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Research article

Modification of agility running technique in reaction to a defender in rugby union

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Abstract
Three-dimensional kinematic analysis examined agility running technique during pre-planned and reactive performance conditions specific to attacking ball carries in rugby union. The variation to running technique of 8 highly trained rugby union players was compared between agility conditions (pre-planned and reactive) and also agility performance speeds (fast, moderate and slow). Kinematic measures were used to determine the velocity of the centre of mass (COM) in the anteroposterior (running speed) and mediolateral (lateral movement speed) planes. The position of foot-strike and toe-off was also examined for the step prior to the agility side-step (pre-change of direction phase) and then the side-step (change of direction phase). This study demonstrated that less lateral movement speed towards the intended direction change occurred during reactive compared to pre-planned conditions at pre-change of direction (0.08 ± 0.28 $m \cdot s^{-1}$ and 0.42 ± 0.25 $m \cdot s^{-1}$, respectively) and change of direction foot-strikes (0.25 ± 0.42 $m \cdot s^{-1}$ and 0.69 ± 0.43 $m \cdot s^{-1}$, respectively). Less lateral movement speed during reactive conditions was associated with greater lateral foot displacement (44.52 ± 6.10% leg length) at the change of direction step compared to pre-planned conditions (41.35 ± 5.85%). Importantly, the anticipation abilities during reactive conditions provided a means to differentiate between speeds of agility performance, with faster performances displaying greater lateral movement speed at the change of direction foot-strike (0.52 ± 0.34 $m \cdot s^{-1}$) compared to moderate (0.20 ± 0.37 $m \cdot s^{-1}$) and slow (-0.08 ± 0.31 $m \cdot s^{-1}$). The changes to running technique during reactive conditions highlight the need to incorporate decision-making in rugby union agility programs.

Key words: Agility, decision-making, kinematic analysis, locomotion, side-step, rugby football.

Introduction

The fundamental elements contributing to success in open skilled sports such as rugby union are ultimately determined by effective decision-making strategies (Abernethy, 1991). In addition, expressions of agility performance (such as evasive running patterns during attacking ball carries) are essential skills in rugby union (Sayers and Washington-King, 2005). Attacking ball carriers who demonstrate proficient agility do so with accurate decision-making strategies in response to the movements and body positions of the opposition so that they outmanoeuvre defenders and advance the ball (Sayers, 1999). It is important to note that previous research has observed less than 50% commonality between reactive (decision required) and pre-planned (no decision necessary) agility performances (Farrow et al., 2005; Sheppard et al., 2006). Despite this, the assessment of agility performance without a decision making element has been a characteristic of many biomechanical studies in this area (Bencke et al., 2000; Rand and Ohtsuki, 2000; Schot et al., 1995). Accordingly, there exists a limited understanding regarding the modification to agility running technique during reactive agility when compared to pre-planned agility conditions.

The importance of understanding the difference between reactive and pre-planned agility is demonstrated in the fact that agility performance times during pre-planned movement patterns cannot differentiate between levels of team sport athletes (e.g. high performance and less skilled athletes) (Baker and Newton, 2008; Gabbett et al., 2008). In contrast, faster agility performances during reactive conditions have been observed in high performance athletes compared to athletes of lesser ability (Farrow et al., 2005; Sheppard et al., 2006). High performance athletes clearly possess superior decision-making strategies within a sports specific context that subsequently enhances the speed of reactive agility performance (Farrow et al., 2005; Sheppard et al., 2006). Moreover, the ability to extract precise information based on subtle movement cues of opponents and then predict the movements of these opponents is a common observation of highly skilled performers within open skilled sports (Abernethy, 2001). Importantly, further research has suggested that superior anticipation strategies allow more effective movement patterns (particularly muscle activation strategies) during the initial side-step of an agility manoeuvre (Besier et al., 2001a). However, beyond this, there is a gap in the research where decision-making strategies associated with a variation to movement patterns and foot positions during evasive agility manoeuvres are not described in the scientific literature.

