The mechanical response to hockey-specific running gait:

Implications for the objective monitoring of (p)rehabilitation.

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Abstract

Field hockey is characterised by a unique dribbling position which has been associated with a prevalence of low back pain and lumbar injury. To quantify the biomechanical response of the hockey-specific running gait, twelve field hockey players completed treadmill running at speeds of 6, 9, and 12 $km \cdot hr^{-1}$ with a normal running gait and whilst manipulating the hockey stick to replicate dribbling. Mechanical loading was quantified using tri-axial accelerometery at L4, and muscular activity was measured for biceps femoris (BF), gluteus medius (GM), and quadratus lumborum (QL) of each limb. Running with the stick elicited greater mechanical loading in the medio-lateral ($P = 0.001$) and antero-posterior ($P = 0.003$) planes, and increased peak ($P = 0.004$) and mean ($P = 0.002$) EMG response of QL ($P = 0.004$). The greater planar mechanical loading and QL activation in response to hockey-specific running technique supports epidemiological observations of lower back pain prevalence. The sensitivity of uni-axial mechanical loading to the hockey-specific running posture provides an efficacious means of objectively monitoring mechanical loading in-vivo, whilst the QL activation response has implications for (p)rehabilitative interventions. Running posture and speed can be considered as discrete progressions when considering training load.

Key Words: Field Hockey, mechanical loading, injury

Introduction

Field hockey is an intermittent sport with a 70-minute duration and a mean running speed of ~7km·hr^{-1} (Delves et al., 2021). Field hockey places unique physical demands on the players, attributed to the external constraint of the stick used during dribbling, passing and tackling (Reilly and Seaton, 1990; Hollville et al., 2018). Field hockey players spend most of their playing time in postures between 30-50° of torso flexion (Warman et al., 2019), with up to 30% of match play comprising dribbling with the stick and ball (Lidor and Ziv, 2015; Van Hilst et al., 2015).

The asymmetrical locomotion in field hockey when dribbling forces players into a semi-crouched position combined with trunk flexion and rotation towards the stick side (Reilly and Seaton, 1990; Lidor et al., 2015). This position has been shown to produce repetitive postural stress on the musculoskeletal system with field hockey players at 3-5 times greater risk of sustaining lower back pain than other sports (van Hilst et al., 2015; Gümüs et al., 2018; Rees et al., 2021). Haydt et al. (2012) reported that 59% of field hockey players suffer from lower back pain. Tapsell et al. (2022) reporting reduced running speeds when adding the external constraint of the hockey stick, demonstrating how the compromised biomechanical efficiency impacts upon performance. However, there is little evidence to associate the mechanical response to hockey-specific running posture with the prevalence of lower back pain.

The aim of the current study was to quantify the biomechanical response to the hockey-specific running gait, with specific focus on the influence of running posture and speed to reflect the demands of field hockey. Biomechanical response was quantified using tri-axial accelerometry and electromyography, with implications for objective load management and rehabilitation.

Materials and Methods

Participants

A sample of 12 (6 male, 6 female) field hockey outfield players (20.4 ± 0.79 years, 167.9 ± 7.27 cm, 67.25 ± 7.88 kg) completed the study, with inclusion criteria requiring a minimum of 4 years playing experience, a current training status of 4 hours per week, and free from injury at the time of testing. Testing was completed during the competitive season, with 72 hours recovery post competition. Each participant provided written consent, with ethics provided by the host academic department.

Data Collection and Procedures

Participants were required to attend a single testing session, completed between 14:00-17:00 to mitigate the effects of circadian variation and in accord with habitual competition scheduling. Each participant completed an intermittent treadmill (HP Cosmos, Pulsar, Germany) protocol designed to replicate the running speeds performed during a field hockey game (Delves et al., 2021). The participants were harnessed for safety and familiarised with each running speed in an incremental manner as part of a standardised warm-up which also included dynamic flexibility, in accord with habitual pre-match routines. The testing protocol comprised running speeds of 6, 9, and 12 km·hr^{-1}, completed with and without the hockey stick, in standardised order. These speeds were selected to reflect the activity profile of match-play (Lythe and Kilding, 2011; McGuiness et al., 2019).

Each running speed was maintained to achieve a steady state bout of 30 seconds duration, with a 10 second acceleration and deceleration phase at 3 km·hr^{-1}, and a 10 second passive rest between speeds. A constant treadmill incline of 2% was utilised to reflect the energetic costs of outdoor running at these speeds (Jones and Doust, 1999). The 'without' trial required that the participant carried the hockey stick in their right hand but adopted a normal, upright running gait (all participants were right-handed). The ‘with’ trial required that the participant ran in the semi-crouched position with all participants holding the stick in their right side and manipulating a fixed marker on the treadmill at ground level used to replicate ball manipulation during dribbling.

