Rugby Union Contact Skills Alter Evasive Agility Performance During Attacking Ball Carries

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ABSTRACT
Rugby union is a collision sport where evasive agility running patterns and the tackle contest determine the effectiveness of attacking ball carries. This study used three-dimensional kinematic analysis to examine the running technique of eight highly trained rugby union players during three rugby based reactive (in response to a defender positioned at the *side-step*) agility conditions (non-contact, contact and fend). The fend condition involved pushing a defender away with the upper body during the *side-step* and both fend and contact conditions required impact with an additional defender at the *straighten-step*, simulating a rugby tackle. Results demonstrated that a reduction in the relative height of the centre of mass relative to standing height (%CM) occurred at the *straighten-step* during the contact condition (47.2 ±1.9 %CM) compared to the non-contact condition (49.1 ±1.8 %CM, $p < .001$). The fend condition was then shown to increase %CM at the *straighten-step* (48.4 ±2.7 %CM) when compared to the contact condition (47.2 ±1.9 %CM, $p = .017$). However this difference was not observed at tackle impact during the *straighten-step*, with similar %CM values for fend (45.1 ±3.4 %CM) and contact conditions (44.6 ±2.6 %CM, $p = .205$). Further analysis showed that the number of steps displayed between the *side-step* and *straighten-step* (*transition phase*) altered the %CM, with one step during the *transition phase* increasing %CM (49.3 ±1.5 %CM) compared to two *transition phase* steps (46.9 ±1.6 %CM, $p < .001$) and no *transition phase* steps (46.5 ±1.6 %CM, $p < .001$). The changes to running technique during agility conditions involving tackle situations highlight the need for running programs in rugby union to meet the specific requirements of match-play activities.

Key words: Centre of Mass, Defence Skills, Fending, Rugby Football, Running Speed

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Mike Lambert (University of Cape Town, South Africa)

INTRODUCTION

The ability to dominate the tackle contest during attacking ball carries is a central component of successful performance in rugby union [1]. Performance analysis research has demonstrated that the top 4 teams in the Super 14 rugby union competition demonstrate a higher percentage (19%) of tackle-breaks (attacking ball carriers successfully breaking-free of the attempted tackle from the defence) compared to the middle five (16%) and bottom five (11%) ranked teams [2]. Further research on attacking ball carries in rugby union has identified evasive agility strategies (change of direction manoeuvres) as key elements in determining these positive tackle outcomes [2-4]. Attacking ball carriers are likely to achieve a tackle-break when they receive possession of the ball at more than two body lengths from the defensive line with high running speed, then execute a *side-step* (direction change angle 20 – 60° with respect to running direction) one to two body lengths from the defence and then followed by a *straighten-step* (straighten angle 20 – 60° with respect to running direction) to advance the ball and gain territory [2].

It has also been shown that modifications to running technique when executing agility manoeuvres can improve dynamic stability and promote positive tackle outcomes for the attacking rugby player [5]. For example, the movements associated with the *side-step* function to increase the base of support and as a result, enhance the properties of dynamic stability when compared to other stepping strategies such as swerving [6, 7]. In addition, rapid step patterns (as opposed to long strides) have been shown to increase dynamic stability and enhance the effectiveness of running ability in evasive sports [5, 6, 8]. Beyond this, running technique in sports such as rugby union and the variation to technique during match-simulated conditions has received little consideration in the biomechanics literature.

The technical attributes displayed by the attacking ball carrier when in contact with the defence have also been shown to determine tackle outcome [1, 9]. For many years, rugby coaches have advocated that lowering body position (decreasing the centre of mass (CM)) through alterations to running technique such as increasing forward trunk lean represents an effective ball carrying technique during contact conditions [6, 8]. This concept has been explored further in performance analysis research examining attacking ball carries in rugby union [4]. It has been reported that over 95% of tackle-breaks were achieved with a combination of low body positions (characterised by low %CM relative to standing height and greater forward trunk lean relative to the horizontal) and strong leg drive characterised by the attacking ball carrier not submitting to the tackle [4]. From a practical view-point, effective ball carrying ability in rugby union is based on a combination of body positioning in the tackle as well as pre-contact evasive skill. Despite this, the biomechanics of combining contact skills and running ability in rugby union remains undescribed within the biomechanics literature.

Fending (the use of the hand/arm to push defenders away) is an attacking skill that is common to contact sports such as rugby union. Analysis of rugby union has shown that over a third of tackle-breaks were achieved when the attacking ball carrier used a fend [4]. This research also observed that in addition to resisting a tackle from a defender, fending created opportunities for the attacking ball carrier to offload the ball in the tackle, which is a key skill in rugby union [4]. The use of fending in this way suggests that it is a skill given considerable emphasis within training environments. Surprisingly, the skill of fending has not been described in the biomechanics literature. Clearly, an understanding of fending relating to effective contact skills would assist coaches in designing appropriate training programs and sport specific assessment procedures. There is also considerable scope to investigate how contact skills such as lowering body positions (e.g., decreasing %CM) and resistive fending alter the mechanics of evasive agility running technique during attacking ball carries in rugby union.

Accordingly, the current study explored the modification to agility running technique and body positions during three reactive (in response to a defender positioned at the *side-step*) performance conditions when an attacking ball carrier either made no contact with a defender (no contact condition), contact with a defender (contact condition) or fended a defensive opponent (fend condition). The fend condition required the attacking ball carrier to push a defender away with the upper body during the *side-step* and both fend and contact conditions required impact with an additional defender at the *straighten-step*, simulating a rugby tackle. Analysis explored the relationship between the speed of agility performance and running technique specific to rugby union attacking ball carries.

