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Differences in the kinetics and kinematics of supported and un-supported landings of the rugby union line out.

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Abstract

The aim of the current investigation was to comparatively examine the kinetics and kinematics of supported and un-supported landings during the rugby union line out. Eleven male line-out jumpers were tested under two conditions, ‘supported’ in which the lifters maintained supportive contact with the jumper until the jumpers’ feet touched the floor and ‘un-supported’ in which the lifters released the jumper once they had caught the ball. Kinematics were examined using an eight camera motion capture system and kinetics using a force platform. Differences between conditions were examined using paired t-tests. The findings showed the instantaneous loading rate (supported = 212.9 ± 102.5 BW/s & un-supported = 449.0 ± 142.4 BW/s) and vertical velocity (supported = 2.7 ± 0.4 m/s & un-supported = 4.0 ± 0.4 m/s) at foot contact were significantly larger in the un-supported condition. The findings from the current investigation indicate that if the line-out jumper is un-supported by the lifters in returning to the ground then their risk from injury is likely to be greater. Therefore, given the number of line-outs that are conducted per game it is recommended that this law be clarified to also specify supported lowering of the jumper at all levels of play.

Introduction

In rugby union the lineout is a fundamental mechanism for restarting the game when the ball has left the field (Trewartha et al., 2008). The lineout is accomplished when the thrower throws the ball infield towards the two opposing units of jumpers and lifters whose aim it is to retain/ regain possession of the ball (Sayers, 2011). The lineout is a key attacking platform in rugby union that provides a mechanism for scoring opportunities (Trewartha et al., 2008). In professional rugby match play, the team who is in possession (i.e. the team that initiate the infield throw) will subsequently acquire possession of the ball in around 80 % instances and 26 % of all tries are attained after securing possession of the ball directly from a lineout (Trewartha et al., 2008).

In professional level rugby union matches there are approximately 34 lineouts in each game, (IRB, 2007). The ball must be thrown directly down the middle of the two opposing teams (separated by a gap of 1 m), thus teams must utilize a range of mechanisms in an attempt to secure possession. The principal manner by which this is achieved is by having the lifters hoist the jumper as high as possible allowing them to catch the ball prior to the opposition (Croft et al., 2011). Due to this the majority of lineout throws are now caught at a height of around 3.5 m (Sayers, 2011). The mass of the jumper is distributed equally between lifters at the start of the motion; however this is then transferred towards the rear lifter towards the end of the lineout (Sayers, 2011).

Once the ball has been caught and the lifters from both teams release the jumper resulting in a landing for the jumper. As such whilst each of the distinct positions in the lineout places different stresses on the body, given the height at which they are landing from it is likely that the jumpers are at greatest risk from musculoskeletal injury during the lineout. This notion is supported by the observations of Bathgate et al., (2002) who demonstrated that second row forwards are at the highest risk from injury in relation to all other players. Similarly, Brooks & Kemp, (2011) showed that firstly that second row forwards were at greater risk from injury at the Achilles tendon, ankle collateral ligament and knee anterior/ medial collateral ligaments in relation to other forwards and secondly that a higher proportion of these injuries were sustained as a function of the lineout in relation to other forwards.

The World-Rugby Law 19.10 (g) indicates that ‘’players who support a jumping team-mate must lower that player to the ground as soon as the ball has been won by a player of either team’’ (IRB, 2005). This rule is somewhat ambiguous in that it does not stipulate that supported lowering of the jumper by the lifters is a specific requirement. Rather it mandates that the lifters must not continue to support the jumper in the air once the ball is secured by either the attacking or defensive side. Therefore, in their haste to make it quickly to the next play, the jumper rotating 90° in order to set-up a driving maul from an attacking lineout, interference from the opposing jumpers challenging for the ball or competition from opposing forwards necessitating the rapid establishment of an attacking/ defensive maul; lifters may neglect or are unable to support the jumper appropriately in returning to the ground (Patton et al., 2006).

Despite the importance of the line-out to success in modern rugby union there is currently a paucity of published biomechanical information regarding the line-out and the majority has concerned the mechanics of the thrower (Sayers, (2005; Trewartha et al., 2008). However, whilst there is some information in scientific literature concerning the biomechanics of the thrower and the accuracy of the throw, there is currently no information regarding the mechanics of the jumper. Therefore, the aim of the current investigation was to examine the kinetics and kinematics of supported and un-supported landings during the rugby union line out. The current investigation may give important information to officials regarding the interpretation and clarity of law World-Rugby Law 19.10 (g).

