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MUSCLE ACTIVITY OF THE STANCE KNEE IN ELITE RACE WALKERS

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The purpose of this study was to compare knee muscle activity in race walkers with different knee extension patterns. Three international athletes walked over two force plates recording at 1000 Hz. Video data were simultaneously recorded at 100 Hz; the digitised data were combined with the force data to calculate net muscle moments and joint powers. EMG testing was carried out on three muscles which cross the knee. The two walkers with legal techniques had similar moment and power patterns, whereas the non-legal walker experienced a longer period of eccentric flexor moment at the beginning of stance, which may have affected his ability to extend his knee correctly. After this, all three athletes experienced a period of isometric contraction at the knee. Achieving correct technique requires both strength endurance exercises and mobility development.

KEY WORDS: athletics, electromyography, muscle moment, race walking

INTRODUCTION: In race walking, the knee must be straightened from the point of contact until the 'vertical upright position' (referred to here as 'midstance'). Knicker and Loch (1990) defined straightness as a knee angle between 175 and 185°. Kinematic studies (e.g. Hanley et al., 2008) have shown that many athletes are able to achieve full extension throughout the required period. Others had slightly flexed knees at contact but their knees extended so quickly during the early part of stance that the lack of extension went unnoticed. Also, many race walkers hyperextend their knees considerably during stance (Hanley et al., 2008). The activity of the muscles responsible for knee extension during race walking stance is not well documented. Although not always generalisable to a larger population, single subject analyses on elite athletes can be useful for qualitatively analysing specific movements. The purpose of the study was to describe knee moment, power and EMG patterns in athletes with different extension patterns to establish if there may be a difference on an individual basis.

METHODS: International race walkers gave informed consent and the study was approved by the University's ethics committee. Each athlete walked at race pace over two 900 mm X 600 mm force plates (Kistler, Winterthur) recording at 1000 Hz. Timing gates were placed 4 m apart to ensure they walked within 2% of the target speed. There was a 25 m approach along an indoor running track to the force plates and a further 25 m after. Athletes completed at least ten trials and the three closest to the target time were analysed provided the athlete did not alter their gait to contact the force plate. Following the completion of data analysis, athletes were split into three groups (two 'legal' and one 'non-legal'): 1) knee extended at contact (175 - 185°) with the knee remaining extended until midstance; 2) knee extended at contact (175 - 185°) and hyperextented (>185°) at midstance; and 3) knee flexed at contact (<175°), remaining flexed and not reaching extension at any point. One athlete from each subgroup was chosen as a case study and are named after the group to which they belong (Athlete 1: female, 1.70 m, 58.5 kg; Athlete 2: male, 1.88 m, 73.9 kg; Athlete 3: male, 1.79 m, 69.4 kg).

Two-dimensional video data were collected at 100 Hz using a RedLake Motion Pro camera. The shutter speed was 1/500 s. The camera was placed 12 m from the line of walking. The video data were manually digitised by a single experienced operator using motion analysis software (SIMI, Munich). De Leva's (1996) body segment parameter models were used to obtain data for the right thigh, right lower leg, and right foot. A cross-validated quintic spline was used to smooth the displacement calculations and a second-order, low-pass Butterworth filter used to filter the derivatives. The cut-off frequencies were based on residual analysis (Winter, 2005) and ranged from 8.6 – 12.2 Hz. The kinematic and force data were used to calculate net joint moments and powers at the knee during stance using a link segment rigid body model (Winter, 2005). A positive knee moment indicated a net extensor moment; a negative moment a flexor moment. Positive power values indicated concentric contraction and negative power values eccentric contraction. Muscle moments have been normalised using the product of body mass and stature; powers have been normalised using body mass. Surface EMG data were recorded of three muscles crossing the right knee (1000 Hz). The muscles were rectus femoris, vastus lateralis, and biceps femoris. Skin preparation included shaving and cleansing of the surface with swabs. Each electrode was placed over the belly of the muscle in the direction of the muscle fibres. The electrodes (Delsys, Boston) consisted of two silver bars 10 mm long, 1 mm wide, and 10 mm apart. One earth, common to all three electrodes, was placed on the spine. The gain was set at 1000 V/V. A Delsys Myomonitor telemetry unit was used to collect the data. Wires connecting the electrodes to the unit were held in place by elastic net bandages. Average rectified EMG (AREMG) was used to process the raw EMG, with a time window of 50 ms and overlap of 25 ms. EMG data were collected for 5 seconds and begun about 2 seconds before initial contact. The EMG data collection software was synchronised with the force plate software and the camera system.

RESULTS AND DISCUSSION: The knee moments and powers for the athletes are shown in Figure (upper and lower panels, respectively).