METHOD

EXPERIMENTAL APPROACH TO THE PROBLEM

Three-dimensional (3D) kinematic analysis was used to examine agility movement patterns during reactive performance conditions for non-contact, contact and fend conditions during rugby union ball carries. The requirements of the agility course as well as the contact and fend situations were based on prior performance analysis of attacking ball carries in rugby union [1-4]. In the current study, the body position of attacking ball carriers was assessed through two measures; the vertical height of the whole body centre of mass relative to standing height (%CM) and the forward trunk lean angle relative to the horizontal. Body position as well as foot placement patterns were compared between the conditions (non-contact, contact and fend). Variations to agility running technique with respect to performance speed were also explored.

SUBJECTS

Eight male high performance (international provincial level) rugby union players volunteered to participate in this study (age 23 ± 4 yr, height 1.83 ± .04 m, mass 98 ± 11 kg). Individual agility trials from each player were classified into three speed categories (fast, moderate and slow). Fast agility performances were a 0.5 standard deviation below the mean time and slow a 0.5 standard deviation above the mean time (moderate speeds between a 0.5 standard deviation above and below the mean performance time). Informed consent was obtained from all participants prior to testing and approval was granted by the University Human Research Ethics Committee.

PROCEDURES

Agility performances were measured for six successful *side-step* trials (movement initiated from the contralateral leg in reference to the intended change of direction, as opposed to a *cross-over step* where movement is initiated from the ipsilateral leg), through both right and left running lines during three agility tasks (non-contact, contact and fend). In testing, participants ran at maximal effort through an agility course that involved an evasive task in response to the oblique movement patterns of a defender (Figure 1). Participants were required to evade this defender with an initial *side-step* direction change through the appropriate running line (opposite to the direction of the defender) and then a subsequent straightening in the running line (*straighten-step*). The defender positioned at the initial *side-step* did not attempt to tackle participants, but in the third agility task (fend condition) participants pushed rapidly a target of dense foam located on the sternal region of this defender (fending). Separate to the defender positioned at the *side-step*, the contact situation in the second (contact) and third (fend) agility tasks involved a tackle impact at the *straighten-step*, where participants ran into a hit-shield (Profile Hit Shield, Silver Fern Australia Pty Ltd., Australia) held by a second defender. This was a simulation of the tackle in rugby union as used commonly within rugby union training environments. Testing was conducted on a dry, grassed playing surface and participants were required to carry a rugby ball and wear rugby footwear as well as any other necessary protective equipment, as regulated by the International Rugby Board.

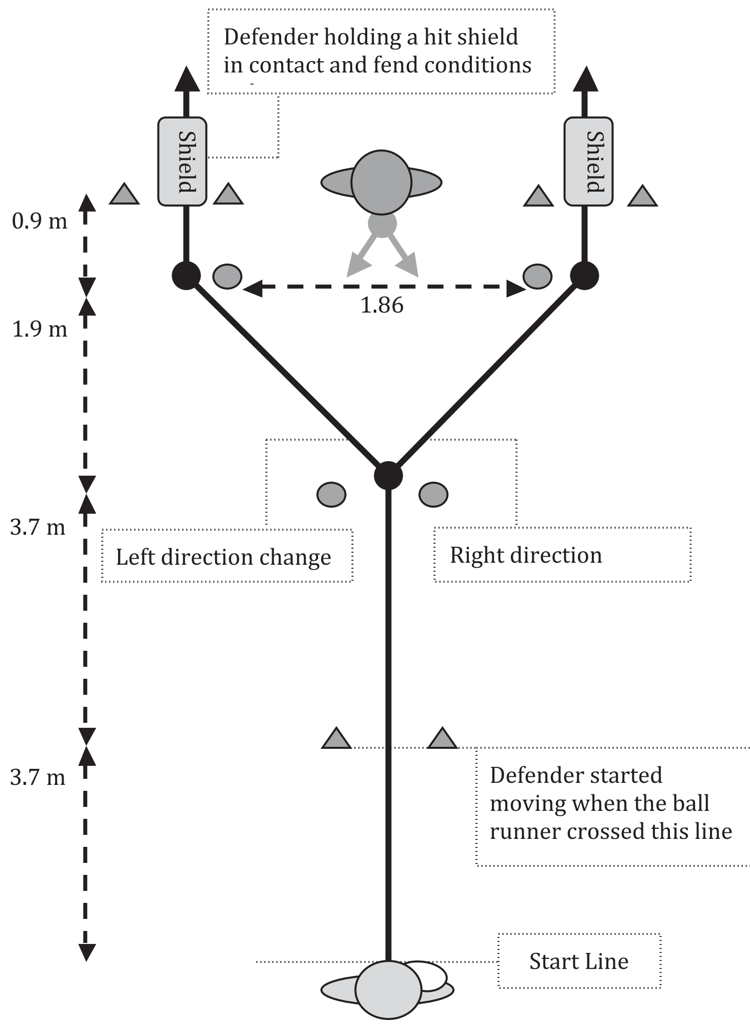

Figure 1. Transverse Plane Representation of the Agility Course Design

Video footage was captured by four PAL digital video cameras (Panasonic Nv-GS180GN, Matsushita Electric Industrial Co., Ltd., Japan) operating at 50 Hz and shutter speed set at 1/2000th s. The cameras were positioned at either ends of the agility course and at oblique angles so that the entire testing area was in the field of view. A single analyst digitized the footage and a 13-segment model of the body (20 anatomical landmarks) was created using the Ariel Performance Analysis System (Ariel Dynamics, Inc., USA) (5 Hz digital filter and 25 stationary control points for direct linear transfer calibration). High digitizing reliability (based on anatomical landmark coordinates) was established using Coefficient of Variation (CV) and Typical Error of Measurement (TEM) values in the mediolateral (CV = 0.4%, TEM = 0.01 m), anterioposterior (CV = 3.1%, TEM = 0.01 m) and vertical planes (CV = 0.9%, TEM = 0.01 m) [10].

