EFFECTS OF FATIGUE ON RUGBY PLACE KICKING TECHNIQUE AND PERFORMANCE

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The aim of this study was to identify differences in place kicking performance and technique following a rugby-specific fatigue protocol. Three skilled place kickers performed four blocks of the protocol, between which they took three place kicks from a challenging pitch location. The success of the kicks, measures of physical exertion and lower body and torso kinematic variables were measured. Kicking success dropped following blocks 2 and 4 of the protocol, all missed kicks were wide of the goalposts. Individual differences were apparent. After block 2 the kickers demonstrated greater upper body motion, potentially a strategy to obtain fast foot velocity but at a detriment to accuracy. After block 4, collapse of the stance leg was observed which may have impacted the kickers' stability. Further research with more participants and a specific focus on muscular fatigue is required.

KEYWORDS: BURST protocol, inertia measurement unit, kinematic, success.

INTRODUCTION: Place kicking has been identified as a critical factor in determining the outcome of rugby union matches, contributing 45% of total points scored in 582 international rugby union matches (2002-2011; Quarrie & Hopkins, 2015). Given the impact points gained from kicks have on match outcomes, researchers have investigated place kicking biomechanics to identify what traits characterise success (e.g. Atack et al., 2019; Sinclair et al., 2017). However, whilst understanding technique is crucial for improving kickers' performance, investigating how they are influenced by stressors such as physical fatigue is equally important (Pocock et al., 2021).
Through notational analysis of international matches, Pocock et al. (2018) identified that mean place kick success was 67% in the final 10 minutes before half-time compared to 80% in the first 10 minutes of matches. The authors suggested that this was a result of accumulated physical fatigue from the first half of the game.
Physical fatigue has been shown to decrease ball velocity in soccer instep kicks (Apriantono et al., 2006), which was attributed to reduced muscle and interactive moments meaning slower linear and angular velocities of the kicking leg were achieved (Apriantono et al., 2006). Similarly, in AFL, a sport specific fatigue protocol elicited changes in the kicking strategy employed during drop punt kicks, with a greater reliance on the kicking hip following fatigue (Coventry et al., 2015). In rugby, physical fatigue has been demonstrated to detrimentally affect tackle technique (Gabbett, 2008), though researchers have not yet investigated the effect on place kicking. Given the observed reduction in place kick success after prolonged physical activity during competition, there is a need for empirical research investigating the effect of physical fatigue on technique to ascertain the potential causes for these drops in performance. Therefore, the aim of this study is to investigate the effect of rugby-specific fatigue on technical processes underpinning place kicking performance in a representative, on-field place kicking task.

METHODS: Three healthy male place kickers (age = 24 ± 1 years, height = 1.78 ± 0.05 m, mass = 81.7 ± 6.0 kg) volunteered to participate in this study. Kickers were experienced place kickers at amateur or semi-professional club level. All gave informed consent prior to the study and ethical approval was granted by the local research ethics committee. All testing was performed outdoors on a rugby pitch (mean temperature 20°C and wind 4 mph).
Eight inertial measurement units (IMUs; Blue Trident, Vicon) consisting of a triaxial low-g accelerometer (range: ±16g, sample rate: 1125Hz), high-g accelerometer (range: ±200g, sample rate: 1600Hz), gyroscope (range: ±2000 °/s, sample rate: 1125Hz) and magnetometer (range: ±4900μT, sample rate: 100Hz) were attached bilaterally to the kickers in the following locations: foot, shank, thigh, pelvis (between PSIS) and the sternum. These enabled lower limb and torso kinematics to be recorded throughout the kicking trials. Sensor orientation was

calculated at 225Hz before being up sampled to 1600Hz as per manufacturer design. All orientations were represented in quaternion format. Similar IMU systems have been deemed valid for soccer, AFL, and rugby place kicking (Blair et al., 2018).
First, participants completed a self-directed warm-up including three place kicks taken from the 22m line directly in front of the goal posts. A baseline measure of RPE and heart rate (HR) was noted before three baseline place kicks were taken 32m, and at an angle of 39°, from the centre of the goalposts, representative of a challenging kick (Pocock et al., 2018). Participants were allowed a maximum of 60 seconds between kicks to limit the degree of recovery that occurred over the course of each set of three kicks, though on no occasion did any of the participants use the full 60 seconds. The success of the kick (and reason for failure where applicable) and data from the IMUs were recorded. To induce fatigue, the kickers performed a modified version of the Bath University Rugby Shuttle Test (BURST) protocol (described by Pocock et al., 2021; Figure 1). A 15 m sprint through timing gates both preceded and followed each set, with times recorded. Following each block of the protocol RPE was noted before three place kicks were performed and the kick outcome and IMU data were recorded.