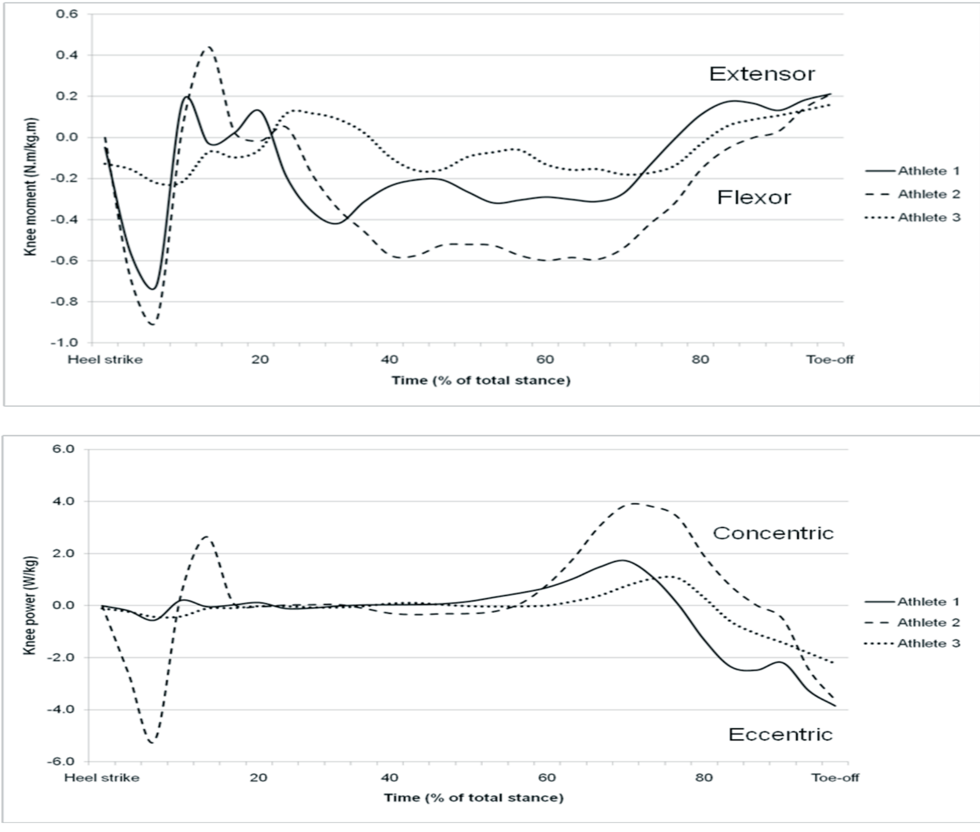

Figure 1: Knee net moments (upper panel) and knee net powers (lower panel) during right foot stance.

The AREMG results for the biceps femoris, rectus femoris and vastus lateralis are shown in Figure 2 (upper, middle and lower panels, respectively) and have been qualitatively described in this paper.

