THE EFFECTS OF BALL CARRYING ON SPRINT MECHANICS: AN INSIGHT INTO THE TECHNICAL DEMANDS OF RUGBY

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Sprinting ability is fundamental to success in rugby, where athletes are repetitively required to accelerate and occasionally reach maximal velocities while carrying a ball. Despite this, the mechanical influences of ball carrying are not understood. The aim of this study was to examine the effects of ball carrying technique on sprint performance and underlying mechanics. Sprint kinetics were collected with a radar gun on 16 male rugby athletes during three maximal 40-m sprints under three conditions: no ball, ball in two hands and ball in one hand. Carrying a ball in two hands produced similar mechanics to no ball over acceleration while carrying a ball in one hand had advantageous alterations at maximal velocity. A new sprint training protocol is proposed based on these findings.

KEYWORDS: horizontal force, power, velocity, split-time, performance, skill.

INTRODUCTION: In recent years (more specifically at the 33rd International Conference on Biomechanics in Sport's 'Applied Session' – Sprint Acceleration Biomechanics), sport scientists have begun to incorporate the use of radar guns and new methods to assess sprint mechanics and performance in many sporting codes due to its low financial cost, user-friendly interface and practicality. Using a macroscopic inverse dynamics approach, researchers gain an understanding of the mechanical and technical sprint characteristics of the neuromuscular system (Samozino et al., 2015). Mechanical profiling, which is unique to the individual athlete, helps us better understand *how* the sprint is performed as opposed to the traditional timing-splits that inform us on *what* was performed. While the benefits of such a useful understanding into sprint mechanics have been primarily focused on track athletes, the importance has been transferred to rugby codes due to the sports' inherent demands (Cross et al., 2015).
While rugby athletes are known to perform a high incidence of short-distance sprints (≤ 20-m), maximal longer-distance sprints (> 20-m) remain central to on-field performance (Grant et al., 2003). Mechanical variables including theoretical relative horizontal force (F_0), theoretical maximal sprinting velocity (v_0) and relative maximal mechanical power (P_{max}), describe an athlete's ability to produce horizontal force and power during acceleration and high velocity. The ability to orientate (specifically horizontal force in the forward direction as a ratio of total force; described as the maximal ratio of force after 0.3-s [RF_{max}]) *and* maintain (slope/rate of decrease in RF with increasing velocity [D_{RF}]) ground-reaction forces allows further insight into an athlete's effectiveness with their raw ability and may be a strong indicator of performance compared to the overall magnitude of the force (Morin, Edouard, & Samozino, 2011; Morin & Samozino, 2015). The combination of the above mentioned variables allow for an in-depth analysis of an individual athlete's sprint mechanics and abilities.
As sprint accelerations in rugby are typically performed from a stationary starting position (1) in anticipation of the movement of the ball to begin an offensive/defensive 'attack' or (2) when reaccelerating following a change-of-direction (Duthie, Pyne, Marsh, & Hooper, 2006), the possession or retention of the ball is an essential component in match outcome. Authors (Barr, Sheppard, Gabbett, & Newton, 2015; Grant et al., 2003; Walsh, Young, Hill, Kittredge, & Horn, 2007) agree that sprinting with a ball is commonly overlooked in rugby training despite its inherent connection to success. The purpose of this research was to gain more insight into the effects of ball carrying on sprint mechanics among male rugby athletes by comparing maximal sprints with a ball in one hand or two hands to maximal sprints with no ball.

METHODS: Sixteen male academy (high-performance development) rugby athletes (age 19 ± 1 y, body-height 1.8 ± 0.1m, body-mass 94 ± 9 kg) performed three maximal 40-m sprints.

Data collection: Testing occurred during the athletes' off-season after ~24-h of rest from gym and field training. All athletes were free from any acute or chronic injury, cleared for full competitive play in the 2016 season and were highly familiarised with the 40-m sprint testing requirements. A rubberised athletics track (Mondo) was chosen as a highly uniform surface on which to perform research due to the high variability assumed in grass surfaces between/within grounds. While different to the surface on which rugby athletes practice/compete, given the purpose of this study was to examine the mechanical distinctions between ball carrying skill, it was assumed the same results would be reproducible across surfaces. Sprinting was therefore performed with athletes wearing standard athletic footwear (non-studded trainers) on an outdoor Mondo track surface, where temperature and barometric pressure variables were recorded for subsequent calculations. Following a dynamic warm-up, athletes performed three 40-m build-up sprints at 60, 80 and 90% maximal intensity. Ensuing the warm-up trials, athletes performed three randomised maximal effort 40-m sprints with: (1) no ball, (2) ball in two hands and (3) ball in one hand. Three minute rest periods were given between all warm-up and maximum trials. Maximal sprint trials were recorded with a Stalker Acceleration Testing System (ATS) II radar device (Applied Concepts, Inc., Plano, TX, USA) collecting at 46.9 Hz. The radar was secured to a tripod positioned 3-m behind the starting line at a height of 1-m above the ground, approximately in-line with the athletes' centre-of-mass. A successful trial consisted of athletes maximally accelerating and sprinting through cones placed at 45-m from the start line to ensure a 40-m collection without deceleration.