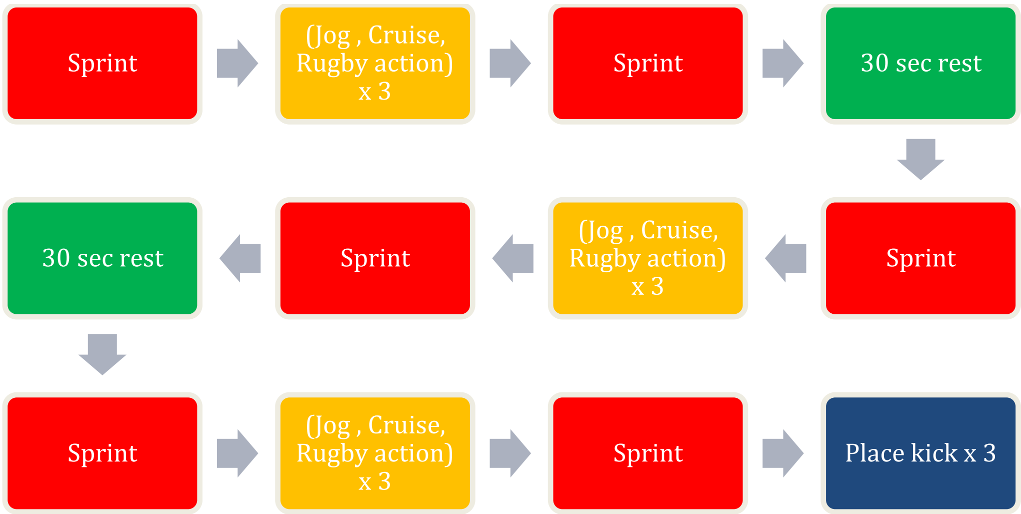

Figure 1: The order of activities involved in one block of the rugby-specific fatiguing protocol.

Three-dimensional (3D) linear velocity of the kicking foot was obtained through integration of the accelerometer data from the foot IMU in the global frame. Additionally, 3D joint angular displacements and velocities of the kicking and stance legs were calculated using the pelvis, thigh and shank IMUs. IMU to segment alignment was performed such that the flexion-extension, abduction-adduction and axial rotation axes were directed mediolaterally, anteriorly and upwards respectively. Joint angle data were decomposed using an XYZ rotation sequence using custom Matlab scripts. 3D relative pelvis-torso separation angles were also determined. Ball contact (BC) was identified as the frame where peak resultant kicking foot velocity was achieved. All trials were cropped from 0.2 s prior, up to, BC reflective of the downswing (place kick downswing duration previously identified as 0.11 ± 0.01 s; Atack et al., 2019). Differences in performance and technique between the protocol blocks were analysed on both a group and individual level. Effect sizes were calculated to determine the magnitude of any differences.

RESULTS AND DISCUSSION: The effects of the protocol on place kick success and select measures of physical exertion are presented in Table 1. Measures of physical exertion (sprint time, HR and RPE) increased during the fatiguing protocol demonstrating its effectiveness in increasing the physical load experienced by the kickers.
Kick success was highest after the first and third fatigue blocks, and lowest after the second and fourth (Table 1). All unsuccessful kicks were limited by accuracy, missing either the left or right goalpost, none dropped short of the crossbar. Pocock et al. (2018) observed that the mean success percentage in the 2015 World Cup was equivalent to 75%. The mean success percentage of these three kickers was 49% across the five time points, the lower success

percentage likely reflective of their playing level. Participants did demonstrate higher performance levels after blocks 1 and 3, compared with the baseline trials but returned to baseline levels after blocks 2 and 4. The success rate after block 4, representative of the period prior to half-time, has previously been identified as having the lowest success percentage in international matches (Pocock et al., 2018).

Table 1: Performance and physical exertion measures across blocks of the adapted BURST protocol (mean ± SD)

	Baseline	Block 1	Block 2	Block 3	Block 4
Kick Success (/9)	3	6	3	7	3
Sprint Time (s)	-	2.65 ± 0.21	2.69 ± 0.21	2.67 ± 0.21	2.75 ± 0.31
Heart Rate (bpm)	116 ± 9	153 ± 30	171 ± 3	173 ± 10	170 ± 5
RPE	7 ± 1	12 ± 3	14 ± 2	16 ± 2	16 ± 1

Measurement of upper and lower-body kinematics allowed us to consider the reasons for these changes in performance. The small sample size limited the statistical power of the analysis; thus, we have only reported descriptive data (Table 2). On a group level, few large effects were observed (increases in pelvis-torso rotation baseline-block 1 and block 1-block 2; ES of 0.86 and 0.91 respectively). Similar to previous research in AFL punt kicking no reduction in kicking foot velocity was observed (Coventry et al., 2015), but increases were seen in both knee extension and hip flexion velocities from baseline-block 4 which likely explains why no kicks missed short of the goalposts and suggests other factors led to the reduction in performance.

