FATIGUE INDUCED POSTURAL CHANGES IN AUSTRALIAN RULES FOOTBALL PLAYERS WITH AND WITHOUT A HISTORY OF HAMSTRING INJURY

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The purpose of this study was to explore the influence of game fatigue on sprint mechanics in Australian Rules Football (ARF) players with and without a history of hamstring strain injury (HSI). Thirty community level ARF players, 11 with a HSI within the previous two years, undertook a game protocol simulating the running requirements of an ARF match. Three-dimensional kinematic trunk and lower limb data of 10 sprints were collected prior to the game protocol, and at the end of each simulated quarter, allowing the influence of game fatigue to be assessed. In players with a history of HSI, joint angle data revealed changes in sagittal plane hip and lumbar spine position with increasing fatigue. Persistent hamstring dysfunction may be revealed as the athlete progresses through a game and has potential implications for injury recurrence.

KEYWORDS: Sprint, protocol, kinematic, trunk, lumbar

INTRODUCTION: ARF is an intermittent sport requiring repeat bouts of high-intensity sprinting, kicking, tackling and changes of direction. Even with extensive research in sports medicine over the past 20 years, HSI rates have remained the greatest problem in dynamic sports such as ARF, most commonly occurring during high speed running, and currently contributing around 15% of all injuries (Pizzari, Taylor & Coburn, 2012; Orchard, Seward & Orchard, 2013; Australian Football League, 2016). The increased prevalence of HSI late in matches has highlighted game fatigue as a risk factor (Pizzari, Taylor & Coburn, 2012). Previous HSI has also been linked to future injury risk, however the exact nature of the relationship is uncertain (Opar, Williams & Shield, 2012), and may be the consequence of abnormal interactions between the hamstrings, lumbar spine and pelvis (Buchtelova, Tichy & Vanikova, 2013). To date, retrospective assessment has not linked previous HSI to postural changes, however reduced lumbo-pelvic control has been recognised as a risk factor for future HSI (Schuermans, Van Tiggelen, Palmans, Danneels & Witvrouw, 2017). The purpose of this study was to examine the influence of game fatigue on trunk and lower limb mechanics during sprinting in ARF players both with and without a history of HSI.

METHODS: Thirty community level ARF players between the ages of 18 and 35 years who were free of injury at the time of testing, 11 with a HSI within the previous two years (mean 12±8.05 months), participated in this cross-sectional study. Based on player recall, a HSI was defined as an injury to the hamstring that resulted in the participant missing at least one match. The intention of the laboratory-based study was to simulate the running requirements of an ARF match using a combination of treadmill and over ground running. The game protocol was separated into a warm-up and four quarters. A quarter consisted of a treadmill component, involving 39 speed changes over an average of 3.23 km, followed by 10 maximal over ground sprints 30 meters in distance. This protocol was based on prior research evaluating the running activities of elite ARF players (Coutts, Quinn, Hocking, Castagna & Rampinini, 2010). Ranges were provided for both speed and distance achieved among elite players, with the lower end of each range reported being used given the likely participants were community level players. To monitor fatigue, blood lactate, rating of perceived exertion (RPE), hand grip and sprint speed were assessed pre-activity, and periodically throughout the protocol. Three-dimensional kinematic data were collected during the 30m maximal over ground sprints using an eight camera Vicon system with Nexus

software (Version 1.8.5, Oxford Metrics, UK). Visual 3D (Version 6, C-Motion, USA) was used for data reduction and analysis. Kinematic data were filtered using a fourth-order Butterworth low-pass filter (f_c=18Hz). Data analysis involved the fatigue protocol being separated into two groups (HSI, control), five levels of fatigue based on quarters (PRE, Q1, Q2, Q3, Q4), while the sprint data comprised of six temporal events of the gait cycle, 18 joint angles, and five segment angles. Mixed-design factorial analyses of variance (ANOVA) calculations identified whether differences existed between the means of all outcome measures (P<0.05). Upon identification of main effects, Tukey *post hoc* tests were selected to identify statistical relationships. All statistical analysis was completed using Statistica (13.2; StatSoft Inc., USA).

