LATE SWING KNEE MECHANICS IN ELITE RUGBY UNION PLAYERS AND TRAINED SPRINTERS

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Hamstring injuries are highly prevalent in running-based sports such as sprinting and rugby union, and are thought to occur during the late swing phase where the hamstrings are under great load and strain. The aim of this study was to investigate the knee mechanics of elite rugby players and speed-matched sprinters during the late swing phase of maximum effort over-ground running. Elite rugby players demonstrated reduced knee extension velocity through late swing, which was associated with a smaller maximum knee flexion angle during the mid-swing phase. As rugby players displayed a greater absolute knee flexion moment, power absorption and negative work, we suggest that the kinematic differences displayed by rugby players may be an adaptation to reduce the velocity of hamstring stretch and load on the hamstring muscles during late swing.

KEYWORDS: running, over-ground gait, injury, hamstring

INTRODUCTION: Hamstring injuries most commonly occur during high-speed running, and are therefore highly prevalent in running-based sports such as sprinting, soccer and rugby union (Opar, Williams, & Shield, 2012). While still a topic of contention, many researchers believe that hamstring injuries are most likely to occur in the late swing phase of high-speed running (Chumanov, Schache, Heiderscheit, & Thelen, 2012). During this phase, the hip is approaching peak flexion, and the knee is rapidly extending. This results in the hamstrings reaching peak lengths and force, with negative work also observed as the hamstrings decelerate the rotation of the shank around the knee in preparation for foot strike. These demands during late swing have been suggested to increase the risk of hamstring injury (Schache, Dorn, Blanch, Brown, & Pandy, 2012). Therefore, the mechanics of the knee during the late swing phase of sprinting provide valuable insight into hamstring function and potential for injury.
While the sprint mechanics of elite sprinters has been well researched, the sprint mechanics of team sport athletes such as elite rugby players has attracted much less research attention. Therefore, it is common for practitioners in team sports to draw on track and field sprinting knowledge and research (Sayers, 1999). It has been previously suggested that the sprint mechanics of elite rugby players may deviate from the ideal ‘sprinters model’ in order to facilitate adaptations to game demands such as sudden changes in direction (Sayers, 1999). Hence, it is reasonable to assume that some kinematic and kinetic differences in sprint technique may be evident between elite rugby players and sprinters, which consequently may influence hamstring mechanics and injury risk. Therefore, the purpose of this study was to compare the knee joint kinematics and kinetics of elite rugby players and trained sprinters during the late swing phase of maximal-effort sprinting.

METHODS: Ten elite rugby union players were sampled from a professional rugby team in the Super Rugby competition. Subsequently, 10 trained sprinters of similar maximal running speeds were recruited, and in doing so the two cohorts were matched for maximal running velocity. All participants were free from any injury that affected their ability to perform maximal effort sprints. Data collection took place at the Australian Institute of Sport indoor track, and all participants provided informed consent prior to the commencement of testing.

Participants were fitted with reflective markers in accordance with a lower body model marker set (Besier, Sturnieks, Alderson, & Lloyd, 2003). After undertaking a self-selected warm up, participants were asked to perform three maximal 50m sprint efforts. A 20-camera 3D motion analysis system (VICON, Oxford Metrics Ltd., Oxford, United Kingdom) sampling at 250Hz was positioned around the 30-50m region of the sprint in order to obtain trajectory data through the maximum velocity phase of each sprint. Eight contiguous 900 x 600 mm force plates (Kistler Instrument Corp., Winterthur, Switzerland) sampling at 1000Hz were centred within the capture area to facilitate collection of ground reaction forces.

A residual analysis and visual inspection of the data was performed in order to determine appropriate filtering levels (Winter, 1990). Marker trajectory and ground reaction force data were filtered using a 4^{th} order low pass Butterworth filter with cut-off frequencies of 15Hz and 80Hz, respectively. A lower body model (Besier et al., 2003) was then used to calculate lower body kinematics and joint kinetics via inverse dynamics. Data were averaged over three strides for each participant, and only right strides were included for analysis. Each stride was normalised from 0% (right toe off) to 100% (subsequent right toe off) of the gait cycle. Foot strike and toe off events were identified using a 10N threshold in the vertical ground reaction force. The late swing phase was defined from contralateral (left) toe off (50% gait cycle) to right foot strike (75% gait cycle). Velocity was calculated as the average velocity of the centre of the pelvis segment across each stride.

Participant characteristics, as well as peaks of key sagittal plane knee kinematic (flexion/extension angle, angular velocity) and kinetic (flexion moment, power absorption, negative work) variables during the late swing phase were compared between the two cohorts using independent samples t–tests. Differences were considered statistically significant at $p < 0.05$.