Methods

Participants

Eleven male rugby union players volunteered to take part in this investigation. Each player had a minimum of 2 years of lineout jumping experience and played competitive rugby union at university first team level. All participants were free from musculoskeletal pathology at the time of data collection and provided written informed consent in accordance with the principles outlined in the Declaration of Helsinki. The mean characteristics of the participants were: age 22 ± 4 years, height 1.9 ± 0.1 m and body mass 93 ± 6 kg. The procedure utilized for this investigation was approved by the University of Central Lancashire, Science, Technology, Engineering and Mathematics, ethical committee.

Procedure

The test protocol required jumpers to catch 10 throws (5 supported and 5 un-supported) from a single thrower with 5 years of lineout throwing experience who competed at university first team level. World-Rugby Law mandates that front of the lineout must be at least 5 m infield, therefore in order to simulate a throw to a jumper at the front of the lineout, a linear distance of 6 m was chosen. The jumpers all wore taped jumping supports on their thighs and were supported by the same two lifters throughout, who had a minimum of 5 years of lineout lifting experience and who also were competitive at university first team level. In the supported condition the lifters were instructed to maintain supportive contact with the jumper until the point at which the jumpers’ feet touched the floor, whereas in the un-supported condition the lifters were required to release the jumper once they had caught the ball. The lifters and jumpers were positioned so that the jumpers dominant foot landed on an embedded piezoelectric force platform (Kistler, Kistler Instruments Ltd., Alton, Hampshire). To prevent any order effects, the supported and un-supported conditions were presented in a counterbalanced manner whereby five participants performed their supported trials first followed by the un-supported trials and vice versa. Participants (lifters and jumpers) were required to undergo a traditional warm-up procedure and several minutes of practice lineout drills prior to the commencement of data collection. The landing movement was defined as the duration from foot contact (defined as > 20 N of vertical force applied to the force platform) to maximum knee flexion.

Kinematics and ground reaction forces data were synchronously collected via an analogue board. Kinematic data was captured at 250 Hz via an eight camera motion analysis system (Qualisys Medical AB, Goteburg, Sweden). Dynamic calibration of the motion capture system was performed before each data collection session. Lower extremity segments were modelled in 6 degrees of freedom using the calibrated anatomical systems technique (Cappozzo et al., 1995). To define the segment co-ordinate axes of the foot, shank and thigh, retroreflective markers were placed bilaterally onto 1st metatarsal, 5th metatarsal, calcaneus, medial and lateral malleoli, medial and lateral epicondyles of the femur. To define the pelvis segment further markers were posited onto the anterior (ASIS) and posterior (PSIS) superior iliac spines. Carbon fiber tracking clusters were positioned onto the shank and thigh segments. The foot was tracked using the 1st metatarsal, 5th metatarsal and calcaneus markers and the pelvis using the ASIS and PSIS markers. The centres of the ankle and knee joints were delineated as the mid-point between the malleoli and femoral epicondyle markers (Sinclair et al., 2015; Graydon et al., 2015), whereas the hip joint centre was obtained using the positions of the ASIS markers (Sinclair et al., 2014). Static calibration trials were obtained allowing for the anatomical markers to be referenced in relation to the tracking markers/ clusters. The Z (transverse) axis was oriented vertically from the distal segment end to the proximal segment end. The Y (coronal) axis was oriented in the segment from posterior to anterior. Finally, the X (sagittal) axis orientation was determined using the right hand rule and was oriented from medial to lateral.

Data processing

Lineout trials from both supported and un-supported conditions were processed in Qualisys Track Manager and then exported as C3D files. Kinematic parameters were quantified using Visual 3-D (C-Motion Inc, Gaithersburg, USA) after marker data was smoothed using a low-pass Butterworth 4th order zero-lag filter at a cut off frequency of 15 Hz. Kinematics of the hip, knee and ankle were quantified using an XYZ cardan sequence of rotations (where X is flexion-extension; Y is ab-adduction and is Z is internal-external rotation). All data were normalized to 100 % of the landing phase then processed trials were averaged. Sagittal plane kinematic measures from the hip, knee and ankle which were extracted for statistical analysis were 1) angle at foot contact 2) angle at landing termination, 3) peak angle during landing, 4) angular range of motion (ROM) from footstrike to landing termination, and 5) relative ROM from foot contact to peak angle.

