SPORT-SPECIFIC DIFFERENCES IN HIP JOINT KINETICS DURING RUNNING GAIT IN HIGH LEVEL MALE ATHLETES.

Damien O'Meara[1] and Mark Moresi[1 2]

NSW Institute of Sport, Sydney, Australia[1]
Centre of Physical Activity Across the Lifespan (CoPAAL), Australian Catholic University, Sydney, Australia[2]

The purpose of this study was to investigate the differences in running gait joint kinetics within high level triathletes, middle distance runners and sprinters. Fifteen high level athletes (five athletes from each discipline group) ran at their typical race pace along a 55m indoor track. Kinematic and ground reaction force data were captured and average joint angles, velocities, moments and powers calculated for the lower limb. Group average curves with 95% confidence intervals were calculated. Differences in running velocity, ground reaction forces and hip joint kinematics and kinetics were observed. It was suggested that differences reflected potential training adaptations and/or coaching strategies specific to each discipline group. Observed differences may provide valuable insight into potential areas for performance enhancement.

KEY WORDS: triathlon, track and field, sprinting, locomotion, motion analysis.

INTRODUCTION: A number of concepts that relate to running technique can be considered fundamental across the spectrum of running disciplines, e.g. sprint, middle-distance, long-distance. One key concept involves the relationship between stride length and frequency. To reach higher speeds requires greater stride frequency changes compared to stride length. Another key concept involves the minimisation of braking and maximisation of propulsive force during ground contact. However across the spectrum of running disciplines the running technique or strategy differs depending on the required distance. A sprinter is effective at maximising acceleration and top speed, while a long-distance runner efficiently maintains speed over longer distances. The different strategies, and subsequent training methods, adopted by elite athletes across the spectrum of running disciplines suggest subtle differences in the mechanism responsible for running performance.

Changes to running speed can affect leg stiffness (Arampatzis, Bruggemann, & Metzler, 1999; Kuitunen, Komi & Kyrolainen, 2002) and hip and knee joint torques and powers (Schache, Blanch, Dorn, Brown, Rosemond & Pandy, 2011). However, although the magnitude of joint kinetics increases with speed, patterns of joint torques and powers has been shown to remain consistent for a sample of runners (Schache et al., 2011). Studies that have measured joint kinetics show the muscles that work across the hip play the greatest role during higher running speeds (Mann 1981, Arampatzis et.al. 1999, Bezodis, Kerwin & Salo 2008, Schache et al., 2011). This is not surprising when you consider the role of hip muscles to flex and extend the leg and importance of stride frequency at high speed.

Adopting an inverse dynamic approach to the analysis of running gait provides objective measurement of net joint kinetics. These data represent the net result of kinetics responsible for body segment acceleration. Although limited, i.e. does not determine specific muscle contributions, these data can help to illustrate muscle coordination patterns. There is potential to use inverse dynamic methods to objectively determine running gait patterns for elite athletes from specific running disciplines. This knowledge will improve understanding of specific mechanisms associated with different running gait strategies/training that are adopted across the spectrum of running disciplines.

The aims of this study were to a) Compare horizontal ground reaction forces, and hip joint kinematics and kinetics to investigate fundamental running strategies across a range of running disciplines (sprint, middle-distance and triathlon), and b) Establish a spectrum of normative data by monitoring elite athletes whose technical abilities are specific to their running discipline.

METHODS: Five triathletes, five middle distance runners and five high-level sprinters (Table 1) performed six running trials (3 left, 3 right) at their typical race pace along a 55 m synthetic indoor track. Gait analysis was conducted as part of their regular sport science servicing at their state institute of sport. Informed consent to use anonymous data for research purposes was obtained from all athletes as part of their normal scholarship agreement. An eight camera motion analysis system (Vicon MX 13; Oxford Metrics Ltd., Oxford, United Kingdom at 250 Hz) and four force plates (Kistler 9281CA, Winterthur, Switzerland @ 500 Hz) were used to analyse kinematics and joint kinetics in the sagittal plane at the 35 m mark using the plug-in gait full body model. Average gait curves from both left and right trials during ground contact (normalised to -20% to 120% of stance) were generated for each participant. A group average and 95% confidence interval (CI) for each specific event group was generated for comparison. If a group mean was outside the CI of another group for a considerable percentage of stance, 5%, then the groups were considered significantly different over this period.

