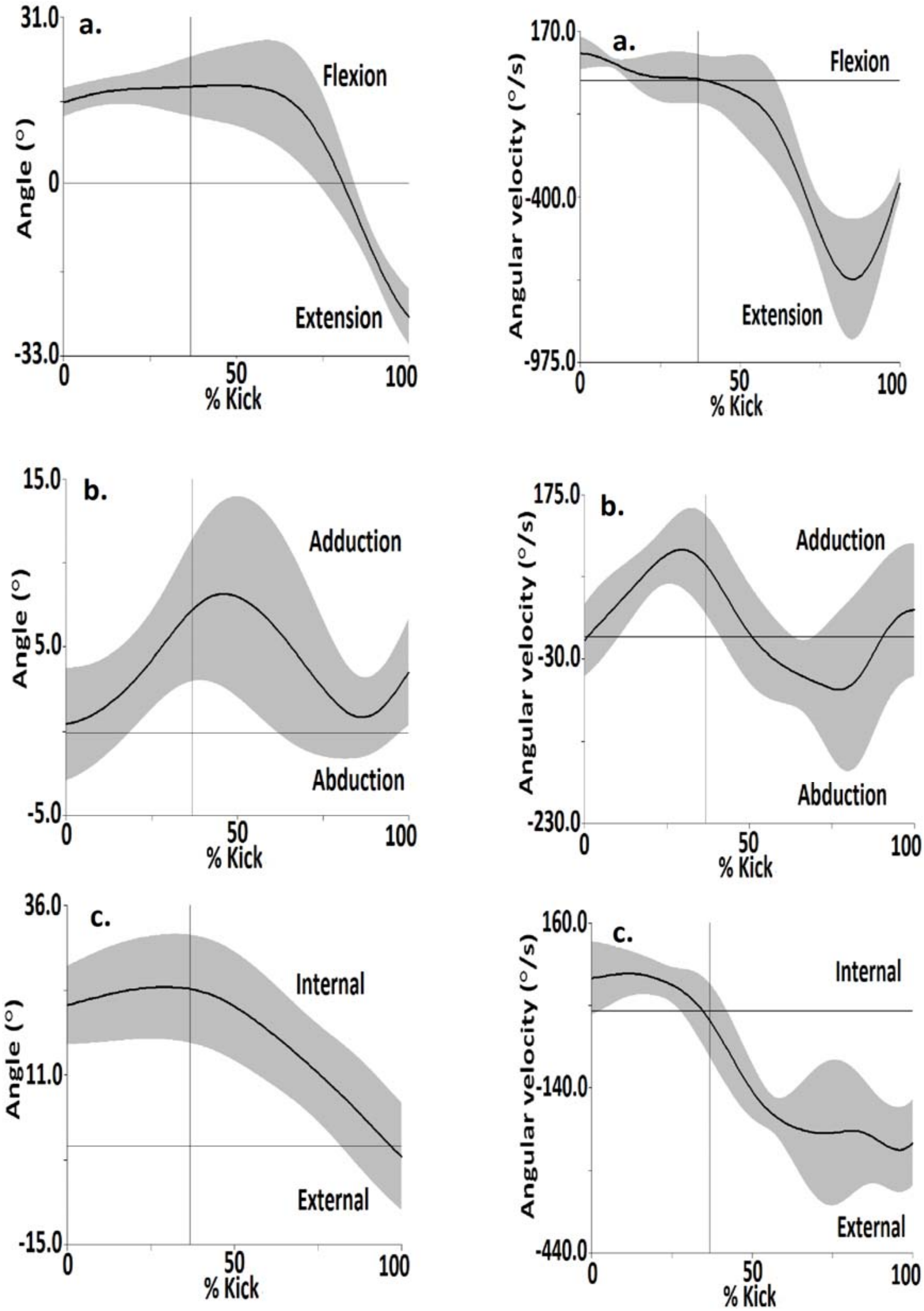

Figure 1: Mean and standard deviation torso kinematics in the (a) sagittal, (b) coronal, and (c) transverse planes (Shaded area = 1SD). Vertical line denotes stance limb foot placement.