Prior to exercise, each participant was fitted with a tri-axial accelerometer (MinimaxX S4, Catapult Innovations, Canberra, ACT, Australia) placed at the 4th lumbar vertebra (L4) and secured using under-wrap tape. The accelerometers collected data at a sampling frequency of 100 Hz. Surface electromyography electrodes (Noraxon, Myoxp, USA) were placed at the muscle belly of the bicep femoris (BF), gluteus medius (GM) and quadratus lumborum (QL) on each leg. Site preparation included local cleansing with placement of the electrodes informed by manual palpation and SENIAM guidelines. Pairs of disposable bipolar silver-silver chloride passive wet gel surface electrodes with an inter-electrode distance of 2cm were used, with a sampling frequency of 1500 Hz.

Data Analysis

Accelerometery data was analysed (Catapult Sprint, Catapult Innovations, Australia) for 20 consecutive strides at each running speed and in each running posture to define PlayerLoad in the anterio-posterior (PL_{AP}), medio-lateral (PL_{ML}), and vertical (PL_{V}) planes. Analysis of the EMG data (Noraxon MyoResearch XP Master) was applied to the same 20 stride sample for each speed and running posture. Raw data were low-pass (300Hz) and high-pass (10Hz) filtered. Given the dynamic nature of the running task, an isometric maximal voluntary contraction was considered to lack functional relevance. Instead, data was normalised to the EMG response when running at 6 $km \cdot hr^{-1}$ without the ball, considered the baseline condition about which to quantify a main effect for running speed and posture. Peak and mean EMG magnitude was defined for each muscle.

Statistical Analysis

A repeated measures univariate model was used to investigate main effects for running speed and running posture in each dependent variable. Speed *x* posture interactions were also quantified. Laterality (left, right) was introduced as an additional factor in the EMG data, with two- and three-way interactions quantified. Where significant ($P \leq 0.05$) main effects were identified, post-hoc analysis was employed. All data are presented as mean ± standard deviation.

Results

Figure 1 summarises the influence of running posture and speed on the axial PlayerLoad response. There was a significant main effect for posture in PL_{ML} ($P = 0.001$) and in PL_{AP} ($P = 0.003$), running with the stick eliciting greater loading. There was no main effect for posture in PL_V ($P = 0.139$). There was a significant main effect for running speed in each plane ($P < 0.001$), with axial loading increasing significantly with each increment in speed ($P \leq 0.011$), with the exception of PL_V between 9 – 12 km·hr^{-1} ($P = 0.067$). There was no posture *x* speed interaction ($P \geq 0.336$) in any plane.

** Insert Figure 1 near here **

Figure 2 summarises the influence of running posture and speed on the peak EMG response in the BF, GM and QL respectively.

** Insert Figure 2 near here **

There was a significant main effect for posture in QL_{PEAK} ($P = 0.004$), running with the stick eliciting significantly greater magnitude than without. There was no main effect for posture in BF_{PEAK} ($P = 0.858$) or GM_{PEAK} ($P = 0.703$).

There was no significant main effect for running speed in GM_{PEAK} ($P = 0.118$), but there was in BF_{PEAK} ($P = 0.002$) and QL_{PEAK} ($P = 0.001$), with peak EMG increasing significantly between 6 – 9 km·hr^{-1} ($P \leq 0.006$), but not between 9 – 12 km·hr^{-1} ($P \geq 0.303$).

There was no significant main effect for laterality in any muscle ($P \geq 0.313$), and no significant two-way ($P \geq 0.273$) or three-way ($P \geq 0.533$) interactions in any muscle.

Figure 3 summarises the influence of running posture and speed on the mean EMG response in the BF, GM and QL respectively.

** Insert Figure 3 near here **

There was a significant main effect for posture in QL_{MEAN} ($P = 0.002$), running with the stick eliciting significantly greater magnitude than without. There was no main effect for posture in BF_{MEAN} ($P = 0.222$) or GM_{MEAN} ($P = 0.509$).