Table 1: Participant descriptives (Mean ±SD).

Sport	n	Age (y)	Height (m)	Weight (kg)	Event	Personal Best (m:s)
Sprinters	5	24.8 ±2.4	1.81 ±0.03	78.2 ±4.2	100m	10.54 ±0.14
					200m	21.10 ±0.25
					400m	44.80
Middle Distance	5	22.8 ±2.9	1.81 ±0.02	69.9 ±3.8	800m	1:47.82 ±1.81
					1500m	3:36.03 ±4.28
Triathlon	5	20.0 ±1.7	1.79 ±0.03	68.2 ±6.7	10,000m	15:31.00 ±8.44

RESULTS: Mean running velocity at toe-off was 9.32 m/s (CI 9.10 - 9.54), 7.53 m/s (CI 7.06 – 8.00) and 5.45 m/s (CI 5.02 – 5.87) for the sprinters, middle distance runners and triathletes respectively. Ground contact times were 0.105 s (CI 0.100 – 0.111) for the sprinters, 0.129 s (CI 0.115 – 0.142) for middle distance runners and 0.179 s (CI 0.166 – 0.193) for triathletes.

Ground reaction force CI indicated significantly different force traces, particularly in the anterio-posterior (A-P) direction (Figure 1) with the triathletes showing less braking force at initial impact as well as less propulsive force at toe-off. Middle distance runners and sprinters showed similar braking forces during initial contact however the middle distance runners spent a longer percentage of ground contact in the braking phase coupled with less relative propulsive force during the second half of stance.

Although the initial hip angle was similar for all groups, hip velocity, moment and power indicated differences particularly at contact and during the propulsive phase of stance (Figure 2).

DISCUSSION: The present study displays unique patterns of kinematic and kinetic data that reflect fundamental differences in running gait strategies within athletes from different gait-related sporting disciplines. Technical differences or movement patterns are highlighted by deviation of group mean and fluctuations of group variability throughout the stance phase. Such variation in technique and gait strategy may reflect specific training adaptations and/or technical coaching designed specifically for the individual participant disciplines.

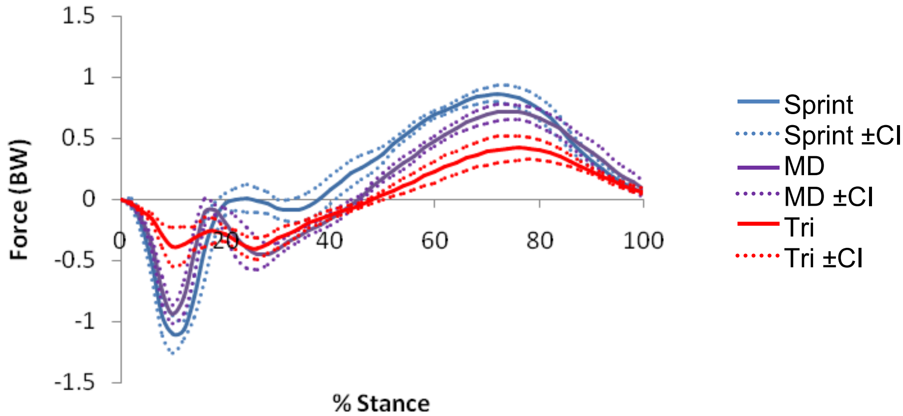

Figure 1: Anterio-posterior (A-P) ground reaction force comparison (sprinters: sprint, middle distance: MD, triathletes: TRI), displayed as the average gait curve (AVE) ±95% CI.