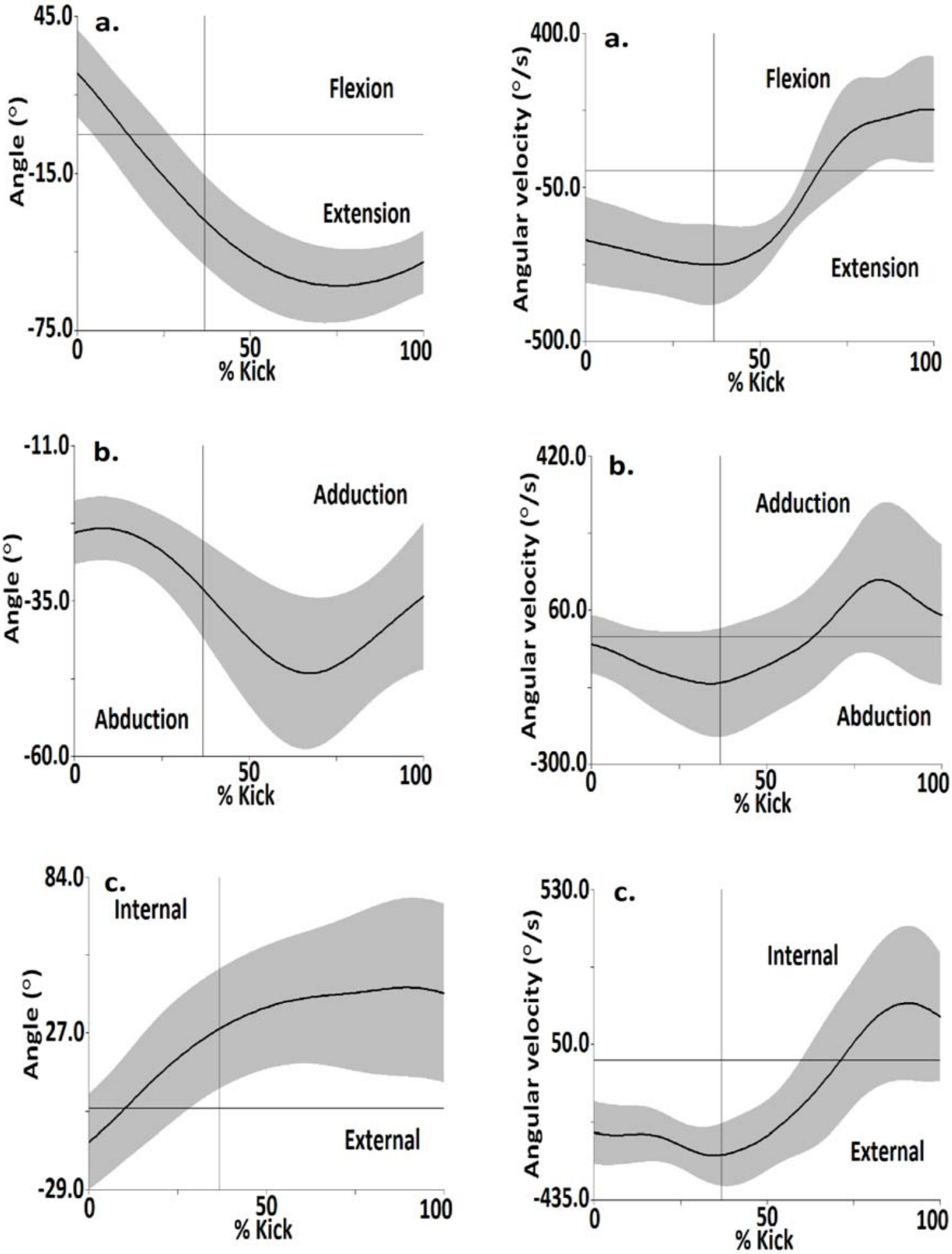

Figure 2: Mean and standard deviation right shoulder joint kinematics in the (a) sagittal, (b) coronal, and (c) transverse planes (Shaded area = 1SD). Vertical line denotes stance limb foot placement.