From the force platform instantaneous loading rate was calculated as the maximum increase in vertical force between adjacent data points (Sinclair et al., 2013). The instantaneous loading rate was normalized by dividing the values by each participant’s body weight (BW/s). In addition limb stiffness was quantified using a mathematical spring-mass model Blickman, (1989). Limb stiffness was calculated by dividing the peak vertical GRF by the amount of limb compression (Farley & Morgenroth, 1999). Limb stiffness was normalized to by dividing by participant’s bodyweight (BW/m).

Statistical analyses

Descriptive statistics (means and standard deviations) were obtained for each line-out condition. Shapiro-Wilk tests were used to screen the data for normality. Differences in kinetic and kinematic parameters were examined using paired t-tests. Statistical significance was accepted at the $P \leq 0.05$ level. All statistical actions were conducted using SPSS v22.0 (SPSS Inc, Chicago, USA).

Results

Kinetics

The kinetic analysis showed that instantaneous loading rate was significantly ($t=5.54$, $P<0.05$) larger in the un-supported (449.0 ± 142.4 BW/s) condition in relation to supported (212.9 ± 102.5 BW/s). In addition it was revealed that limb stiffness was significantly ($t=5.03$, $P<0.05$) greater in the supported (8.5 ± 2.6 BW/m) condition compared to un-supported (5.5 ± 2.0 BW/m).

Kinematics

The kinematic analysis showed that vertical velocity at foot contact was significantly ($t=10.02$, $P<0.05$) greater in the un-supported (4.0 ± 0.3 m/s) condition compared to supported (2.7 ± 0.4 m/s).

Hip

@@@ Table 1 near here @@@

For the angle at landing termination the hip was shown to be flexed to a significantly (t=6.15, P<0.05) greater extent in the un-supported condition. In addition, peak hip flexion was found to the significantly (t=6.02, P<0.05) greater in the un-supported condition. Finally, both ROM (t=10.04, P<0.05) and relative ROM (t=9.59, P<0.05) were shown to be significantly larger in the un-supported condition.

Knee

@@@ Table 2 near here @@@

For the angle at landing termination landing termination the knee was shown to be flexed to a significantly (t=6.89, P<0.05) greater extent in the un-supported condition. In addition, peak knee flexion was found to the significantly (t=6.75, P<0.05) greater in the un-supported condition. Finally, both ROM (t=5.74, P<0.05) and relative ROM (t=5.67, P<0.05) were shown to be significantly larger in the un-supported condition.

Ankle

@@@ Table 3 near here @@@

In addition, peak dorsiflexion was found to the significantly (t=3.17, P<0.05) greater in the un-supported condition.

Discussion

The aim of the current investigation was to examine the kinetics and kinematics of supported and un-supported landings of the rugby union line out. To the authors knowledge this research represents the first to examine the biomechanics of lineout jumpers during different conditions. The current investigation may give important information to coaches, clinicians and officials regarding the appropriate implementation of the lineout.

The first key observation from the current investigation is that instantaneous load rate was significantly larger in the un-supported condition in relation to the supported jumps. This observation may have important implications as there is believed to be a strong association between the magnitude of repeated impact loading and the aetiology of chronic lower limb injuries (Whittle, 1999). Therefore, this investigation suggests that in un-supported conditions jumpers are at increased risk from injury in relation to being supported until they reach the ground.

The current investigation importantly showed that the vertical velocity of the jumpers at foot contact was significantly larger in the un-supported condition. It is proposed that this change vertical velocity relates to the vertical (upwards) forces applied to the jumper by the lifters in the supported line-out condition. This provided resistance to the constant acceleration caused by gravity and thus reduced the velocity of the jumper at the instance of foot contact. It is likely that the increased vertical velocity at the point of foot contact is the mechanism responsible for the larger instantaneous rate of loading that was observed during the un-supported lineouts. The rate of loading is proportional to the change in momentum of the body during landing (Whittle, 1999), therefore an increased vertical velocity of the body at the instance of foot contact will mediate a proportional change in the vertical loading rate experienced by the body (Whittle, 1999).