RESULTS & DISCUSSION: No significant differences were observed for age (rugby players = 26.5 ± 3.3 yrs, sprinters = 30.8 ± 9.0 yrs, $p = 0.174$) or sprint velocity (rugby players = 8.65 ± 0.54 m/s, sprinters = 8.89 ± 0.63 m/s, $p = 0.362$) between the two cohorts. However, height (rugby players = 1.90 ± 0.08 m, sprinters = 1.80 ± 0.05 m, $p = 0.006$) and weight (rugby players = 100.91 ± 12.25 kg, sprinters = 77.56 ± 5.36 kg, $p < 0.001$) were significantly greater in the elite rugby athletes.

In both rugby players and sprinters, a peak in knee extension velocity was observed early in the late swing phase. However, this peak was significantly lower in rugby players ($p = 0.031$). While knee extension angles were similar in the late swing phase, the differences in angular velocity appeared to be driven by a smaller maximum knee flexion angle exhibited by the rugby players during mid-swing (Figure 1a). That is, as both cohorts showed similar knee extension angles at the end of late swing, the rugby players had a smaller excursion of the shank from mid to late swing. Therefore, the shank rotation velocity was lower in rugby players.

Once normalised to athlete body weight, rugby players and sprinters displayed similar peak knee flexion moments, power absorption and negative work done in the late swing phase (Table 1). However, non-normalised kinetic data shows significantly greater peak flexion moment, negative work and a trend towards greater peak power absorption in rugby players. It has been previously suggested that analysing non-normalised data may be a meaningful method to interpret the swing phase of gait (Best & Begg, 2006). We adopted this approach because we were interested in how the knee joint moment related to the capacity of the hamstring muscles to accommodate load in late swing. This is likely to be more closely related to the size and strength of the hamstrings, and may not relate directly to body weight (Wannop, Worobets, & Stefanyshyn, 2012), especially given that previous research has shown that larger rugby players carry a greater proportion of their mass in their upper body compared to smaller athletes (Higham, 2014). Therefore, these results suggest that the hamstrings of rugby players may be under greater load during late swing.

Table 1: Sagittal plane mechanics of the knee during the late swing phase of sprinting.

	Elite rugby players	Trained sprinters	*p*
Kinematics			
Peak knee extension (°)	27.00 ± 3.20	24.43 ± 9.92	0.453
Peak angular velocity (°/s)	-1029.52 ± 78.97	-1175.89 ± 173.25	0.031*
Kinetics			
Peak flexion moment (N·m·kg^{-1})	-2.23 ± 0.19	-2.16 ± 0.38	0.637
Peak flexion moment (N·m)	-221.98 ± 25.14	-168.96 ± 37.93	0.002*
Peak power absorption (W·kg^{-1})	-35.05 ± 7.54	-35.76 ± 10.40	0.864
Peak power absorption (W)	-3504.66 ± 689.47	-2780.85 ± 866.77	0.053
Negative work done (J·kg^{-1})	-1.90 ± 0.15	-1.83 ± 0.43	0.620
Negative work done (J)	-191.13 ± 24.95	-142.36 ± 38.75	0.004*

*Denotes a significant difference between cohorts

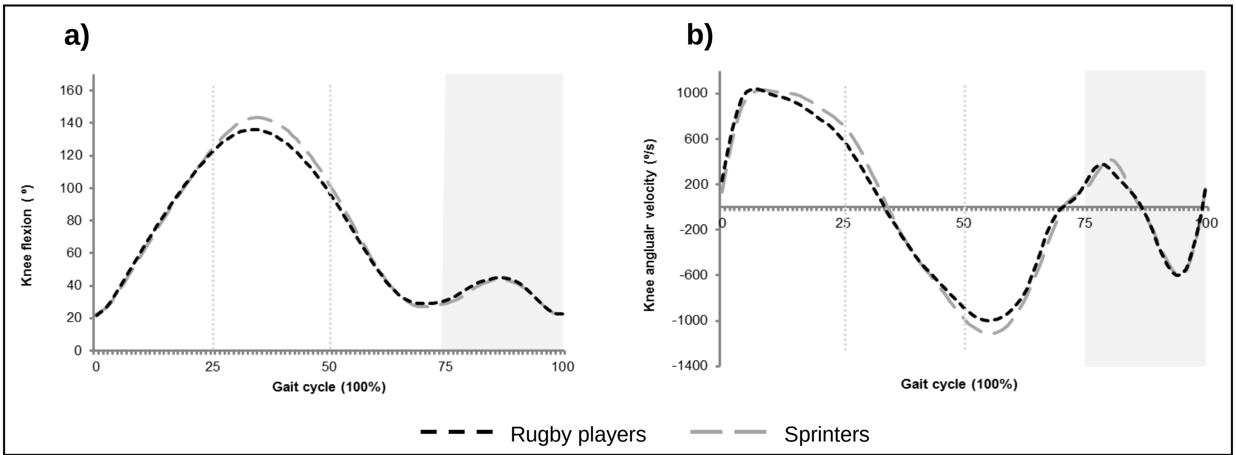

Figure 1: a) Sagittal plane knee angle b) Sagittal plane angular velocity.