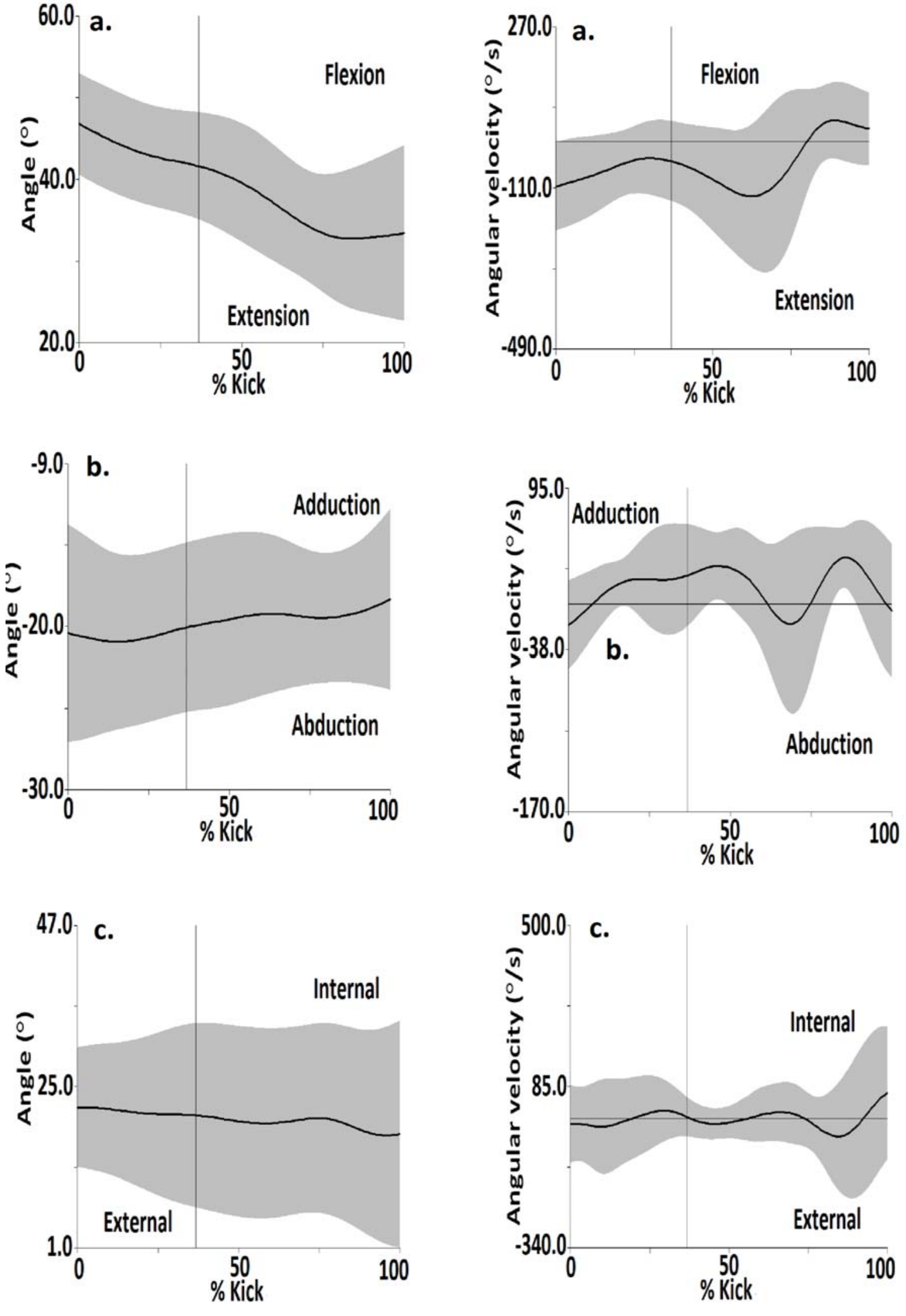

Figure 3: Mean and standard deviation right elbow joint kinematics in the (a) sagittal, (b) coronal, and (c) transverse planes (Shaded area = 1SD). Vertical line denotes stance limb foot placement.