There was no significant main effect for running speed in GM_{MEAN} ($P = 0.191$), but there was in BF_{MEAN} and QL_{MEAN} ($P = 0.001$). BF_{MEAN} increased significantly between 6 – 9 km·hr^{-1} (P

= 0.001), but not between 9 – 12 km·hr^{-1} (P = 0.455), whereas QL_{MEAN} increased significantly between 6 – 9 km·hr^{-1} (P < 0.001) and 9 – 12 km·hr^{-1} (P = 0.013).

There was no significant main effect for laterality in any muscle (P ≥ 0.077), and there were no significant two-way (P ≥ 0.218) or three-way (P ≥ 0.533) interactions in any muscle.

Discussion

The aim of the current study was to quantity the biomechanical response to the field hockey specific running gait. Tri-axial accelerometry at L4 was quantified to reflect the prevalence of lower back pain in field hockey players (Haydt et al., 2012; van Hilst et al., 2015; Gümüs et al., 2018). Previous research has shown that the mechanical loading response is sensitive to anatomical placement, differentiating between L4 and C7 in cricket bowling which also demands spinal flexion and rotation (Greig and Nagy, 2017). Running with the stick elicited greater axial PlayerLoad in the medio-lateral and antero-posterior planes, which can be attributed to spinal rotation and flexion respectively when dribbling the hockey ball. Previous research has reported that this unique running posture increases compression loading and spinal shrinkage when compared to a normal running gait (Reilly and Seaton, 1990; Reilly and Temple, 1993). In the present study, running with the stick did not increase the magnitude of vertical loading. However, the combination of maintained vertical loading and increased medio-lateral and antero-posterior loading will increase the vector magnitude in the frontal and sagittal planes respectively. This type of shear force is potentially more damaging than compression forces, with McGill (2004) highlighting the lack of capacity for a flexed torso, whether flexed about the hips or the lumbar spine, to resist damaging shear forces. More recently, Ogurkowska and Kawalek (2017) attributed chronic degenerative changes in the lumbar spine in professional field hockey players to the repetitive asymmetrical and multi-planar loading of the spine.

Mechanical loading was also quantified using electromyography and running with the stick elicited greater peak and mean EMG response in quadratus lumborum. Direct comparisons with the literature are limited by a lack of previous applications in field hockey, but QL functions to stabilise the lumbar area (Andersson et al., 1996) and thus the increased activity might reflect the prevalence of lumbar spine injury and/or pain in field hockey players (Haydt et al., 2012; Rees et al., 2021). Kawalek and Garsztka (2013) reported chronic asymmetry in QL hypertonicity in professional field hockey players, and whilst non-significant there was a 16% difference in bi-lateral contributions to $\mathrm{QL}_{\mathrm{MEAN}}$. This asymmetry during the 30sec exercise bout used in the present study might be sufficient to create a chronic adaptation over a match, season, or career.

There was no main effect for running posture in biceps femoris or gluteus medius. The dribbling posture has been shown to influence the range of hip and knee flexion during running (Ogurkowska and Kawałek, 2018), with potential implications for activation of the bi-articular hamstrings and the prevalence of hamstring strain injury in field hockey (Rees et al., 2021). With no change in BF activation in response to the dribbling posture, the mechanism of hamstring strain injury in hockey might therefore be attributed to the acceleration and deceleration demands of the intermittent profile, as opposed to the steady state bouts used in the present study. Gluteus medius function has been associated with low back pain (Haydt et al., 2012; Wege, 2006) and Bussey (2010) reported aberrant gluteus medius activation in female hockey players. However, the prolonged standing trial used by Bussey lacks functional relevance to the demands of field hockey, and might explain the non-response during treadmill running observed in the present study.

The present study also considered the influence of running speed on the biomechanical response to hockey dribbling. Whilst there were no posture *x* speed interactions in any metric, increasing running speed was shown to elicit a progressive increase in axial PlayerLoad in each plane. Barrett et al. (2014) observed similar incremental patterns in loading with increasing running speed, with a normal gait. Increased speed also elicited increased peak and mean EMG response in BF and QL. High-speed running with the stick therefore presents the greatest functional challenge and risk of injury. High speed running is widely acknowledged as the primary mechanism of hamstring strain injury in field-based team sports like hockey (Danielsson et al., 2020). Faster running is also likely to increase the demands on postural stability (Zemkova and Zapletalova, 2022) with implications for QL activation and subsequent lumbar spine pain and/or injury.