Agility tasks that involve reaction to a sport specific stimulus have been shown to differentiate between respective athletic levels, that were not apparent with less specific conditions such as directional light displays (Shim et al., 2005; Ward and Williams, 2003). Clearly, the presence of sport specific perception and decision-making strategies (reactive conditions) are important considerations when designing effective agility assessment procedures. Despite this, the reactive components of agility testing are presented frequently throughout the literature in forms unrelated to sports specific performance such as light cues, verbal instructions and hand signals (Besier et al., 2003; Besier et al., 2001b; Maki et al.,

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1996; Pollard et al., 2004; Rand and Ohtsuki, 2000). It is necessary to include the presence of sport specific reactive conditions during agility assessment procedures. Building on this, there is considerable scope to implement this sort of research within the context of attacking ball carries in rugby union.

This study investigated the differences in agility (side-stepping manoeuvres) running technique between reactive and pre-planned performance conditions during a rugby specific task. In addition, the modification to running technique during reactive conditions (evasive side-stepping manoeuvres) was examined with respect to the speed of agility performance. Importantly, the current study observed evasive agility running technique with the inclusion of a decision-making element (reactive agility) that resembled the performance characteristics of attacking ball carries in rugby union.

Methods

Participants

Eight high performance (national and international representatives) male rugby union players volunteered to participate in this study (age 23 ± 4 yr, height 1.83 ± 0.04 m, mass 98 ± 11 kg). Players were divided into three speed categories based on their mean agility performance times, with fast performances above 0.5 standard deviations from the mean performance time, slow 0.5 standard deviations below the mean and moderate between these categories. The speed of agility performance was calculated as the time between the foot-strike of the pre-change of direction phase until toe-off of the first re-acceleration step as the athlete straightened the running line after the initial direction change. All test procedures were approved by the University Human Research Ethics Committee, and informed consent was obtained from all participants prior to testing. Participants received descriptions and demonstrations of the agility assessment tasks (pre-planned and reactive conditions) and completed non-measurable performances of the agility course (including the reactive condition) as part of their warm-up.

Data collection

Six digital video cameras (Panasonic Nv-GS180GN, Matsushita Electric Industrial Co., Ltd., Japan) operating at 50 Hz and with the shutter speed manually set to capture at 1/2000th s were used to record each trial. The video cameras were positioned at oblique angles to the agility testing area. Testing was conducted on a dry, grassed playing surface with participants required to wear rugby boots and carry a rugby ball whilst running at maximal effort through the agility course (Figure 1). Two different test conditions were examined. In the first test, participants nominated which direction (right or left) they were going to run through the course prior to commencing each trial (pre-planned). The second test condition included a decision-making element with the stimulus (in the form of a defender simulating rugby union defensive movement patterns) presented during the initial direction change (Figure 1). This task required participants to traverse the opposite running line to the oblique movements of the defender (e.g. if the defender moved to the participant's left then they would react and step to the right and continue through the right side of the course) (Figure 1). It should be noted that the defender was used as a reactive stimulus only and did not tackle the participants as they completed the reactive agility task. Participants completed 12 trials for each condition (6 trials for both right and left directions) with the order and condition randomised throughout testing.

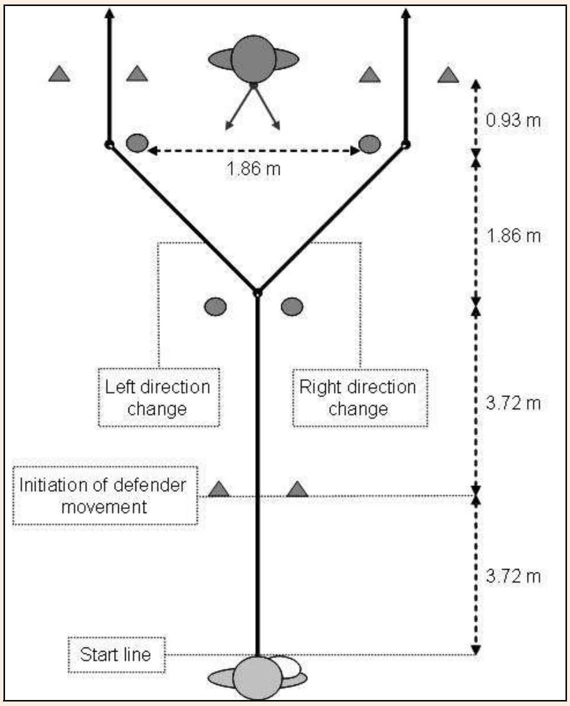

Figure 1. Transverse plane diagram of the agility course design.