Table 2: Kinematic variables across blocks of the adapted BURST protocol (mean ± SD)

	Baseline	Block 1	Block 2	Block 3	Block 4
Kicking Leg					
Resultant foot velocity (m/s)	15.3 ± 3.5	14.8 ± 3.9	16.1 ± 5.5	14.4 ± 3.3	14.3 ± 3.0
Knee ROM (°)	37 ± 16	38 ± 26	49 ± 49	54 ± 64	39 ± 44
Max knee extension velocity (°/s)	324 ± 98	381 ± 255	595 ± 480	669 ± 723	603 ± 604
Hip ROM (°)	95 ± 15	98 ± 18	98 ± 21	94 ± 22	105 ± 16
Max hip flexion velocity (°/s)	226 ± 198	192 ± 120	183 ± 102	211 ± 111	255 ± 171
Stance Leg					
Knee ROM (°)	28 ± 7	31 ± 19	38 ± 30	42 ± 31	39 ± 22
Max knee extension velocity (°/s)	304 ± 84	378 ± 205	453 ± 348	478 ± 348	438 ± 246
Hip ROM (°)	45 ± 14	45 ± 14	53 ± 12	52 ± 12	45 ± 14
Max hip extension velocity (°/s)	50 ± 39	49 ± 43	50 ± 40	49 ± 38	50 ± 40
Pelvis & Torso					
Pelvis-Torso Separation ROM (°)	11 ± 5	15 ± 4	20 ± 6	18 ± 8	16 ± 11

Abbreviations: ROM, range of motion

Individual kicker analysis was more insightful. Regarding the drop in performance from block 1-2, all kickers missed an additional kick. As mentioned, greater pelvis-torso rotation was demonstrated by all kickers (mean increases of 7°, 3° and 4° respectively; ES 0.86, 3.69 and 0.65) alongside greater hip ROM (mean increases of 6°, 3° and 15° respectively; ES of 0.79, 0.35, 1.22). Greater pelvis-torso rotation accompanied by increased kicking leg hip action has previously enabled kickers to achieve a fast foot velocity but at a detriment to kick accuracy (Atack et al., 2019). This may, therefore, explain how the first and third kickers achieved faster kicking foot velocities, but were ultimately less successful. The second kicker, in contrast, did not see an increase in foot velocity (mean decrease of 0.6 m/s; ES -0.40) but was still less successful suggesting pelvis-torso rotation alone may have impacted their accuracy.
Similar reductions in performance were seen following block 4, compared to the kicks taken after block 3 (Table 1). While kicker 1 maintained their success rate (2/3), kickers 2 and 3 both

missed two additional kicks (success rates of 0/3 and 1/3). However, when considering these less successful kickers, the differences seen after block 2 were not apparent. In fact, less pelvis-torso rotation was seen (6° and 3° reductions respectively; ES - 0.84, -1.28). Instead, collapse of the stance knee was seen, with maximum flexion angle increases of 7° and 9° (ES 1.09 and 0.84). Greater stance knee flexion has previously been associated with inaccurate AFL goalkicking (Blair et al., 2020) and is suggested to reflect reduced stability, limiting control over the kicking leg motion (Ball, 2013) and leading to a misdirected kicking foot velocity vector.

CONCLUSION: This study provides an initial investigation into the effects of induced fatigue on rugby place kicking. Kick success reduced following 40 minutes of match-representative activity, with kickers demonstrating greater trunk rotation and stance leg collapse, potentially due to muscular fatigue of the lower limbs. Further studies should focus specifically on this aspect to understand if muscular fatigue is observed in place kickers following 40 minutes of match-representative play. Additionally, while the current study counted the number of successful kicks over the posts, in future, it is recommended that the distance and direction from the goal centre also be measured. A more precise measure of performance would allow researchers to detect subtle changes resulting from increased load. Given the limited sample size and individual differences observed, additional participants are required to provide appropriate practical recommendations, however, the use of IMUs presents an opportunity to improve the ecological validity of future studies investigating similar field-based skills.

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