Previous research demonstrates that the knee flexion moment in late swing is primarily composed of a large motion-dependent extension torque, resulting from the motion of the shank, and a large muscle-generated flexion torque, produced by the hamstrings to counter this (Zhong, Fu, Wei, Li, & Liu, 2017). Therefore, the reduced angular velocity exhibited by the rugby players may assist in moderating their large hamstring loads by reducing the motion-dependent extension torque and therefore the counteracting hamstring muscle torque. A larger angular velocity in rugby players may increase hamstring load further by increasing the power absorption and negative work required to decelerate the shank. However, it may also be the case that the rugby players perform a large amount of negative work in order limit the angular velocity at the knee, and presumably, the velocity of hamstring stretch. Reducing the velocity of hamstring stretch likely protects the rugby athletes against hamstring injury. In contrast, the greater knee extension velocity shown by the sprinters may reflect a more compliant hamstring musculotendon complex, and therefore a greater ability to withstand rapid excursion of the hamstrings, although this would require further investigation.
To further investigate the kinematic differences as a potential adaptation to manage hamstring load and velocity of hamstring stretch in rugby athletes, the maximum knee flexion (during mid swing) and maximum extension velocity were plotted against the maximum knee flexion moment. When all athletes were considered, there was a trend towards those athletes with larger knee flexion moment during late swing exhibiting smaller maximum knee flexion angles (r= 0.44, p=0.054) and a lower extension velocity (r= -0.42, p=0.063). While more data is needed, the correlation plots suggest that the rugby athletes cluster differently to sprinters (Figure 2). This potentially reflects a strategy by rugby players to reduce knee

flexion in mid swing, in order to reduce the angular velocity of the shank, moderating the large loads placed on the hamstring, and reducing the velocity of hamstring stretch.

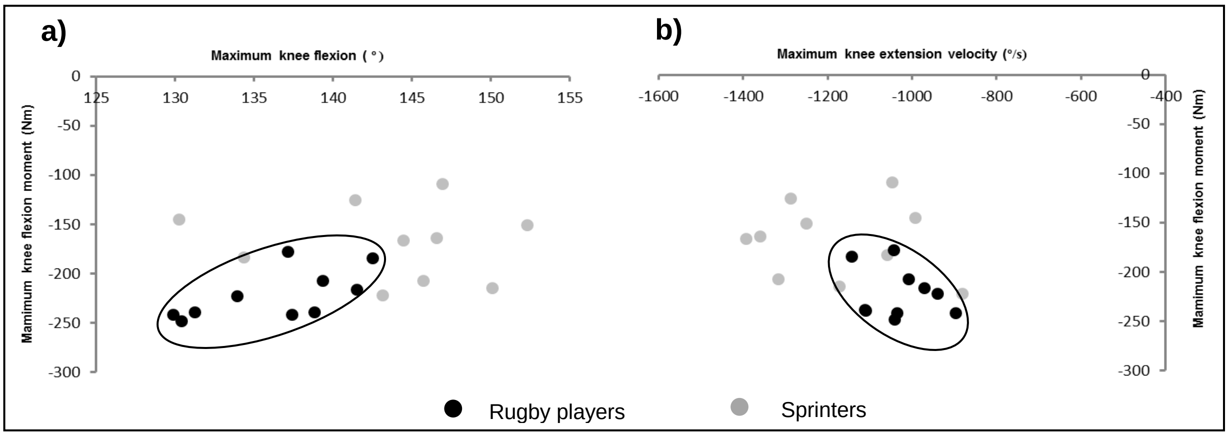

Figure 2: a) The relationship between maximum knee flexion angle and maximum knee flexion moment b) The relationship between maximum knee angular velocity and maximum knee flexion moment.

CONCLUSION: When compared to trained sprinters, elite rugby players exhibit differences in knee kinematics and kinetics during the swing phase of sprinting. These kinematic discrepancies may assist in managing the negative work required to decelerate the shank at late swing, and also limit the velocity of hamstring stretch, thereby providing a protective mechanism against hamstring injury during sprinting. Therefore, caution needs to be taken if rugby performance coaches try to replicate the sprint mechanics of trained sprinters.

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