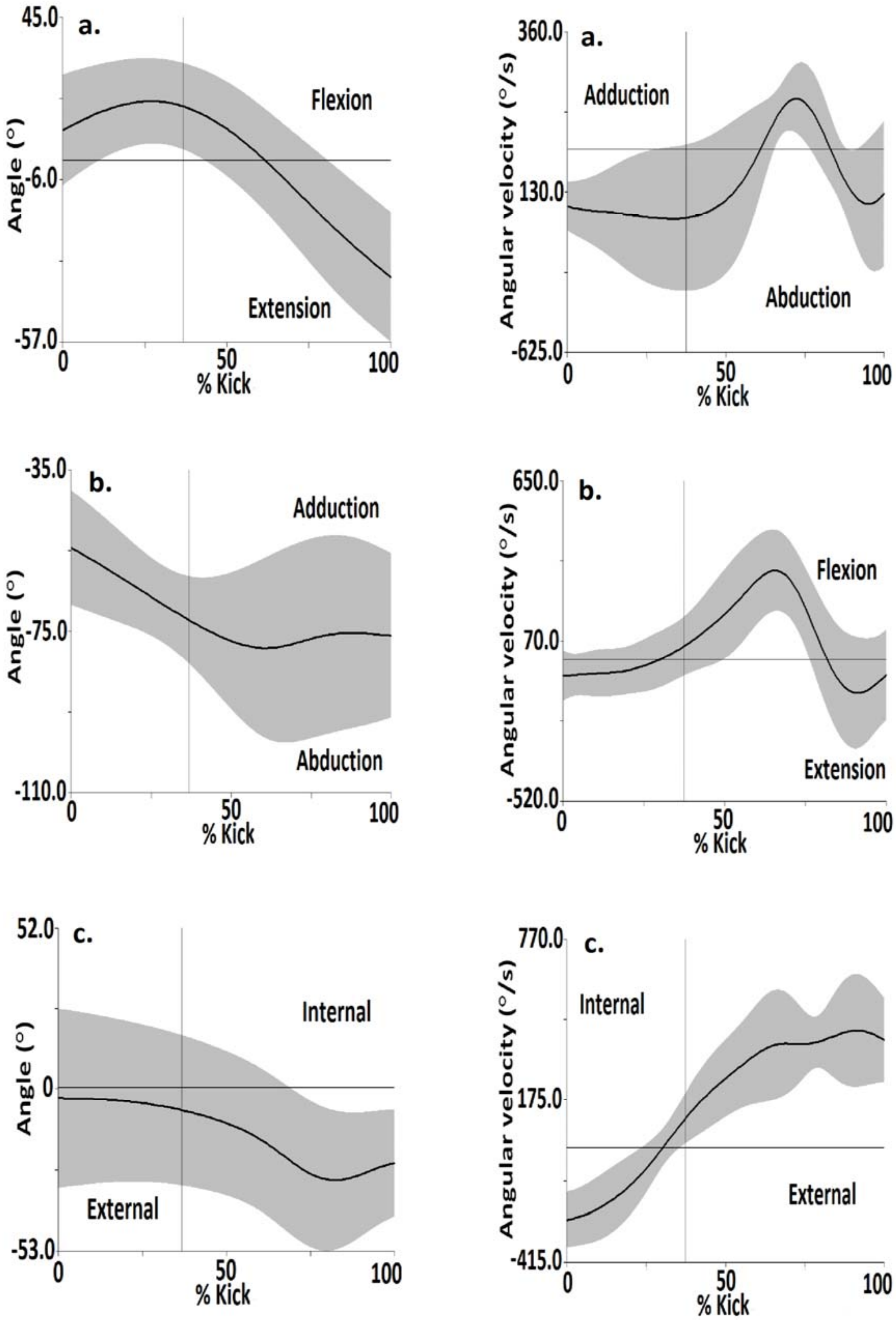

Figure 4: Mean and standard deviation left shoulder joint kinematics in the (a) sagittal, (b) coronal, and (c) transverse planes (Shaded area = 1SD). Vertical line denotes stance limb foot placement.