RESULTS: A significant main effect of fatigue was noted for blood lactate ($F_{5,115}$=5.82, p<0.00, η_p^2 = 0.2019), speed ($F_{5,115}$=6.73, p<0.00, η_p^2 = 0.2263) and RPE ($F_{3,69}$=11.86, p<0.00, η_p^2 = 0.3402). *Post hoc* testing identified significant increases from Q1 to Q4 (p<0.00) for RPE and speed, and conversely a significant decrease from PRE to Q4 (p<0.00) for blood lactate. Expressed as an average of all temporal events, the fatigue*angles*history interaction provided an overall depiction of joint angle changes across the gait cycle. The main effect was significant ($F_{68,1496}$=1.41, p=0.017, η_p^2 = 0.0602, Figure 1), with *post hoc* testing revealing the history group as having greater hip flexion at PRE (p=0.01), Q1 (p<0.00) and Q2 (p=0.01) when compared to the control group, however returned to comparable results between-group at Q3 and Q4. Within group analysis found the history group had a significant reduction in hip flexion from PRE compared to Q4 (p=0.01). When compared to the control group, the history group showed significantly less L5-S1 extension at PRE (p<0.00), Q1 (p=0.04), Q2 (p=0.03) and Q4 (p<0.00); and significantly less T12-L1 flexion at PRE, Q1, Q2, Q3 and Q4 (all p<0.00). A significant main effect was observed for fatigue*segments ($F_{16,352}$=1.97, p=0.01, η_p^2 = 0.0823), showing a reduction in anterior pelvic tilt, increase in flexion of the thigh, and decrease in flexion at the mid-trunk, upper-trunk and trunk-abdominal segments. Significant main effects did exist for analysis involving history, however no interactions were observed with *post hoc* testing.

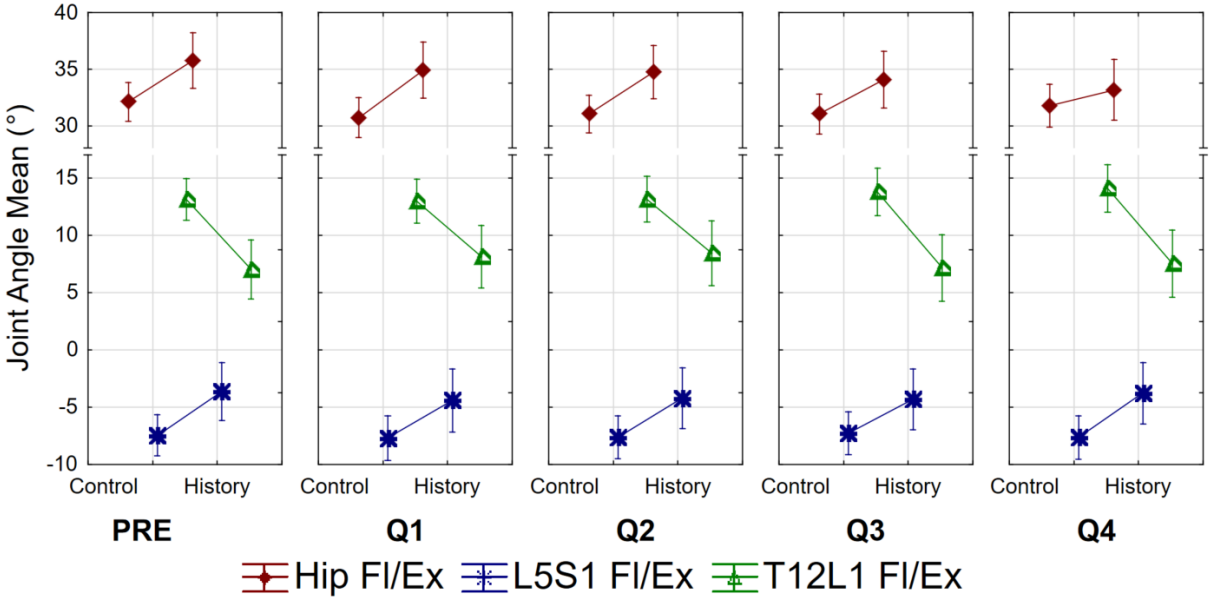

Figure 1. Mean values (± SE) for control vs. history cohorts for sagittal plane joint angles (°).