Agility performances were divided into three components consisting *side-step* (initial change of direction) and *straighten-step* (straightening of the running line following the *side-step* direction change) with the *transition phase* between the *side-step* and *straighten-step* (Figure 2) [2]. The CM velocity was calculated for both running speed and lateral movement speed for the *side-step* and *straighten-step* (foot-strike to toe-off) as well as the *transition phase* (*side-step* toe-off to *straighten-step* foot-strike). The number of steps (foot contacts) taken during the *transition phase* was recorded for agility performances. Anterioposterior and mediolateral foot displacement at foot-strike and toe-off for each agility phase was also

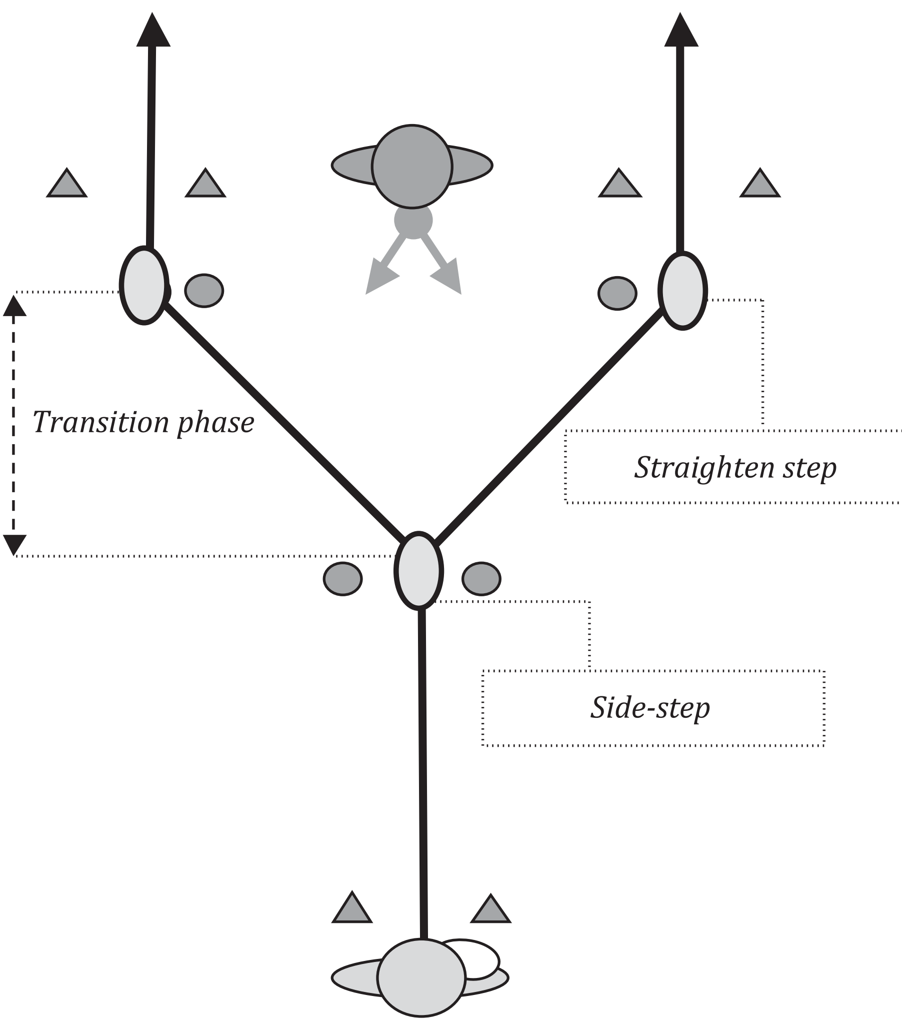

Figure 2. Transverse Plane Representation of Agility Phases

calculated relative to the CM and as a percentage of leg length (Figure 3). This study then examined two measures of body position (Figure 3). The first was forward trunk lean, which was the angle formed between the trunk and the anterioposterior line (e.g., 90° denotes upright posture). The second measure of body position was the vertical height of the CM relative to standing height (%CM). The %CM during the *transition phase* when players used any of the three different step strategies (0, 1 and 2) was then explored for the agility conditions.