In respect to rehabilitative or training progressions, increasing speed from 6 to 9 km·hr^{-1} presented a significant increase in challenge as quantified by planar mechanical loading and electromyographical response (with the exception of gluteus medius). However, increasing from 9 to 12 km·hr^{-1} did not present a unique progression in PL_{V}, BF_{PEAK}, BF_{MEAN} or QL_{PEAK}, perhaps reflecting the running gait adaptations to treadmill running. Field hockey has an intermittent and multi-directional activity profile, with the emphasis on speed and directional change increasing the complexity of the mechanical demands. The reactive directional change places greater emphasis on stride frequency than stride length as a means to achieve directional and speed changes. The linear nature of the treadmill running task used in the present study might also influence the observation of no main effects for laterality, and no interactions between laterality and posture or speed. Despite the right-sided flexion towards the ball, the running was still performed in a straight line, with foot contacts within the constraints of the treadmill belt.

Care should therefore be taken when generalising beyond the specific research design elements of the present. Whilst the treadmill-task facilitated standardisation of the running speeds, future research might consider progression to field-based skills and position-specific demands (Warman et al., 2019), faster speeds (Dewar and Clarke, 2021) and greater ecological validity. The present study quantified the mechanical response to a 30 second bout of running, and the chronic adaptations to a game, season or career should also be considered for the long-term health benefits of the player. In considering future research, tri-axial accelerometry does provide an efficacious means of objectively monitoring mechanical loading during hockey-specific exercise. Accelerometer placement around L4 as opposed to the traditionally used C7 placement (when employing GPS technology) is advocated to better understand the prevalence of lumbar spine injury in hockey players. Multi-planar analysis is also advocated to reflect the complexity of the hockey-specific running posture. Whilst EMG lacks the same degree of accessibility, QL presents primary focus for injury risk. In training or rehabilitative progressions running with the ball and increasing running speed should be considered as discrete progressions.

Conclusion

The prevalence of lower back pain and injury in field hockey players is a primary concern. Tri-axial accelerometery provides an in-vivo method for quantifying lumbar spine loading and showed that the modified running gait used when dribbling the ball elicited increased loading in the medio-lateral and antero-posterior planes. This modified running action characterised by spinal flexion and rotation also increased the electromyographical demand on quadratus lumborum. This increased muscular demand is indicative of greater spinal stabilisation, and in association with the increased planar loading has implications for lumbar spine injury, supporting epidemiological observations. In addition to running posture, and reflecting the demands of the sport, running speed also influenced the loading and muscular response. Running speed and running with *vs* without the ball should therefore be considered as discrete progressions when planning conditioning or rehabilitative sessions.

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Declaration of Interest Statement: None

Figure Captions

Figure 1. The influence of field hockey running posture and speed on the planar mechanical loading response.

Figure 2. The influence of field hockey running posture and speed on the peak EMG response.

Figure 3. The influence of field hockey running posture and speed on the mean EMG response.

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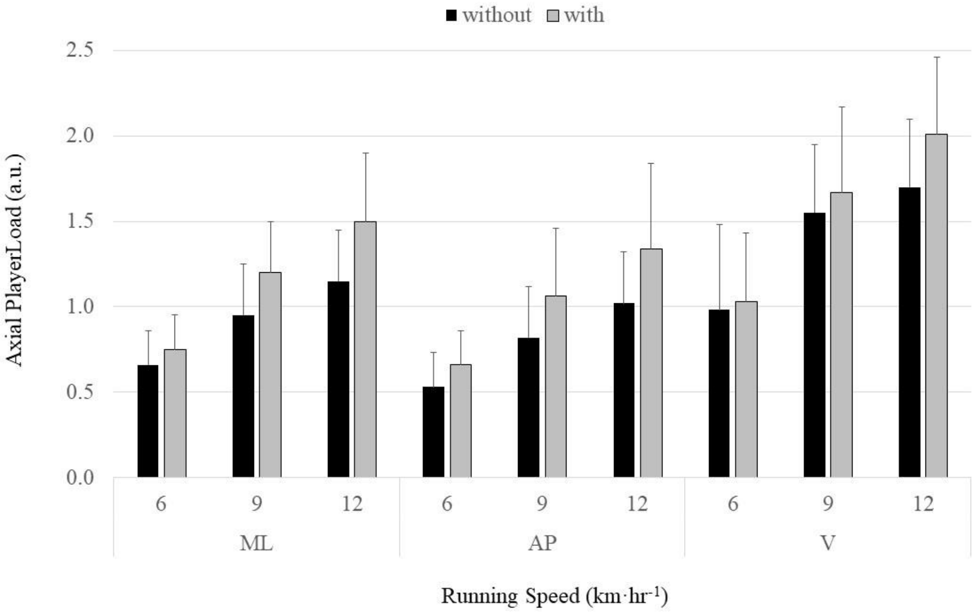

Figure 1. The influence of field hockey running posture and speed on the planar mechanical loading response.