In addition, the findings from the current investigation confirmed that significant changes in sagittal plane kinematics at all of the lower extremity joints were evident between lifting conditions. Specifically it was shown that peak angles at the hip, knee and ankle and ranges of motion at the hip and knee joints were significantly larger in the un-supported condition. It is proposed that jumpers utilized these mechanical alterations to promote deceleration as a result of the increased vertical velocity observed in the un-supported condition (Derrick, 2004). These alterations in lower extremity biomechanics serve to reduce the bodies' effective mass, and are utilized extensively in sports movements in response to a perceived high impact situation in order to decrease the proportion of total body mass that is decelerated during the impact phase (Derrick, 2004).

Of further importance to the current investigation is that limb stiffness was shown to be significantly larger in the supported in relation to the un-supported condition. This was to be expected given the kinematic observations as limb stiffness is expressed as a function of limb deformation under a given load (Farley & Morgenroth, 1999). It is proposed that this alteration in limb stiffness is a result of the changes in sagittal plane kinematics that were observed between the line-out conditions, which served to mediate increases in limb deformation. It is alleged that limb stiffness during the absorption phase preconditions the muscle-tendon units to store elastic energy, which may improve power production during explosive movements (Kyrolainen et al., 2001). It is currently unknown what implications this may have for performance at the line-out; but it is nonetheless an avenue that future investigations may wish to explore.

A potential limitation to the current research is the laboratory based nature of the data collection protocol. Although this was necessary in order to scientifically obtain synchronous kinetic and kinematic data in a controlled manner, the ecological validity of the procedure from a practical context was compromised. Furthermore, in the interest of generating an impartial comparison between the two line-out conditions the current investigation simulated an attacking line-out, during which there was no requirement to continue play after the jumper had landed. This indicates that the variants of the line-out that are dictated by the state of play and the position of the set-piece on the pitch were not accounted for. Future work may wish to concentrate on the different variants of the line-out in order to provide a more comprehensive representation of the biomechanics of jumper during the line-out.

In conclusion, although the biomechanics of the line-out have been examined previously (Sayers, 2005; Trewartha et al., 2008), there is currently no information regarding the mechanics of the jumper and therefore the effect of supported and un-supported conditions on injury risk has not been investigated. As such the current investigation adds to the current knowledge by generating a comprehensive evaluation of both kinetic and kinematic parameters measured during supported and un-supported line-outs. The results from this investigation indicate that both instantaneous loading rate and vertical velocity at foot contact were significantly larger in the un-supported condition, despite lower body kinematics in this condition being modified in favour of deceleration. The findings from the current investigation indicate that if the line-out jumper is un-supported by the lifters in returning to the ground then increased exposure to the mechanisms linked to injury are likely to be greater. Therefore, given the number of line-outs that are conducted per game it is recommended that this law be clarified to also specify supported lowering of the jumper at all levels of play.

References

1. Arampatzis, A., Brüggemann, G. P., & Metzler, V. (1999). The effect of speed on leg stiffness and joint kinetics in human running. Journal of Biomechanics, 32, 1349-1353.
2. Bathgate, A., Best, J. P., Craig, G., & Jamieson, M. (2002). A prospective study of injuries to elite Australian rugby union players. British Journal of Sports Medicine, 36, 265-269.
3. Blickhan, R. (1989). The spring-mass model for running and hopping. Journal of Biomechanics, 22, 1217-1227.
4. Brooks, J. H., & Kemp, S. P. T. (2011). Injury-prevention priorities according to playing position in professional rugby union players. British Journal of Sports Medicine, 45, 765-775.
5. Cappozzo, A., Catani, F., Della Croce, U., & Leardini, A. (1995). Position and orientation in space of bones during movement: anatomical frame definition and determination. Clinical Biomechanics, 10, 171-178.
6. Croft, H., Chong, A., & Wilson, B. (2011). Virtual reality assessment of rugby lineout throw kinematics. Sports Technology, 4, 2-12.
7. Derrick, T.R. (2004). The effects of knee contact angle on impact forces and accelerations. Medicine and Science in Sports and Exercise, 36, 832-837.