Data analysis

The Ariel Performance Analysis System (Ariel Dynamics, Inc., USA) with a 5Hz digital filter was used to manually digitise 20 anatomical landmarks (forming a full body model) and 25 stationary control points (direct linear transfer calibration) for kinematic analysis. Digitising was completed by a single analyst demonstrating high intra-tester reliability (based on anatomical landmark coordinates digitised over two occasions for one complete agility performance) using Coefficient of Variation (CV) and Typical Error of Measurement (TEM) values in the anteroposterior (CV = 3.12%, TEM = 0.01 m), mediolateral (CV = 0.42%, TEM = 0.01 m) and vertical planes (CV = .87%, TEM = 0.01 m) (Menz et al., 2004).

Kinematic analysis examined the affects of decision-making for the step prior to the agility side-step (pre-change of direction phase) and then the side-step (change of direction phase) (Figure 2). Variables were then collected at foot-strike and toe-off of the pre-change of direction and change of direction phases. Kinematic measures were used to determine the velocity of the centre of mass (COM) in the anteroposterior (running speed) and mediolateral (lateral movement speed) planes. The change in velocity during agility phases was then calculated for both running speed and lateral movement speed and was based on the difference between values at foot-strike and toe-off. Foot displacement relative to the COM and as a percentage of leg length was also calculated (Figure 3). The position of the foot at foot-strike and toe-off of each agility phase was then collected.

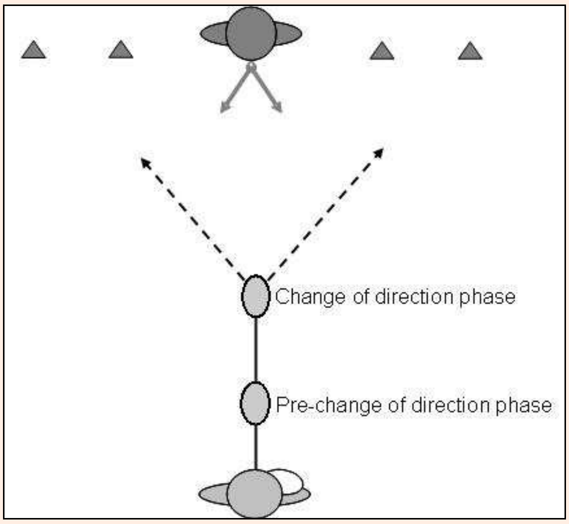

Figure 2. Transverse plane representation of pre-change of direction and change of direction phases.

Statistical analysis

The SPSS software package (Version 17.0 for Windows, SPSS, Inc., USA) was used to present descriptive statistics ($\bar{x}$ ± SD) and perform statistical analyses. The differences in kinematic measures were compared between agility performance conditions (pre-planned and reactive) using *t*-tests (t(df) = 000, p = 0.000), whilst one-way between subjects analysis of variance was used to compare the kinematics measures between performance speeds (fast, moderate and slow) (F (df) = 000, p = 0.000). Dependant variables included running speed and lateral movement speed as well as anteroposterior and mediolateral foot positions.

Results

Pre-change of direction phase

Analysis of the pre-change of direction phase showed a greater acceleration of lateral movement speed occurred during pre-planned condition, with increases of 0.29±0.35 $m \cdot s^{-1}$ compared to just 0.02 ± 0.39 $m \cdot s^{-1}$ for reactive conditions (t (94) = 3.476, p = 0.001). This was then associated with greater lateral movement speed at pre-change of direction foot-strike for pre-planned (0.42 ± 0.25 $m \cdot s^{-1}$) compared to reactive conditions (0.08 ± 0.28 $m \cdot s^{-1}$, t (94) = 6.130, p < 0.001) (Table 1). It was then demonstrated that the lateral displacement of the foot at pre-change of direction foot-strike had crossed the line of the centre of gravity and was greater during pre-planned (-5.33 ± 11.33%) compared to reactive conditions (0.02 ± 10.71%, t (94) = -2.376, p = 0.020) (Figure 4). Similarly, the lateral displacement of the foot at take-off