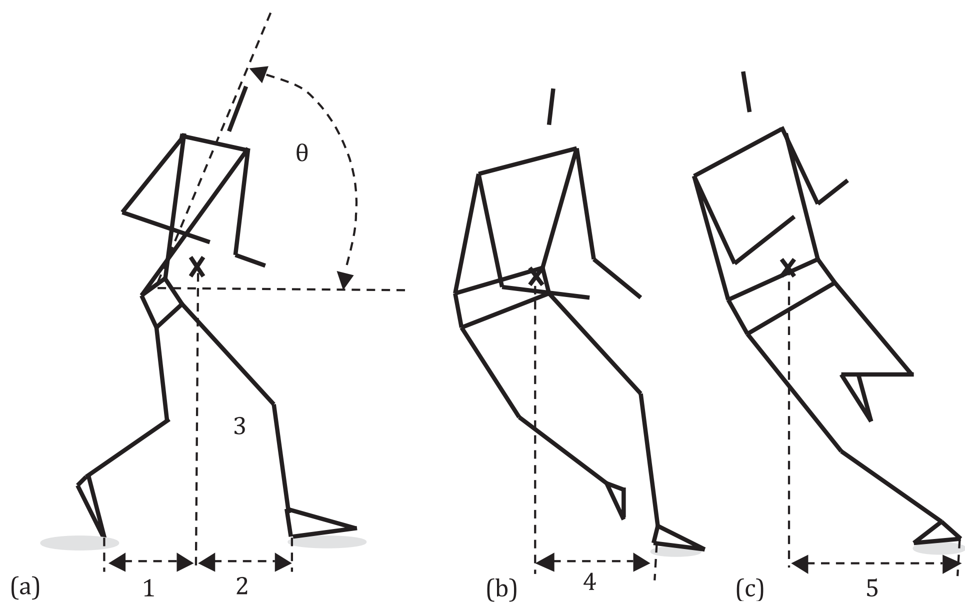

Figure 3. Representation of the Foot and Body Positions in the Sagittal Plane View (a) and Frontal Plane View (b and c)

STATISTICAL ANALYSES

Analysis using *t*-test (t (df) = 000, p = .000) compared the attributes of agility performances between non-contact and contact agility conditions as well as between contact and fend agility conditions (non-contact, contact and fend). Levene's test of equal variance was assumed unless stated otherwise. The use of *t*-test statistics to examine non-contact and contact conditions as well as contact and fend conditions was determined through exploratory data analysis. The difference between non-contact and fend conditions was deemed less relevant to the project aim and objectives, which meant that univariate analysis was not used in this study. Results then examined the differences in performance speeds (fast, moderate and slow) using one-way between subject analysis of variance (F (df) = 000, p = .000). Chi-squared (χ^2) analysis (χ^2 (df) = 000, p = .000) then examined the association between the agility conditions and the *transition phase* step strategy (0, 1 and 2). Significance was set at p < .05 for all analyses. Data is presented as means and (±SD) throughout.

RESULTS

SIDE-STEP

Results showed no significant difference to the change in either running speed (t (94) = -0.520, p = 0.604) or lateral movement speed (t (94) = 1.339, p = 0.184) between the non-contact condition (-1.1 ±0.4 $m.s^{-1}$ and 1.7 ±0.4 $m.s^{-1}$, respectively) and the contact condition (-1.0 ±0.4 $m.s^{-1}$ and 1.6 ±0.4 $m.s^{-1}$, respectively) during the *side-step* (Table 1). However, the fend condition resulted in a greater deceleration of running speed, with a reduction of -1.5 ±0.6 $m.s^{-1}$ compared to -1.0 ±0.4 $m.s^{-1}$ for the contact condition (t (94) = 4.773, $p < 0.001$). Also, running speed at toe-off of the *side-step* was less during the fend condition (3.3 ±0.6 $m.s^{-1}$) compared to the contact condition (4.2 ±0.7 $m.s^{-1}$, t (91.104) = 6.469, $p < 0.001$) (Table 2). Conversely, no significant difference was observed in the anterior position of the foot at foot-strike between the contact condition (40.5% ±13.4 %) and the fend condition (39.9% ±14.0 %) (t (94) = -0.209, p = 0.835). Despite this, the posterior position of the foot at toe-off was less during the fend condition (-20.6 ±14.8 %) compared to the contact condition (-30.2 ±15.1 %, t (94) = -3.157, p = 0.002).

Table 1. Comparison of Running Speed, Lateral Movement Speed and Foot Position During the *Side-Step* of Non-Contact and Contact Conditions

	Agility condition	
	Non-contact	**Contact**
Foot-strike		
Running speed ($m.s^{-1}$)	5.2 ± 0.5	5.2 ± 0.6
Lateral movement speed ($m.s^{-1}$)	0.2 ± 0.4	0.5 ± 0.6*
Anteroposterior foot position (%)	37.9 ± 13.3	39.9 ± 14.0
Lateral foot position (%)	44.5 ± 6.1	43.1 ± 6.1
Toe-off		
Running speed ($m.s^{-1}$)	4.2 ± 0.8	4.2 ± 0.7
Lateral movement speed ($m.s^{-1}$)	2.1 ± 0.5	2.2 ± 0.6
Anteroposterior foot position (%)	-32.1 ± 13.4	-30.2 ± 15.1
Lateral foot position (%)	75.1 ± 8.4	73.0 ± 7.6

* Significant difference between the non-contact condition and the contact condition.

Table 2. Comparison of Running Speed, Lateral Movement Speed and Foot Position During the *Side-Step* of Contact and Fend Conditions

	Agility condition	
	Contact	**Fend**
Foot-strike		
Running speed ($m.s^{-1}$)	5.2 ± 0.6	4.9 ± 0.5*
Lateral movement speed (m/s)	0.5 ± 0.6	0.5 ± 0.6
Anteroposterior foot position (%)	39.9 ± 14.0	40.5 ± 13.4
Lateral foot position (%)	43.1 ± 6.1	42.9 ± 6.7
Toe-off		
Running speed ($m.s^{-1}$)	4.2 ± 0.7	3.3 ± 0.6
Lateral movement speed (m/s)	2.2 ± 0.6	2.4 ± 0.4
Anteroposterior foot position (%)	-30.2 ± 15.1	-20.6 ± 14.8
Lateral foot position (%)	73.0 ± 7.6	75.2 ± 9.7

* Significant difference between the contact condition and the fend condition.