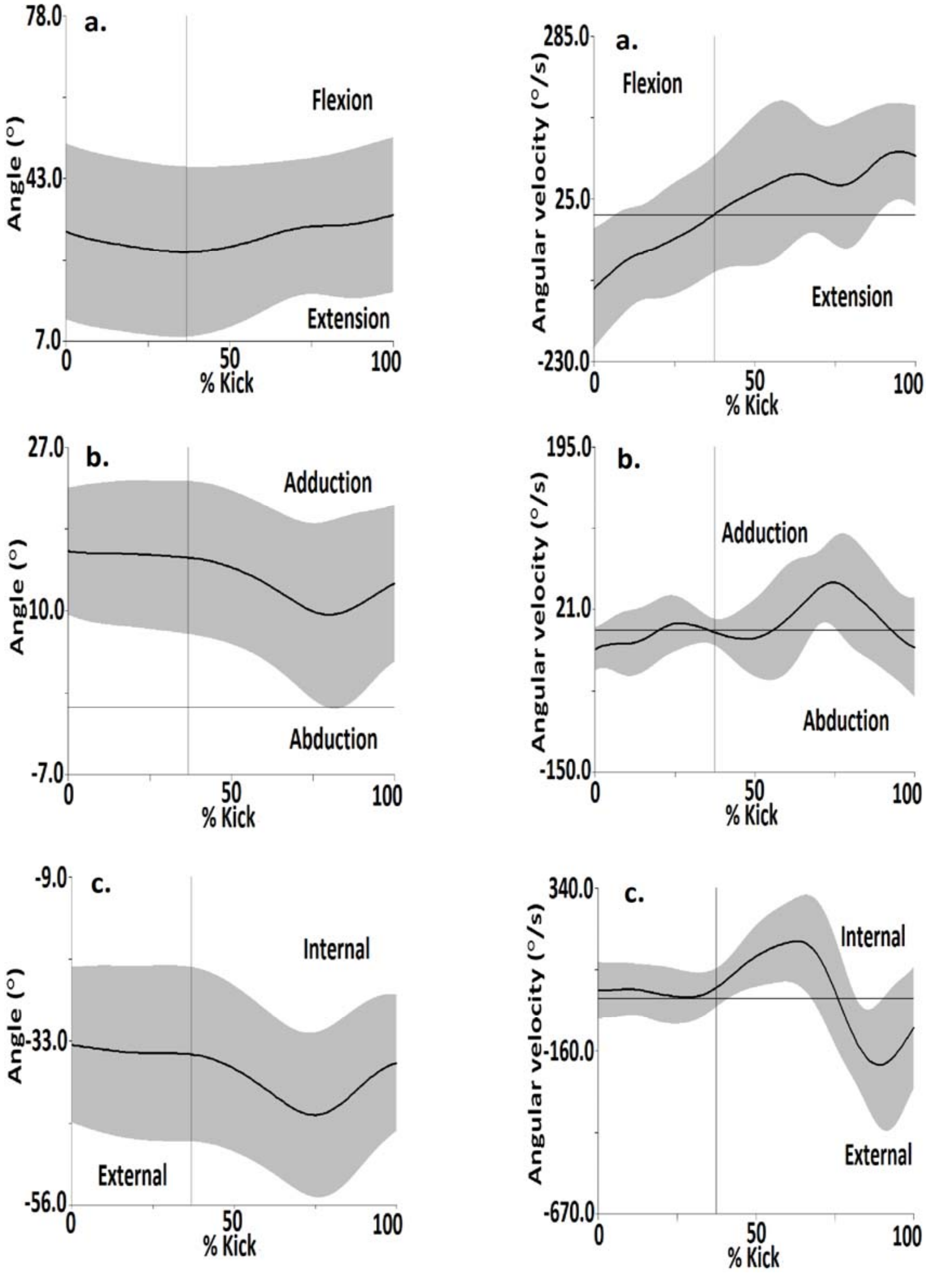

Figure 5: Mean and standard deviation left elbow joint kinematics in the (a) sagittal, (b) coronal, and (c) transverse planes (Shaded area = 1SD). Vertical line denotes stance limb foot placement.

4. Discussion

The aim of the current investigation was to determine the upper body discrete kinematic parameters pertinent to the development of ball velocity during maximal out of hand kicking. This study represents the first to examine these factors in rugby league using international standard kickers.

The key observation of the current investigation is the significant regression model. This suggests that ball velocity is significantly influenced by upper body movement kinematics during out of hand punt kicking. The overall regression analysis revealed that was the best predictors of ball velocity. The fit of the multiple regression analysis (Adj R^2 =0.81) suggests that variance in ball velocity may be significantly influenced by the upper body kicking technique employed by the player. This concurs with the early proposition by Macmillan (1975) who documented that variations in ball velocity during punt kicking are influenced by alterations in kinematics.

This finding corresponds with the comparative observations of Pfeifer (2012) who demonstrated that torso flexion angle increased with ball velocity. However that arm kinematics did not contribute strongly to the resultant ball velocity opposes the observations of Chen & Chang (2010) who noted that arm swing significantly influenced the resultant ball velocity. However, Chen & Chang (2010) examined the kinematic contributors to ball velocity during maximal instep football kicking. During instep football kicking the upper arm and forearm segments are free to move as they are not required to hold the rugby ball for the duration of the kick phase, thus their overall contribution of the arm swing to ball velocity is likely to be greater.