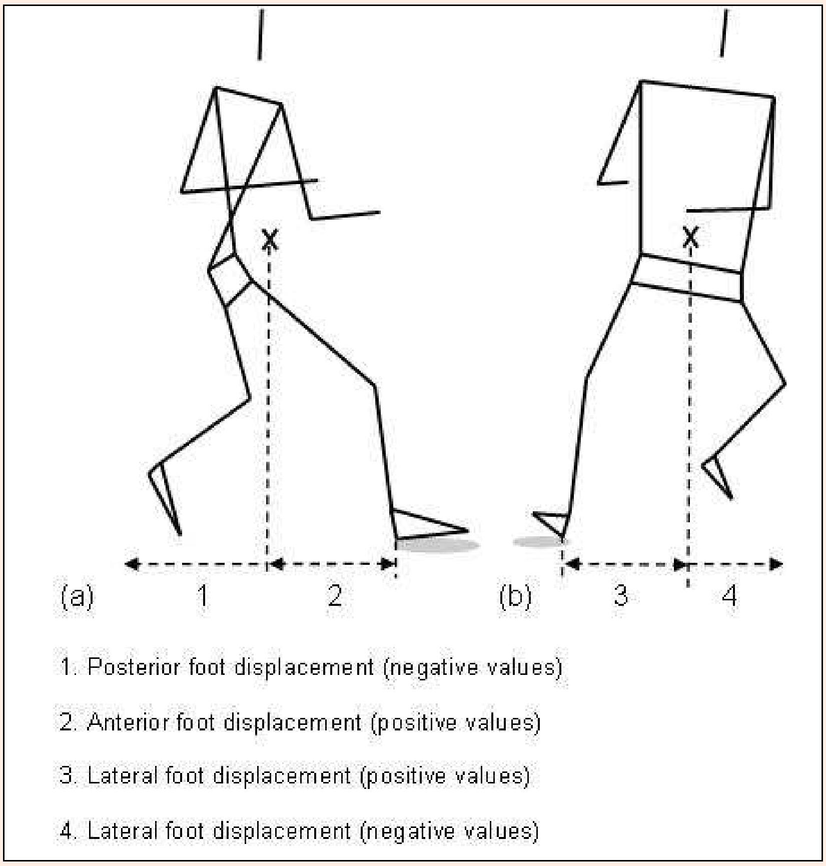

Figure 3. Illustration of foot displacement relative to the centre of mass (X) and as a percentage of leg length (a) sagittal plane view of anterioposterior foot displacement (b) frontal plane view of mediolateral foot displacement.

Table 1. Measures of velocity and foot position during the pre-change of direction phase.

	Agility Condition	
	Pre-planned	Reactive
Foot-strike		
Running speed (m·s^{-1})	5.89 (.53)	5.71 (.38)
Lateral movement speed (m·s^{-1})	.42 (.25)	.08 (.28) *
Anteroposterior foot position (%)	41.68 (14.78)	31.52 (16.12) *
Lateral foot position (%)	-5.33 (11.33)	.02 (10.71) *
Toe-off		
Running speed (m·s^{-1})	5.25 (.76)	5.28 (.62)
Lateral movement speed (m·s^{-1})	.72 (.49)	.28 (.44) *
Anteroposterior foot position (%)	-6.82 (15.85)	-4.92 (16.45)
Lateral foot position (%)	-11.20 (17.26)	-1.60 (15.98) *

* Significant difference between agility conditions.

had further crossed the line of the centre of gravity and was greater during pre-planned conditions (-11.20 ±17.26%) compared to reactive (-1.60 ±15.98%, t (94) = -2.826, p = 0.006). Analysis of the speed of performance then demonstrated that fast performances displayed greater increases to lateral movement speed (0.29 ± 0.22 m·s^{-1}) compared to moderate (0.05 ± 0.23 m·s^{-1}, p = 0.005) and slow (-0.18 ± 0.13 m·s^{-1}, p < .001) (*F* (2,45) = 22.858, p < 0.001) during reactive conditions.

Change of direction phase

Analysis of the change of direction phase showed no significant difference in the change in lateral movement speed between agility conditions (t (94) = -1.088, *p* = 0.279) but greater lateral movement speed at foot-strike for pre-planned (0.69 ± 0.43 m·s^{-1}) compared to reactive conditions (0.25 ± 0.42 m·s^{-1}, t (94) = 4.953, p < 0.001) (Table 2). Further analysis showed that lateral displacement of the foot at change of direction foot-strike was greater during reactive conditions (44.52 ± 6.10%) compared to pre-planned (41.35 ± 5.85%, t (94) = -2.601, p = 0.011). It was also found that fast performances displayed greater lateral movement speed at foot-strike (0.52 ± 0.34 m/s) compared to moderate (0.20 ± 0.37 m·s^{-1}, p = 0.034) and slow (-0.08 ± 0.31 m·s^{-1}, p < 0.001) (F (2,45) = 13.017, p < 0.001). Additionally, fast performances exhibited greater increases to lateral movement speed during the side-step (1.83 ± 0.37 m·s^{-1}) compared to slower performances (1.50 ± 0.41 m·s^{-1}, F (2,45) = 3.634, p = 0.041) for reactive conditions.