Analysis of the variation to velocity profiles with performance speed showed that moderate speed performances exhibited greater increases to lateral movement during the resistive fend execution (1.3 ±0.1 $m.s^{-1}$) compared to fast (0.8 ±0.1 $m.s^{-1}$, p = 0.014) and slow (0.8 ±0.1 $m.s^{-1}$, p = 0.019) (F (2, 45) = 6.008, p = 0.005) for the fend condition. It should be noted that fast performances displayed greater lateral movement speed at foot-strike of the *side-step* (0.9 ±0.6 $m.s^{-1}$) compared to moderate (0.3 ±0.3 $m.s^{-1}$, p = 0.005) and slow (0.2 ±0.5 $m.s^{-1}$, p = 0.002) during the fend condition (F (2, 45) = 8.845, p < 0.001). However, during the fend condition, fast performances displayed greater lateral movement speed at toe-off (2.7 ± 0.3 $m.s^{-1}$) compared to only slow performances (2.1 ±0.4 $m.s^{-1}$, F (2, 45) = 10.092, p < 0.001).

TRANSITION PHASE

Results showed that less deceleration of running speed occurred during the contact condition, with a reduction of -0.1 ±0.4 $m.s^{-1}$ compared to -0.3 ±0.5 $m.s^{-1}$ for the non-contact condition (t (94) = -2.425, p = 0.017). It was then shown that significant increases to %CM at the *straighten-step* foot-strike occurred with one *transition phase* step (49.3 ±1.5 %CM) compared to two *transition phase* steps (46.9 ±1.6 %CM, p = 0.001) and no *transition phase* steps (46.5 ±1.6 %CM, p < 0.001) (F (2, 45) = 10.057, p < 0.001) for the contact condition. It was also illustrated that attacking ball carriers demonstrated a greater increase to %CM during the *transition phase* when displaying only one *transition phase* step, compared to much smaller increases when using two *transition phase* steps or no *transition phase* steps (Figure 4).

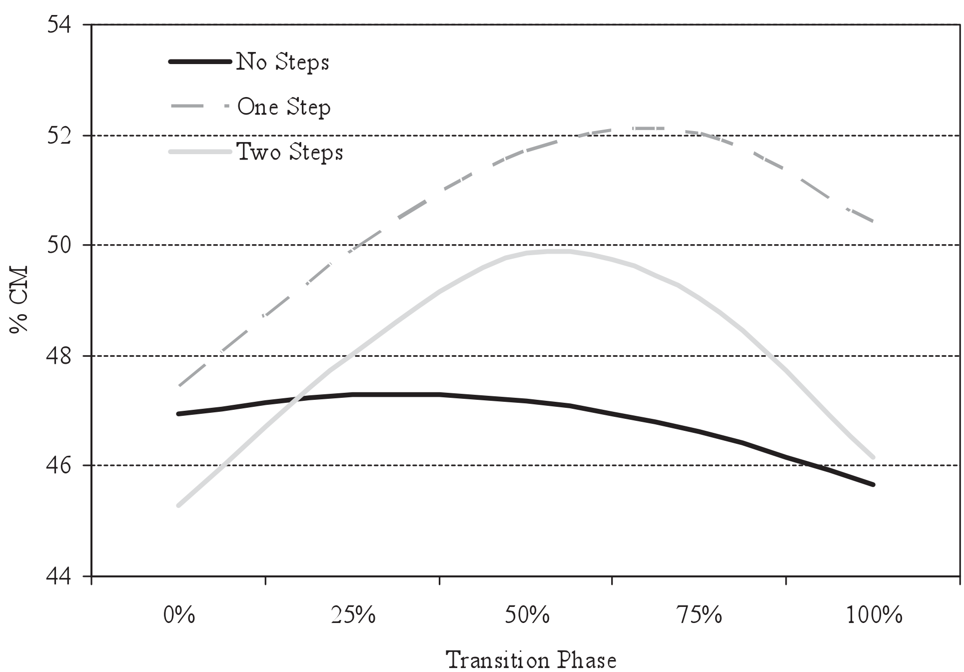

Figure 4. Greater Increase in %CM with One *Transition Phase* Step Compared to Lower %CM with No or Two *Transition Phase* Steps

During the transition phase, there was no significant difference in the change in running speed (t (94) = .260, p = .795) or the change in lateral movement speed (t (94) = 1.231, p = .222) between the contact condition (-0.1 ±0.5 m.s-1 and 0.1 ±0.4 m.s-1, respectively) and the fend condition (-0.1 ±0.4 m.s-1 and 0.2 ±0.4 m.s-1, respectively). Furthermore, a statistically significant association was not observed between agility conditions (non-contact, contact and fend) and the number of transition phase steps (0, 1 and 2) ($\chi 2(4) = 8.618$, p = .071). However, the standardised residuals (SR) indicated a positive association between the contact condition and no transition phase steps (SR = 2.0), with a third of performances in the contact condition displaying no steps during this phase. A negative trend was also observed where ball carriers completing the fend condition were less likely to use the no transition phase step strategy (SR = -1.2).