Data processing: Data were collected using the provided radar software (version 5.0.3.0) and further analysed using the methods described by Samozino et al. (2015) in Excel; equivalent to the methods reported by Cross et al. (2015) who used a custom-made LabVIEW programme. In short, individual raw data presented as sprint velocity–time curves ($v[t]$) were fitted by a mono-exponential function. Split times (2-, 5-, 10-, 20-, 30- and 40-m) and mechanical variables (F_0, v_0, P_{max}, RF_{max} and D_{RF} [shown in Figure 1]) were calculated to practically describe the sprint efforts (Morin & Samozino, 2015).

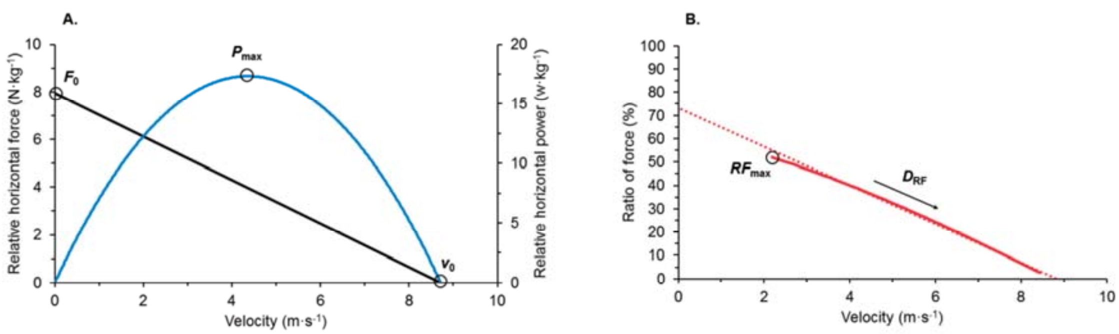

Figure 1: Graphical representations of (A.) relative horizontal force-velocity-power and (B.) ratio of force-velocity profiles of a 96.0 kg rugby athlete acquired via radar gun during a 40-m sprint.

Data analysis: Magnitude-based inferences were used to assess the standardised effects (the difference between the means was divided by the standard deviation of sprinting without a ball; effect size [ES]) of sprinting with a ball in one hand and two hands using previously established methods (Hopkins, Marshall, Batterham, & Hanin, 2009). If the confidence limits were within the levels of the negative, trivial or positive mechanistic scale, the outcome was noted as clear and the likelihood of the true effect observed was described. If the confidence limits spanned all three levels, the outcome was noted as unclear.

RESULTS: Sprinting with a ball in two hands slightly increased split-times at 30-m (ES = 0.27) and 40-m (ES = 0.27) compared to sprinting with no ball whereas sprinting with a ball in one hand increased all split-times (ES = 0.57, 0.48, 0.55, 0.43, 0.38 and 0.32 for 2-, 5-, 10-, 20-, 30- and 40-m respectively). The time between 30- and 40-m was also slightly greater with a ball in two hands (ES = 0.21) compared to no ball. Compared to sprinting with no ball, athletes sprinting with a ball in two hands showed a decreased v_0 (ES = -0.26, -1.3%) while sprinting with a ball in one hand showed decreased F_0 (ES = -0.43; -4.5%), P_{max} (ES = -0.45; -4.4%), RF_{max} (ES = -0.47; -2.3%) and D_{RF} (ES = 0.33; -4.1%). All other differences were unclear.

Table 1. Timing splits and mechanical variables while sprinting with no ball, ball in two hands and ball in one hand and inferences for the mean change.