Further analysis showed no significant difference in the running speed at change of direction foot-strike

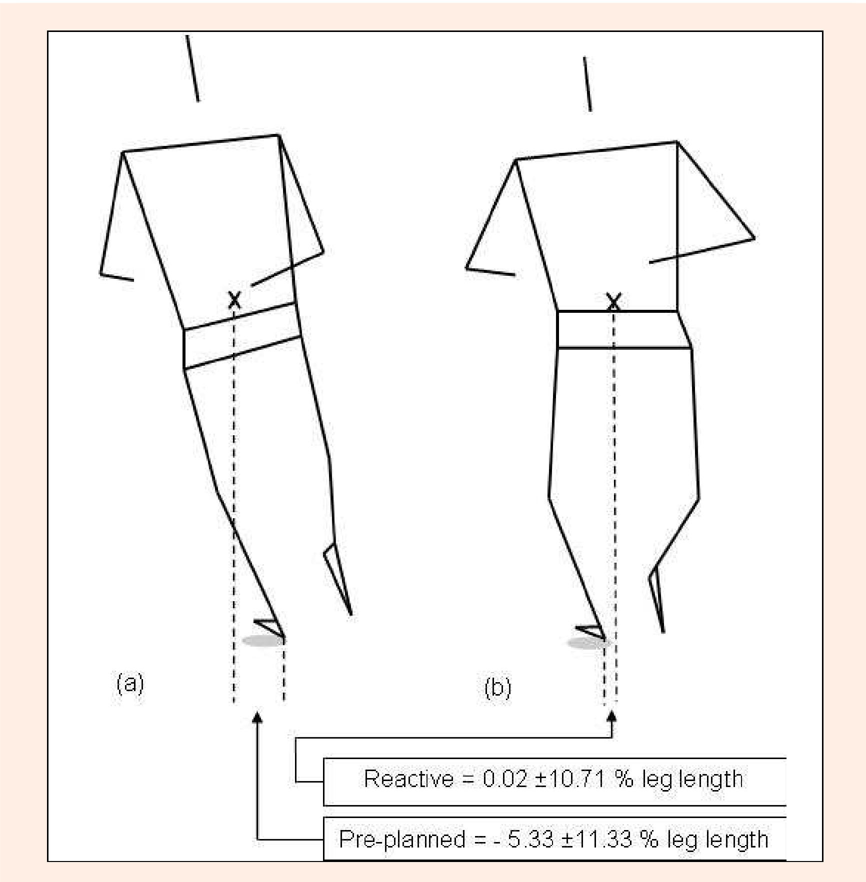

Figure 4. Frontal plane representation of the lateral displacement of pre-change of direction foot-strike (a) pre-planned conditions (b) reactive conditions.

Table 2. Measures of velocity and foot position during the change of direction phase.

	Agility Condition Pre-planned	Reactive
Foot-strike		
Running speed ($m \cdot s^{-1}$)	5.22 (.62)	5.25 (.52)
Lateral movement speed ($m \cdot s^{-1}$)	.69 (.43)	.25 (.42) *
Anteroposterior foot position (%)	41.24 (11.20)	37.94 (13.32) *
Lateral foot position (%)	-41.35 (5.85)	44.52 (6.10) *
Toe-off		
Running speed ($m \cdot s^{-1}$)	4.04 (.74)	4.12 (.77)
Lateral movement speed ($m \cdot s^{-1}$)	2.36 (.42)	2.13 (.47) *
Anteroposterior foot position (%)	-22.92 (15.52)	-32.10 (13.44)
Lateral foot position (%)	74.04 (8.34)	75.15 (8.43) *

* Significant difference between agility conditions.