STRAIGHTEN-STEP

Results showed no significant difference in the change in running speed between the non-contact condition (0.8 ±0.4 $m.s^{-1}$) and the contact condition (0.7 ±0.3 $m.s^{-1}$, *t* (94) = 1.882, p = 0.063) (Table 3). There was also no significant difference observed in the change in lateral movement speed between the non-contact condition (-1.5 ±0.4 $m.s^{-1}$) and the contact condition (-1.5 ±0.4 $m.s^{-1}$, *t* (94) = -0.005, p = 0.996), but posterior foot position at toe-off was greater during the contact condition (-86.7 ±6.1 %) compared to the non-contact condition (-83.3 ±5.9 %, *t* (94) = 2.766, p = 0.007). During the contact condition, it was also shown that fast performers executed the *straighten-step* earlier preceding contact (-0.8 ±0.2 m) compared to the moderate (-0.5 ±0.2 m, p = .004) and slow (-0.3 ±0.2 m, p < .001) (*t* (2, 45) = 19.271, p < 0.001) performers who executed the *straighten-step* closer to the contact event. Further analysis showed greater running speed occurred at *straighten-step* foot-strike during the contact condition (4.1 $m.s^{-1}$) compared to the fend condition (3.2 $m.s^{-1}$, *t* (94) = 8.132, p < 0.001), which was associated with a posterior placement of foot-strike closer the vertical line of the centre of gravity (contact = -7.5 % and fend = -18.4 %, *t* (92.929) = 8.242, p = 0.002, equal variance not assumed) (Table 4). This difference remained during the *straighten-step* with an increased running speed observed at toe-off during the contact conditions (4.7 $m.s^{-1}$) compared to the fend condition (4.0 $m.s^{-1}$, *t* (92.462) = , p < 0.001, equal variance not assumed).

Table 3. Comparison of Running Speed, Lateral Movement Speed and Foot Position During the *Straighten-Step* of Non-Contact and Contact Conditions

	Agility condition	
	Non-contact	**Contact**
Foot-strike		
Running speed ($m.s^{-1}$)	3.8 ± 0.3	4.1 ± 0.6
Lateral movement speed (m/s)	2.5 ± 0.3	2.4 ± 0.4
Anteroposterior foot position (%)	-5.9 ± 16.0	-7.5 ± 15.7
Lateral foot position (%)	46.2 ± 9.5	46.8 ± 9.1
Toe-off		
Running speed ($m.s^{-1}$)	4.7 ± 0.5	4.7 ± 0.5
Lateral movement speed (m/s)	0.9 ± 0.5	0.9 ± 0.6
Anteroposterior foot position (%)	-83.3 ± 5.9	-86.7 ± 6.1*
Lateral foot position (%)	30.4 ± 10.8	31.2 ± 13.1

* Significant difference between the non-contact condition and the contact condition.

Table 4. Comparison of Running Speed, Lateral Movement Speed and Foot Position During the *Straighten-Step* of Contact and Fend Conditions

	Agility condition	
	Contact	**Fend**
Foot-strike		
Running speed (m.s-1)	4.1 ± 0.6	3.2 ± 0.5*
Lateral movement speed (m/s)	2.4 ± 0.4	2.5 ± 0.3
Anteroposterior foot position (%)	-7.5 ± 15.7	-18.4 ± 17.4*
Lateral foot position (%)	46.8 ± 9.1	47.0 ± 10.9
Toe-off		
Running speed (m.s-1)	4.7 ± 0.5	4.0 ± 0.4*
Lateral movement speed (m/s)	0.9 ± 0.6	0.7 ± 0.6
Anteroposterior foot position (%)	-86.7 ± 6.1	-84.6 ± 9.1*
Lateral foot position (%)	31.2 ± 13.1	35.6 ± 13.3

* Significant difference between the contact condition and the fend condition.

Analysis showed that %CM at the *straighten-step* foot-strike was less during the contact (47.2 ±1.9 %) compared to the non-contact condition (49.1 ±1.8 %, t (94) = 5.098, $p < 0.001$). The %CM at the *straighten-step* toe-off was also less during the contact (44.0 ±2.1 %) compared to non-contact condition (46.8 ±2.1 %, t (94) = 6.426, $p < 0.001$). This was then reflected in the forward trunk lean values where greater forward trunk lean (lower body positions) at the *straighten-step* toe-off was observed during the contact (51.1 ±9.2°) compared to non-contact condition (65.1 ±9.2°, t (94) = 8.133, $p < 0.001$). Importantly, it was shown that greater increases in forward trunk lean (resulting in lower body positions) were observed during the contact (-19.8 ±11.0°) compared to the non-contact condition (-10.5 ±8.9°, t (94) = 4.566, $p < 0.001$). Figure 5 represents the body position at the *straighten-step*