That trunk flexion magnitude at ball impact was found to be the strongest predictor of ball velocity makes intuitive sense. Shan and Westerhoff (2005) showed that the key attributes of maximal kicking could be summarized as the formation of a tension arc and the fast release of the tension developed. The release consists of a quasi-whip-like control sequence complimentary upper body movement. Shan and Westerhoff confirmed that the tension arc created by the kicking leg and upper-body generated an explosive muscle contraction through the pre-lengthening and makes the kick more powerful.

Furthermore, previous analyses have documented that greater reductions in centre of mass velocity prior to ball contact has been linked to increases in ball speed in both kicking (Potthast et al., 2010) and cricket bowling actions (Ferdinands et al., 2010). Both studies suggested this was due to a better transfer of momentum from full body motion of the approach into the more distal segments of the thigh in the case of soccer (Potthast et al., 2010) and the upper body and arm in the case of cricket bowing (Ferdinands et al., 2010). The trunk flexion angle is likely to relate strongly to modifications in centre of mass velocity when kicking by increasing the braking impulse produced during the stance phase. Therefore, although further research is necessary the influence of the trunk segment on centre of mass motion during kicking can be considered an important factor by coaches and conditioners as important to the enhancement of kicking performance in rugby league kickers.

Based on the findings of the current investigation, recommendations for training modifications can be made in order to improve ball velocity during out of hand punt kicking. There is evidence that an efficacious strength training program which encompasses concentric and eccentric exercises can improves kicking distance and power (DeProft et al., 1988). Given the findings of the current investigation it is recommended that rugby players wishing to improve kicking performance perform specific conditioning exercises aimed at developing the core and trunk flexor musculature. Core stability drills are frequently recommended as training techniques for rehabilitative, injury prevention and performance enhancement purposes (Kibler et al., 2006).The overall core musculature is critical in stabilizing the spine and pelvis during activities such as punt kicking where energy is generated and transferred from one body segment to the other and segmental velocities are summated. Kibler et al., (2006) documented that the core is central to all kinetic chains of sports activities and control of core strength, balance, and motion will capitalize on all kinetic chains of upper and lower extremity function. There is a currently a clear paucity of research available specifically examining the effects core strengthening programs on subsequent performance in tasks necessitating segmental summation along the kinetic chain. Nonetheless, it is recommended that conditioning exercises of the transvers abdominis, multifidus, external obliques, internal obliques, rectus abdominis and erector spinae muscles be integrated by rugby players into their training regimes.

In addition, it is also advocated based on the findings of this research that strengthening exercises of the trunk flexor muscles i.e.rectus abdominis external obliques, internal obliques, psoas erector spinae, iliocostalis, longissimus, spinalis and latissimus dorsi be conducted. This recommendation may have both clinical and performance implications. Togari and Asami (1972) showed that kicking performance was improved following a specific program of trunk strengthening exercises. Furthermore, from a clinical perspective Makalesi (2011) investigated the effects of habitual kickers on the lumbar spine degeneration. It was documented that kickers displayed greater lumbar disc degeneration. Therefore, they recommended that a well-balanced trunk muscle strength and spinal flexibility exercise program be emphasized in training program.

The regression analysis suggests that there is still variance in ball velocity that could not be accounted for by the upper body 3-D kinematic parameters observed in the current investigation. It is possible that some of this will be associated with the nature of impact, reported by various authors as important for kicking tasks (Lees & Nolan 1998; Asai et al., 2005; Plagenhoef, 1971). Bull-Andersen et al., (1999) reported that the resultant ball velocity in soccer kicking was due to foot speed and the coefficient of restitution between foot and ball. Ball flight characteristics could also alter these results, as different angles of trajectory and spin rates of the ball will alter how the ball flies through the air. Finally, whilst this study considered the contribution of the upper body to resultant ball velocity, no other inferences were considered.

5. Conclusions

In conclusion that a significant proportion of the variance in ball velocity was explained by a single kinematic parameters, suggests that this is clearly pertinent to the development of high ball velocities during out of hand kicks in rugby league. It is therefore conceivable that players may benefit from exposure to coaching and strength techniques geared towards the modification of kicking mechanics specific to this study. Whilst the outcomes of interventions featuring biomechanical feedback to improve kicking performance have are currently unknown, future work should still focus on implementing interventions to improve kicking performance.