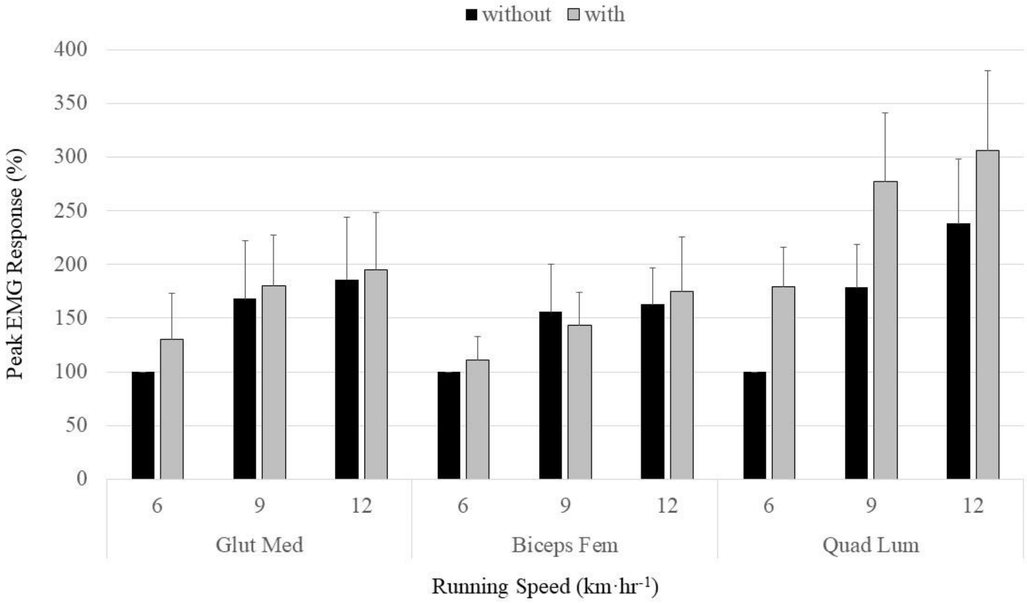

Figure 2. The influence of field hockey running posture and speed on the peak EMG response.

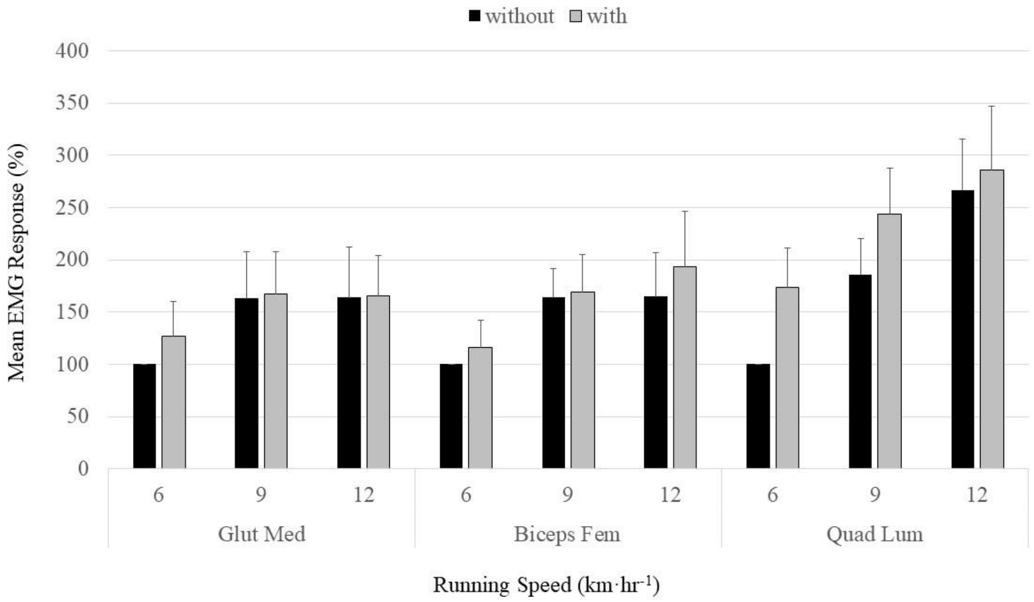

Figure 3. The influence of field hockey running posture and speed on the mean EMG response.