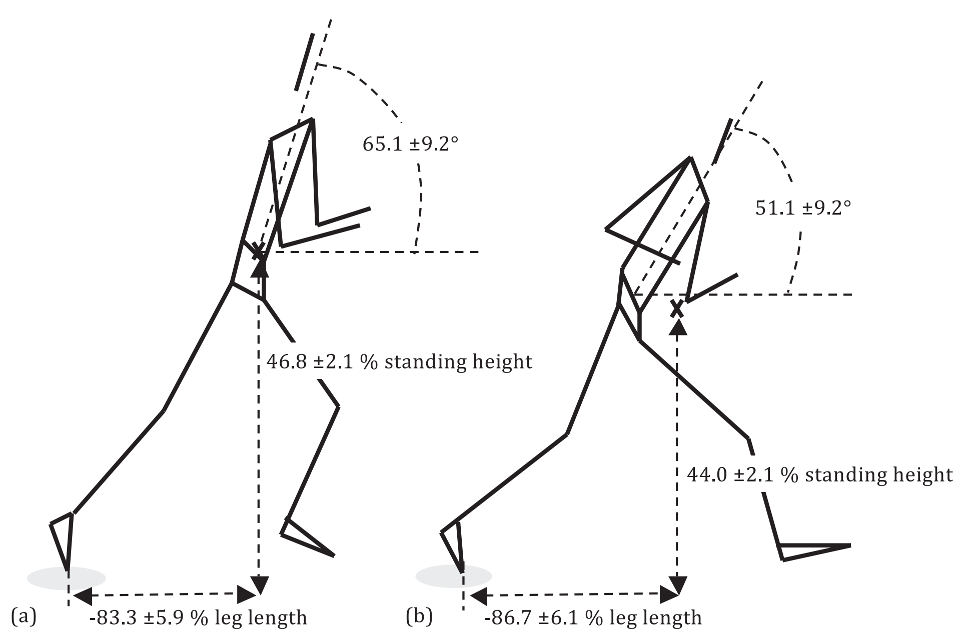

Figure 5. Sagittal Plane Representation of Foot and Body Positions at *Straighten-Step* Toe-Off for the Non-Contact Condition (a) and the Contact Condition (b)

toe-off including forward trunk lean, %CM and the posterior position of the foot observed during non-contact and contact condition.

No significant difference was observed in lateral movement speed at the *straighten-step* foot-strike between the contact condition (2.4 ±0.3 $m.s^{-1}$) and the fend condition (2.5 ±0.4 $m.s^{-1}$, t (94) = -0.494, p = 0.622). However, a greater redirection of lateral movement was observed during the fend condition (-1.8 ±0.5 $m.s^{-1}$) compared to the contact condition (-1.5 ±0.4 $m.s^{-1}$, t (94) = 2.527, p = 0.013). In addition, %CM at *straighten-step* foot-strike was greater during the fend (48.4 ±2.7 %) compared to contact condition (47.2 ±1.9 %, t (84.099) = -2.431, p = 0.017, equal variance not assumed). Despite this, no significant difference was observed in %CM at tackle impact between the contact condition (44.6 ±2.6 %) and the fend condition (45.1 ±3.4 %, t (87.740) = -0.839, p = 0.403, equal variance not assumed), and no significant difference in forward trunk lean at tackle impact between contact (49.7 ±8.7°) and fend conditions (47.1 ±11.4°, t (94) = 1.278, p = 0.205). Figure 6 depicts the similar forward trunk leans angles between the contact condition and the fend condition and the greater forward trunk lean observed during the contact and fend conditions compared to the non-contact condition.

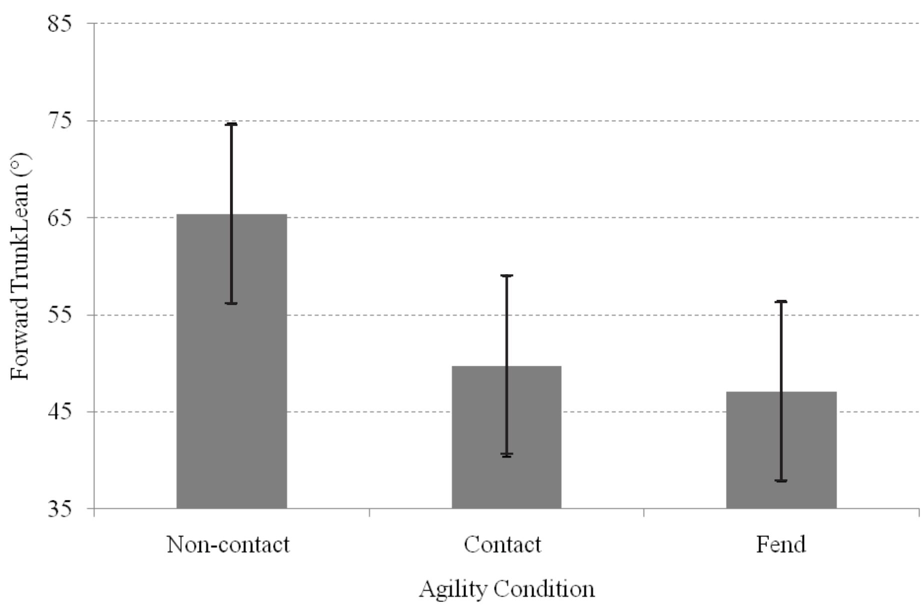

Figure 6. Similar Trunk Lean Angles for the Contact and Fend Conditions and Greater Trunk Lean Angles During the Contact Condition and the Fend Condition Compared to the Non-Contact Condition

DISCUSSION

SIDE-STEP

The findings of this study suggest that fending is a key factor to enhance lateral movement speed during the *side-step* in rugby union, particularly when performers display less lateral movement at the initiation of this step. This was demonstrated where moderate performances had less lateral movement speed at the *side-step* foot-strike (compared to faster performers), but used the fend execution to provide vital increases to lateral movement speed during this phase. This finding builds on performance analysis research that has shown fending strategies promote the likelihood of attacking ball carriers to break free from the defensive tackle in rugby union [4]. Hence, fending in rugby union represents an important strategy in resistance of the defence and also a mechanism to increase lateral movement during evasive agility skill execution. This has implications for training programs in contact sports, where improving the fending technique of players (using the fend to resist defenders and increase lateral movement when changing directions) would no doubt enhance their evasive running ability. Clearly, there is considerable scope for further research to investigate the relationship between the outcome of performance and additional biomechanical factors (e.g., the force-time characteristics of different fending strategies) associated with fending during attacking ball carries in rugby union.