				Ball in two hands –no ball sprinting	Ball in one hand –no ball sprinting
	No ball	Ball in two hands	Ball in one hand	Mean change; ±90% CL	Mean change; ±90% CL
Timing splits					
2m (s)	0.79 ± 0.03	0.79 ± 0.03	0.81 ± 0.04 ‡	0.0038; ±0.0164	0.021; ±0.022
5m (s)	1.35 ± 0.05	1.35 ± 0.04	1.37 ± 0.06 ‡	0.0081; ±0.0232	0.026; ±0.031
10m (s)	2.07 ± 0.07	2.09 ± 0.06	2.11 ± 0.08 ‡	0.014; ±0.030	0.041; ±0.041
20m (s)	3.33 ± 0.10	3.35 ± 0.10	3.38 ± 0.12 ‡	0.018; ±0.038	0.046; ±0.049
30m (s)	4.51 ± 0.13	4.55 ± 0.14 †	4.56 ± 0.15 ‡	0.038; ±0.042	0.052; ±0.046
40m (s)	5.67 ± 0.17	5.72 ± 0.19 †	5.73 ± 0.19 ‡	0.049; ±0.042	0.057; ±0.045
30-40m (s)	1.16 ± 0.05	1.17 ± 0.05 †	1.17 ± 0.04	0.011; ±0.008	0.0046; ±0.0136
Mechanical variables					
F_0 ($N \cdot kg^{-1}$)	8.1 ± 0.8	8.0 ± 0.7	7.7 ± 0.8 ‡	-0.032; ±0.386	-0.38; ±0.49
v_0 ($m \cdot s^{-1}$)	9.02 ± 0.43	8.90 ± 0.45 ‡	9.02 ± 0.39	-0.12; ±0.06	-0.015; ±0.109
P_{max} ($W \cdot kg^{-1}$)	18 ± 2	18 ± 2	17 ± 2 ‡	-0.29; ±0.80	-0.84; ±0.93
RF_{max} (%)	52 ± 3	52 ± 2	51 ± 3 ‡	-0.19; ±1.16	-1.3; ±1.6
D_{RF}	-0.081 ± 0.010	-0.082 ± 0.008	-0.078 ± 0.008 †	-0.00085; ±0.00380	0.0034; ±0.0054

Abbreviations: values are means ± standard deviation, mean change; ±90% confidence limits (CL); †, possibly (25-74%) small inference compared to no ball; ‡, likely (75-94%) small inference compared to no ball.

DISCUSSION: Rapid acceleration is an indispensable skill in rugby, where centimetres and milliseconds can determine the outcome of a match. Unless the ball is kicked, gaining metres and positive field position is obtained by carrying a ball. In fact, nearly all movements in rugby require the inclusion of or reaction to a ball (line-out, kick, sidestep, tackle, etc.), yet traditional sprint training is performed without a ball. The current study provides important information into the mechanical alterations that a ball causes during a sprint effort. Further, this is the first study to investigate these differences in greater detail than simple split-time measurement. Sprinting with a ball in one hand negatively affects mechanical characteristics over the acceleration phase (first 20-m) compared to sprinting with no ball, while the ability to produce horizontal force at higher velocities appears unaffected.

Based on the results found in this study, we propose the importance of balance (both upper- and lower-body) during the acceleration phase of sprinting (i.e. the first ~20-m). When accelerating with no ball, the arms move in opposition in a forward and backward sagittal plane motion to aid in counterbalancing the rotation of the hips resulting from the angular momentum of the legs (Barr et al., 2015). The mechanical differences found in F_0, P_{max} and RF_{max} while sprinting with a ball in one hand compared to no ball may indicate an asymmetry in the upper- to lower-body counterbalance. For example, if the free arm drives forward and backward in the sagittal plane and the restrained arm (the arm holding the ball) drives the elbow backward and then laterally forward across the body, the torso may unevenly rotate to one side (Walsh et al., 2007). These mechanical differences resulted in slower split-times over every split compared to sprinting with no ball. Conversely, sprinting with a ball in two hands may have created the appropriate upper-body counterbalance as seen when sprinting with no ball; potentially achieved by maintaining a rigid upper-extremity chain and driving both elbows backwards (alternating) for a more symmetrical trunk rotation. The tactical advantages of carrying a ball in two hands are widely known to include more passing options (multi-directional passing) and better protection in contact, thus creating a greater offensive threat.

Interestingly, once maximal velocity was obtained, there were similar split times at 30- and 40-m between one hand and two. Additionally, holding a ball in one hand produced a slightly less negative D_{RF}, meaning that the athletes were able to maintain net horizontal force for a longer period of time. Delaying the inevitable decrease in mechanical effectiveness resulted in a higher v_0 while sprinting with a ball in one hand compared to two hands; again showing the ability of the athletes to continue to apply horizontal force at high running velocities (Morin & Samozino, 2015). While our findings at maximal velocity are somewhat in agreement with previous research (Grant et al., 2003; Walsh et al., 2007) examining the effects of ball carrying in male rugby athletes, it should be mentioned that traditional sprint analyses limit the in-depth interpretations of sprinting mechanics that the recent methods (Samozino et al., 2015) used in the current study do not. In fact our results suggest unique benefits from carrying the ball in two hands and in one.

CONCLUSION: Sprinting with a ball, whether in two hands or one, *does* negatively affect nearly all split-times. However, sprinting with a ball in two hands through the first 20-m and sprinting with a ball in one hand through maximal velocity provide advantageous characteristics to overall sprint performance in rugby. Therefore, we would suggest that sprint training for rugby athletes should focus on starting with the ball in two hands, accelerating with the ball in two hands, transferring the ball to one hand at ~20-m and then finishing the ≥ 40-m sprint with the ball in one hand. Using both ball carrying methods during training would theoretically apply a similar mechanical stimulus to sprinting without a ball while including a greater degree of rugby specific skill development.

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