8. Farley, C. T., & Morgenroth, D. C. (1999). Leg stiffness primarily depends on ankle stiffness during human hopping. Journal of Biomechanics, 32, 267-273.
9. Graydon, R., Fewtrell, D., Atkins, S., & Sinclair, J. (2015). The test-retest reliability of different ankle joint center location techniques. The Foot and Ankle Online Journal, 8, 1-11.
10. IRB. (2004). The Laws of the Game of Rugby Union.
11. IRB. (2007). Rugby World Cup 2007 - Statistical Review and Match Analysis Retrieved 5th April, 2008, from http://www.irb.com/mm/document/newsmedia/0/071026ctirbanalysisrwc2007report%5f3830.pd
12. Patton, M. S., Johnstone, A. J., & Smith, F. W. (2006). A complex fracture of the talus following a rugby union line-out. Journal of Science and Medicine in Sport, 9, 185-189.
13. Sayers, M. (2005). A three-dimensional analysis of lineout throwing in rugby union. In Science and Football V: The Proceedings of the Fifth World Congress on Sports Science and Football (p. 99). Routledge.
14. Sayers, M. G. (2011). Kinematic analysis of line-out throwing in elite international rugby union. Journal of Sports Science & Medicine, 10, 553-558.
15. Sinclair, J., Hobbs, S. J., Currigan, G., & Taylor, P. J. (2013). A comparison of several barefoot inspired footwear models in relation to barefoot and conventional running footwear. Comparative Exercise Physiology, 9, 13-21.
16. Sinclair, J., Taylor, P. J., Currigan, G., & Hobbs, S. J. (2014). The test-retest reliability of three different hip joint centre location techniques. Movement & Sport Sciences, 31-39.

17. Sinclair, J., Hebron, J., & Taylor, P. J. (2015). The test-retest reliability of knee joint center location techniques. Journal of Applied Biomechanics, 31, 117-121.

18. Trewartha, G., Casanova, R., & Wilson, C. (2008). A kinematic analysis of rugby lineout throwing. Journal of sports sciences, 26, 845-854.

19. Whittle, M. W. (1999). Generation and attenuation of transient impulsive forces beneath the foot: a review. Gait & Posture, 10, 264-275.

Tables

Table 1: Hip joint kinematics as a function of un-supported and supported conditions.

	Un-supported		**Supported**		**P-value**
	Mean	***SD***	***Mean***	***SD***	
Sagittal plane (+ =flexion & - = extension)					
Angle at foot contact (°)	26.8	13.7	24.4	13.8	0.41
Angle at landing termination (°)	76.7	20.8	45.8	18.6	***0.0001***
Peak flexion (°)	76.9	20.7	46.3	18.3	***0.0001***
ROM (°)	49.9	14.0	21.5	10.0	***0.000002***
Relative ROM (°)	50.1	14.0	21.9	9.9	***0.000004***

Notes: Bold/ italic p-values denote statistical significance

Table 2: Knee joint kinematics as a function of un-supported and supported conditions.

	Un-supported		**Supported**		**P-value**
	Mean	***SD***	***Mean***	***SD***	
Sagittal plane (+ =flexion & - = extension)					
Angle at foot contact (°)	18.7	5.1	15.0	6.6	0.36
Angle at landing termination (°)	93.1	22.6	63.2	16.2	***0.00004***
Peak flexion (°)	93.1	22.6	63.2	16.2	***0.00004***
ROM (°)	74.4	22.7	48.2	14.3	***0.0001***
Relative ROM (°)	74.4	22.7	48.2	14.3	***0.0002***

Notes: Bold/ italic p-values denote statistical significance

Table 3: Ankle joint kinematics as a function of un-supported and supported conditions.

	Un-supported		**Supported**		**P-value**
	Mean	***SD***	***Mean***	***SD***	
Sagittal plane (+ =dorsiflexion & - = plantarflexion)					

Angle at foot contact (°)	-34.4	8.3	-36.8	7.3	0.11
Angle at landing termination (°)	15.5	7.7	14.2	7.3	0.21
Peak dorsiflexion (°)	20.8	8.5	17.6	7.1	***0.01***
ROM (°)	49.9	8.2	50.9	6.3	0.48
Relative ROM (°)	55.2	6.9	54.3	5.8	0.47

Notes: Bold/ italic p-values denote statistical significance