TRANSITION PHASE

Importantly, this study showed that %CM at the *straighten-step* foot-strike was greater when using one step through *transition phase* as opposed to no *transition phase* steps and two *transition phase* steps. It has been noted that measures of body position are an important consideration in contact sports [6, 8]. In rugby union, attacking ball carriers that display increases to the height of their body position promote inherent instabilities to dynamic balance, which decreases the effectiveness of performance when attacking ball carries are attempting to resist a defensive opponent [4]. Conversely, attacking ball carriers who lower their body position into contact considerably increase the chance of retaining the ball at the breakdown and, as such, the considerably lower body positions observed when making contact with a defender in the current study no doubt present as a meaningful change to running mechanics [1, 4]. Adding to the existing understanding of contact skills in rugby, the current study showed that using one step through the *transition phase* raised the athlete's %CM prior to contact, and consequently is an ineffective *transition phase* step strategy during evasive agility manoeuvres in rugby union. In a functional setting, it is important that agility training emphasises low body positions preceding contact and this is achieved when employing no or two steps through the *transition phase* of an evasive agility manoeuvre. Hence, agility training for contact sports should focus on a player's ability to *side-step* and *straighten-step* with minimal flight time (rapid step pattern needed when displaying no *transition phase* steps) or *side-step* then *straighten-step* with two *transition phase* steps (shuffle technique). Preferably, attacking ball carriers should display the shuffle technique to maintain lower body positions and also greater dynamic stability brought about with increased ground contact time.

The stance properties exhibited during the *transition phase* contribute an important component during agility skill execution, where the increase in ground contact time achieved with additional *transition phase* steps (e.g., two *transition phase* steps compared to no *transition phase* steps) enhance dynamic stability [11]. In rugby union, periods of flight during agility manoeuvres (e.g., no *transition phase* steps) provide the body with no stable base of support. Consequently, the ability to resist an opponent would be severely diminished and this would no doubt reduce the effectiveness of running ability during attacking ball carries. In contrast, the inclusion of additional steps during the *transition phase* is a key technique to increase the effectiveness of running ability, by providing a stable base of support in resistance of opponents. Training attacking ball carries to display rapid step patterns when changing directions (such as a shuffling technique as opposed to leaping from *side-step* to *straighten-step*) would no doubt be beneficial to players in contact sports such as rugby union.

The conflicting findings where the contact condition was associated with no *transition phase* steps and players completing the fend condition tended not use the no *transition phase* step strategy, suggests that further investigation of dynamic stability when running with the ball in contact sports is warranted. Despite this, supporting the notion that additional *transition phase* steps promotes enhanced dynamic stability, it was found that the utilisation of the no *transition phase* step pattern was rarely observed during evasive agility performance in the fend condition. The complexity of agility skill execution combined with the fend execution in resistance of the defensive opponent no doubt required greater dynamic stability. Consequently, additional *transition phase* steps functioned to increase lateral movement by providing a more stable base of support in resistance of the defensive opponent. It is proposed that strong fend execution over a short period of time and with a stable base of support would promote the effectiveness of running ability in rugby union. Performance analysis research has demonstrated that the ability to resist defenders using such attacking skills is imperative to success in rugby union [4]. Over a third of tackle-breaks were shown to occur when attacking ball carriers fend opposing defenders [4]. It is necessary that further research examine the characteristics of fend execution (e.g., the most effective hand placement patterns when fending the opposition) with reference to enhancing the running ability of attacking ball carriers in rugby union.

STRAIGHTEN-STEP

The extensive reductions to body position observed with the presence of contact during the *straighten-step* of evasive agility manoeuvres builds on the understanding that lower body positions improve the effectiveness of attacking ball carries in rugby union [1]. To add to this, significant variations to lower extremity biomechanics have been observed with the inclusion of a simulated defensive opponent during agility testing [12]. This emphasises the distinctive kinematic characteristics displayed under sport-specific situations in rugby union, and adds weight to the notion that agility is a unique skill. Clearly, agility training in contact sports must focus on low body positions during situations where attacking ball carriers are colliding with defenders, such as during one-on-one opposed games in a restricted space (e.g., 5 m x 5 m grid). These training methods will no doubt enhance sport specific running ability and can also be used concurrently to improve defensive technique.

CONCLUSION

Although recent advances have been made in the testing of agility [13], the methods used to assess and train agility and more generally running ability in rugby union are typically conducted using non-sport specific conditions [14-19]. In contrast, the findings of the current study suggest that the specific requirements of rugby alter agility running technique, particularly body positions when encountered with defenders. This emphasises that appropriate agility assessment procedures and training programs must reflect match-play conditions, such as including contact and fending skills. Agility training involving contact could be incorporated into existing contact training drills (common in rugby union) to prevent an excessive number of body impacts and associated injury. In addition, appropriate testing and training methods in rugby union must consider ball carrying techniques and decision-making strategies in assessing the effectiveness of running ability. Rugby union coaches are encouraged to use technique analysis (e.g., assess *side-step* strategies and the body positions displayed by attacking ball carriers when attempting to evade defenders) and combine this information with the speed of performance to provide a comprehensive assessment of running ability.

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