between pre-planned and reactive conditions ($t(94) = -.290$, $p = 0.772$). However, a significant difference was observed in the anterior displacement of the change of direction foot-strike between pre-planned (46.24 ± 11.20%) and reactive conditions (37.94 ± 13.32%, $t(94) = 3.307$, $p = .001$). It was then shown that the change of direction step occurred earlier (relative to the change of direction line) for pre-planned conditions (0.13 ± 0.42 m) compared to reactive (-0.24 ± 0.48 m, $t(94) = 4.112$, $p < 0.001$), with fast performances (0.01 ± 0.38 m) executing this step earlier than slow (-0.53 ± 0.43 m, $p = 0.003$) for reactive conditions ($F(2,45) = 6.996$, $p = 0.002$) (Figure 5).

Discussion

Pre-change of direction phase

The increases to lateral movement speed prior to the agility side-step indicate that movement was directed towards the intended direction change. This is consistent with previous research that has demonstrated that athletes typically display lateral movement directed towards the intended running line prior to planned side-stepping actions (Andrews et al., 1977). Importantly, the current study demonstrated that the inclusion of the decision-making element to agility testing limited the development of preliminary lateral movement speed prior to the agility side-step. Despite this, it was observed that fast performances still exhibited greater lateral movement speed during the pre-change of direction phase compared to slow and moderate for reactive conditions. This finding concurs with other studies that have shown the inclusion of decision-making elements differentiates between speeds of agility performance (Farrow et al., 2005; Sheppard et

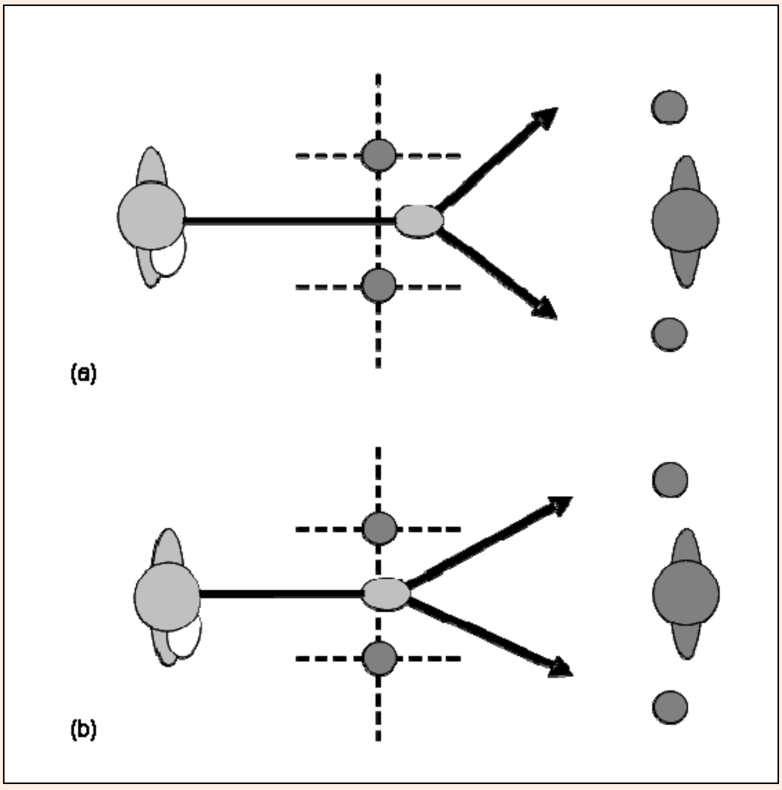

Figure 5. Transverse plane representation of the side-step position (a) slow performance (b) fast performances.