DISCUSSION: This, the first study to retrospectively identify a relationship between lumbo-pelvic function during sprinting, fatigue and hamstring injuries, adds to current knowledge of the persistent deficits observed following hamstring injury (Timmins et al., 2017), and may shed some light on why a recent HSI is predictive of a future HSI (Gabbe, Bennell, Finch,

Wajswelner & Orchard, 2006). Of particular interest is hip flexion among the injured group, given that an increase in hip flexion is associated with increased hamstring stretch (Lee, Reid, Elliott & Lloyd, 2009). This study showed that those with history of HSI exhibited a significantly greater mean hip flexion angle at PRE, Q1 and Q2 compared to the control group. These hip findings are in agreement with previous treadmill based studies assessing fatigue in those with previous HSI, noting an increase in hip flexion during late swing phase (Daly, McCarthy Persson, Twycross-Lewis, Woledge & Morrissey 2016), however is contradictory to other comparable studies showing less (Lee, Reid, Elliott & Lloyd, 2009) or similar (Schuermans, Van Tiggelen, Palmans, Danneels & Witvrouw, 2017) hip flexion. Those noting an increase in hip flexion cited an increase in late swing phase anterior pelvic tilt while fatigued as a likely cause (Daly, McCarthy Persson, Twycross-Lewis, Woledge & Morrissey, 2016; Maas, De Bie, Vanfleteren, Hoogkamer & Vanwanseele, 2017). In contrast, this current study found hip flexion reduced as fatigue increased following Q2 due to the reduced anterior pelvic tilt, which suggests fatigue may offer a protective effect against recurrence of HSI in those with history of HSI via a reduction in hamstring stretch. Observations of a reduction in hip flexion have been attributed to limitations in hamstring extensibility (Lee, Reid, Elliott & Lloyd, 2009; Small, McNaughton, Creig, Nohkamp & Lovell, 2009), which would provide a probable explanation for our post-Q2 findings.

This study provides new critical knowledge of a differing between-group response to fatigue, whereby the control group did not alter their hip flexion throughout the protocol, a similar finding in uninjured soccer players following a game simulated protocol (Small, McNaughton, Creig, Nohkamp & Lovell, 2009). However, the HSI group differed in their response to fatigue demonstrating greater hip flexion up to Q2 compared to controls, potentially increasing their risk of injury during this period. This between-group divergence in hip flexion and HSI injury risk disappeared during Q3 and Q4 when the HSI group decreased their hip flexion to values more consistent with those achieved by the control group throughout the protocol. While convergence of hip flexion results late in the protocol may appear to contradict an increased prevalence of HSI late in matches (Pizzari, Taylor & Coburn, 2012), the significantly different starting point of each group must be considered, and it is therefore likely that the rate in which the hamstring length changes may be a more important contributor than the length. Thus, focusing solely on the comparable end point may understate the important reduction to HSI group hip flexion across the duration of the game protocol, and requires further investigation to clarify the role of hamstring mechanics in sprinting.

This study also identified significantly less L5-S1 extension and T12-L1 flexion when comparing history of HSI to controls, which is a novel finding given gait based literature commonly defines the trunk as a single segment (Schache, Bennell, Blanch & Wrigley, 1999). A typical lumbar lordosis involves a tendency toward kyphotic sagittal plane deviation at the proximal lumbar spine, and lordotic deviation toward the distal lumbar spine (Damasceno, Catarin, Campos & Defino, 2006). When considered along with our findings, a reduction of extension at L5-S1 and flexion at T12-L1, would present clinically as a reduction in the lumbar lordosis in those with a history of HSI. The angle findings are consistent with our segmental findings, showing reduced flexion of the middle-trunk, upper-trunk and trunk-abdominal segments. This is of note, as review articles have described the influences of lumbar lordosis on pelvic position (Schache, Bennell, Blanch & Wrigley, 1999), pelvic position on hamstring muscles, and hamstring muscle on pelvic and lumbar function (Buchtelova, Tichy & Vanikova, 2013). As this is the first example of fatigue, spinal posture and HSI history being assessed in a single study, it appears to describe the specific interaction between previously injured hamstrings and the lumbar spine.

The potential inaccuracies associated with self-reporting injury has been noted as a limitation of this study, as is the improbable application to elite populations given the assessment of community level athletes. Due to specific effects of fatigue (Enoka & Duchateau, 2008), variations in methodology make it inappropriate to make between-study comparison as different protocols elicit different effects of fatigue, as do low numbers of pathological participants.

CONCLUSION: Community level ARF players with a history of HSI might be at higher risk of sustaining another HSI by utilising a gait strategy offering hip flexion that increases their hamstring length up to the end of Q2. When combined with a fatigue-induced reduction in lumbar lordosis for those with a history of HSI, the risks for future HSI are compounded. The findings of this study appear to confirm fatigue and previous HSI as influences on biomechanical function while sprinting, and demonstrate a lower spinal response to HSI.

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