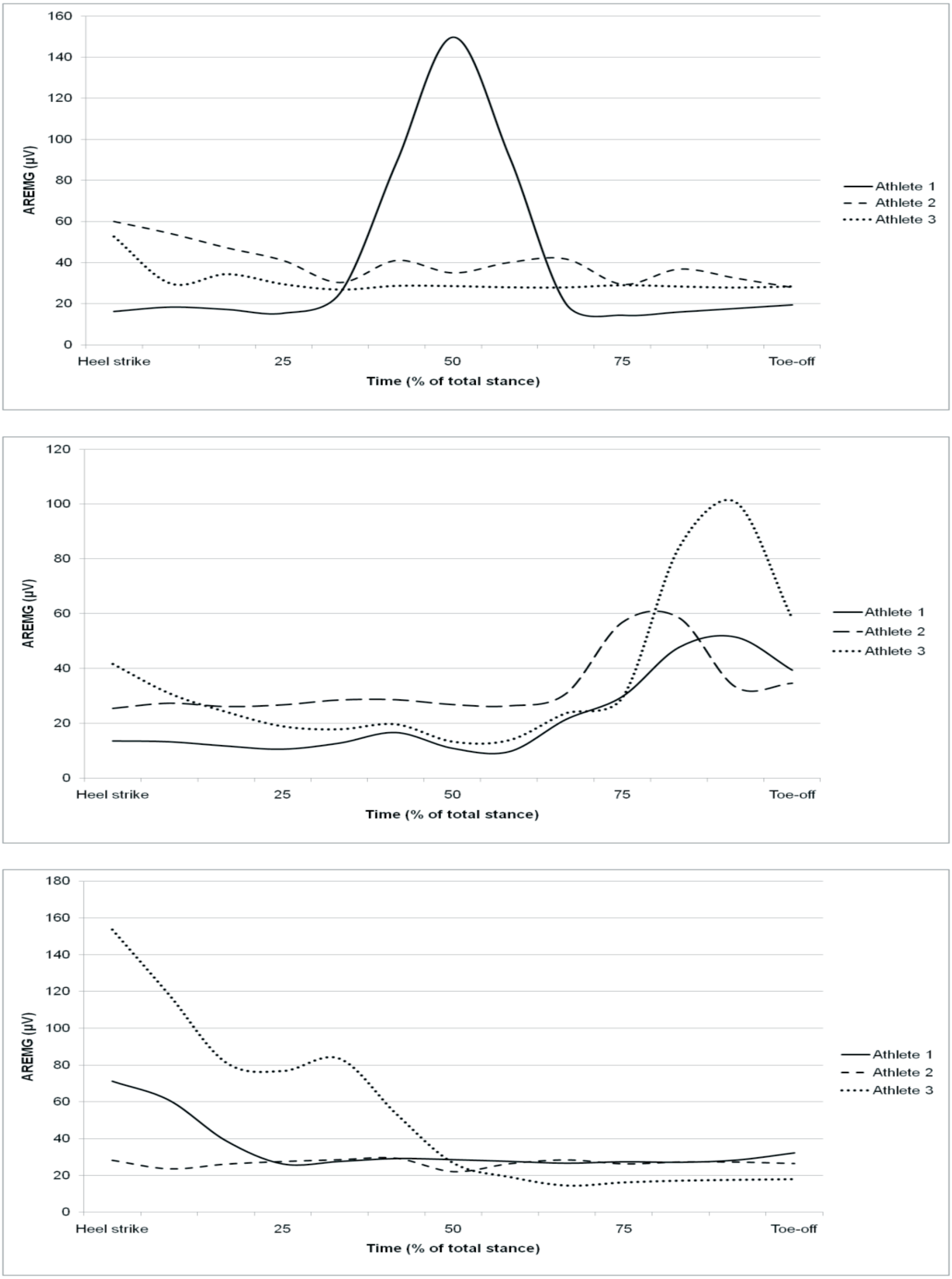

Figure 2 (upper, middle and lower panels): AREMG for the biceps femoris, rectus femoris and vastus lateralis during stance.

In Figure 1, athletes 1 and 2 walked legally and had similar patterns for both moments and powers. An eccentric flexor moment occurred between heel strike and 10% of stance, followed by a concentric extensor moment between about 10% and 20%. In contrast, Athlete 3 experienced a smaller net eccentric flexor moment for a longer period, until about 20% of total contact time. After 20% of stance, while Athletes 1 and 2 experienced a prolonged, mainly isometric flexor moment until about 60% of stance, Athlete 3 underwent an isometric extensor moment at the 20% point and did not experience a similar isometric flexor moment until after 35% of stance. Between 60% to 80% of stance a concentric flexor moment was observed as the knee flexed after midstance; an eccentric extensor contraction occurred after this point until toe-off.

The eccentric flexor moment at the beginning of stance coincided with activation of the biceps femoris in both Athletes 2 and 3, but not Athlete 1 (Figure 2, upper panel). For Athlete 1, a large period of activity was observed between 30 and 70% of stance, during hip extension. Some activity during this period was also noticeable in Athlete 2. The other biarticular muscle, rectus femoris, was found to have relatively small amounts of activation until the last 30% of stance when it was predominantly active as a hip flexor (Figure 2, middle panel).

In Figure 2 (lower panel), vastus lateralis was predominately active during the first 50% of stance for Athlete 3 (who also showed evidence of rectus femoris activation at heel strike). This was presumably in an attempt to extend the knee but the initial activity of the hamstrings during the eccentric knee flexor moment may have resisted this motion. While this also occurred in the two legal walkers, their eccentric flexor moments were much shorter in duration (although larger in magnitude) and their knees were already extended at heel strike. Athlete 1 did also have a brief period of vastus lateralis activity to ensure knee extension, but Athlete 2, who hyperextended his knee beyond 185° at midstance, did not have noticeable vastus lateralis (or rectus femoris) activity and may have the joint laxity required to achieve knee extension without significant muscular activity. Race walkers' knees do not flex and extend in the same manner as in normal walking or running; the isometric contraction from just after heel strike to after midstance results in the knee angle remaining relatively constant. This meant that Athletes 1 and 2 maintained a legal knee position while Athlete 3 maintained a non-legal position instead. It is important therefore for race walkers to try to fully extend the knee prior to initial contact to comply with the rules of the event.

CONCLUSION: The aim of this case study was to describe differences between race walkers with different knee kinematics during stance, and the results are therefore specific to those individuals and not necessarily generalisable to other race walkers. Two race walkers walking legally had different muscle moment and power patterns from an athlete whose technique was not legal. This athlete showed muscle activation of the vastus lateralis at heel strike which suggested an attempt was made to extend the knee. This athlete is advised that achieving legal race walking technique is determined by both muscular strength and joint laxity at the knee and requires training of both strength endurance and mobility development. Further studies on muscle moments, powers and EMG on larger samples of race walkers are warranted.

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