al., 2006). High performance athletes involved in multidirectional (agility) sports have demonstrated superior decision-making strategies over less skilled athletes during reactive agility tasks involving sport related stimuli (Farrow et al., 2005). Hence, the presence of decision-making elements should be considered an essential feature of agility skill development programs in rugby union. Although not examined in this study, it is important to consider factors associated with the psychological refractory period when discussing the presence of preliminary movements in evasion sports. The psychological refractory period refers to the limited capacity of the central nervous system to rapidly process several stimuli presented in succession (McMorris, 2004). From a practical standpoint evasive athletes attempt to exploit this concept by incorporating *faking* movements that provide additional stimuli to deceive defensive opponents as to the intended direction change. Clearly, deceptive movement patterns limit the visual cues offered to the defence prior to initiating an evasive agility manoeuvre during attacking ball carries in rugby union. As a result, *faking* actions are intended to disrupt opponent decision-making and present flaws in defensive strategies, thus enhancing the ability to evade defensive opponents. Building on this, if an attacking ball carrier is required to evade the defence but has poor reactive agility skills (e.g cannot generate rapid lateral movement speed in response to the defensive pattern), this would make the ball carrier easier to tackle. This is further supported by the finding that reactive conditions in the current study altered agility running technique. Hence, the absence of decision-making elements in agility testing and training programs may result in the incorrect movement patterns being trained. This highlights the need to include sport specific performance conditions when designing testing and training programs in open skilled sports. It should also be noted that participants were not required to *fake* in the current study, but that *faking* creates a new research paradigm and should be considered the next step for analysis examining appropriate sport specific testing and training conditions in sports such as rugby union.

Change of direction phase

The reduction to running speed with purposeful increases to the anterior foot displacement represents a fundamental element during the change of direction phase of agility manoeuvres (Andrews et al., 1977). However, the lack of variation in running speed despite different anterior foot positions between agility tasks suggests that the relationship between these components may be affected by reactive conditions. It is possible that the reduction in anterior foot position was related to the unpredictable nature of the reactive agility task. Positioning the foot closer to the COM no doubt meant that movement in either direction in response to the defender (as opposed to a pre-planned direction) was more easily achieved. Clearly, further research investigating the relationship between velocity and foot positions during reactive conditions is necessary.

The decrease to lateral foot positions observed during reactive conditions was also no doubt associated with the unpredictable nature of performance. The result of decreasing the lateral foot position in reactive conditions was a limited the magnitude of lateral movement speed achieved during the side-step (Bobbert et al., 1992; Hunter et al., 2005). Importantly, results suggest that reactive conditions limited preliminary lateral movement speed leading up to the side-step, but did not affect the ability to generate lateral movement speed during the execution of the side-step. Therefore, proficient generation of lateral movement speed during the side-step is a critical component of evasive agility skill execution in rugby union and other multi-lateral sports.

This study subsequently found that anticipation abilities during reactive conditions provided a means to differentiate between agility performance speeds, with fast performances executing the side-step earlier and with greater lateral movement speed directed towards the required running line. Interestingly, slow performances typically displayed negative lateral movement speed at the side-step, suggesting that movement was towards the opposite direction required. This builds on previous research by Farrow et al. (2005) who observed that slower performing athletes waited until the presentation of a decision-making stimulus was complete prior to executing the appropriate evasive agility movement strategy. In contrast, faster performing athletes predicted the appropriate movement strategy required of agility skill execution during the early stages of stimulus presentation (Farrow et al., 2005).

Evasive agility performance during reactive conditions relies on selective attention and advance cue recognition to offer predictive information (anticipation), that enhances decision-making abilities (Abernethy, 1991, 2001). Such abilities are then vital to outmanoeuvring the defence and advancing the ball beyond the advantage line during attacking ball carries in rugby union (Meir, 2005). The current study demonstrated that anticipation strategies represent an important component of evasive agility skill execution in rugby union. Building on this, it was shown that the ability of an attacking ball carrier to anticipate the movements of a defender can be measured using the spatiotemporal characteristics of performance, such as foot positions and velocity profiles. Hence, it is important that agility assessment protocols evaluate the effectiveness of agility running technique when presented with decision-making elements that resemble athletic performance within a specific sporting context.

Conclusion

This study demonstrated that agility skill execution is modified during reactive conditions compared to pre-planned conditions. The presence of a decision-making element limited lateral movement speed when side-stepping and as such, the foot placement patterns were different compared to pre-planned conditions. Importantly, the anticipation abilities during reactive conditions provided a means to differentiate between agility performance speed, with faster performances executing the side-step earlier and with greater lateral movement speed directed towards the required running line. The findings of the current study highlight the need for appropriate agility training methods and assessment procedures in rugby union to include sport specific performance conditions. These sport specific training and testing programs would then evaluate the ability of players to anticipate and implement the correct evasive agility manoeuvre and their capacity to generate rapid lateral movement speed through accurate foot placement patterns.

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Key points

- Changes to running technique occur when required to make a decision.
- Fast agility performers use different stepping strategies in reactive conditions.
- Decision-making must be incorporated in agility training programs.

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