6. Acknowledgements

Thanks go to Glenn Crook for his technical help and support throughout this work.

7. References

[1] Wu G, van der Helm FCT, Veeger HEJ, Makhsous M, Roy PV, Anglin C, Nagels J, Karduna AR, McQuade K, Wang X, Werner FW, Buchholz F. ISB Recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion - Part II: shoulder, elbow, wrist, and hand. *Journal of Biomechanics.* 2005, **38**: 981-992.

[2] Sinclair, J., Edmundson, C.J., Brooks, D., and Hobbs, S.J. Evaluation of kinematic methods of identifying gait Events during running. *International Journal of Sports Science and Engineering.* 2011, **5**: 188-192.

[3] Sinclair J, Greenhalgh, A, Edmundson CJ, and Hobbs SJ. The efficacy of barefoot and shod running and shoes designed to mimic barefoot running. *Footwear Science* (Epub ahead of print). 2012a.

[4] Sinclair, J., Taylor, P.J., Edmundson, C.J., Brooks, D., and Hobbs, S.J. Influence of the helical and six available cardan sequences on 3-D ankle joint kinematic parameters. *Sports Biomechanics.* 2012b, **11**: 430-437.

[5] Lim, E., Lay, B., Dawson, B., Wallman, K., & Anderson, S. Development of player impact ranking matrix in super 14 rugby union. *International Journal of Performance Analysis of Sport.* 2009, **9**: 354-367.

[6] Cappozzo, A., Catani, F., Leardini, A., Benedeti, M.G., & Della, C.U. Position and orientation in space of bones during movement: Anatomical frame definition and determination. *Clinical Biomechanics.* 1995, **10**: 171-178.

[7] Cappozzo, A., Cappello, A., Croce, U., & Pensalfini, F. Surface-marker cluster design criteria for 3-D bone movement reconstruction. *IEEE Transactions on Biomedical Engineering.* 1997, **44**: 1165-1174.

[8] Kibler, W.B., Press, J, and Sciascia, A. The role of core stability in athletic function. *Sports Medicine.* 1997, **36**: 189-198

[9] DeProft, E., Cabri, J., Dufour, W. and Clarys, J.P. Strength training and kick performance in soccer players. *In Science and Football.* Eds: Reilly, T., Lees, A., Davids, K., and Murphy, W.J. New York: E & F.N. Spon. 1988, pp. 108-113.

[10] de Mestre, N. *The mathematics of projectiles in sport.* Cambridge: Cambridge University Press. 1990.

[11] Lees, A., & Nolan, L. The biomechanics of soccer: A review. *Journal of Sports Sciences.* 1998, **16**: 211-234.

[12] Asai, T., Nunome, H., Maeda, A., Matsubara, S., & Lake, M. Computer simulation of ball kicking using the finite element skeletal foot model. In T. Reilly, J. Cabri, & D. Arau´ (Eds.). *Science and football V.* London: Routledge. 2005, pp. 77–82.

[13] Plagenhoef, S. *The patterns of human motion.* Englewood Cliffs, NJ: Prentice-Hall. 1971.

[14] Pottharst, W., Heinrich, K., Schneider, J. and Brueggemann, G. The success of a soccer kick depends on run-up deceleration. *In Proceedings of the 29th International conference on biomechanics in sports* (edited by Jensen, R. and Roemer, K.). USA: Northern Michigan University. 2010.

[15] Ferdinands, R., Marshal, R.N. and Kersting, U. Centre of mass kinematics of fast bowling in Cricket. *Sports Biomechanics.* 2010, **9**: 139-152.

[16] Makalesi, A. Determine the Effects of Long Term Playing Soccer on Lumbar Spine Degeneration: A Preliminary Study, Hacettepe. *Journal of Sport Sciences.* 2011, **22**: 146-153.

[17] Bull-Andersen, T., Dorge, H. C., & Thomsen, F. I. Collisions in soccer kicking. *Sports Engineering.*1999, **2**: 121-

126.

[18] Chen Y, Chang J-H. An investigation of soccer ball velocity on instep kick with and without arm swaying. *XXVIII International Symposium of Biomechanics in Sports July 2010 Marquette, MI, USA.* 2010.

[19] Togari, H and Asami, T. A study of training programs in Soccer, Dept of Physical education, University of Tokyo. 1972.