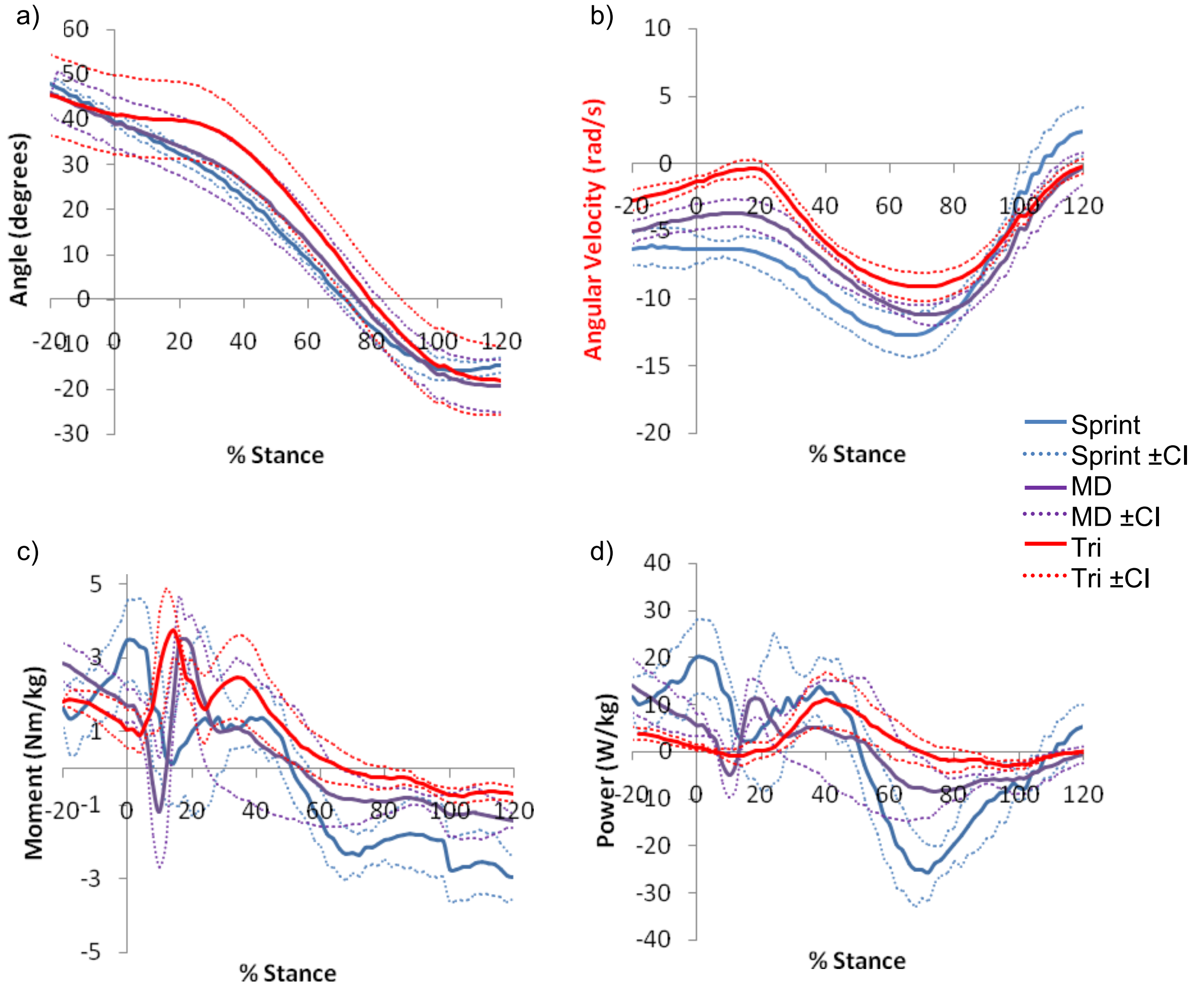

Figure 2: Hip a) angle, b) velocity, c) moment, and d) power comparison during stance. NB. Sprinters: Sprint, middle distance: MD, triathletes: TRI; curves displayed as the average gait curve (AVE) ±95% CI.

Despite similar hip angles at contact, sprinters appeared most effective in hip extension during the early stance. This was coupled with increased hip flexion moments in the mid and later stages of stance. Although the triathletes appear to exhibit relatively high hip extension moments immediately following initial stance and through to mid-stance, hip joint velocities and subsequent powers would suggest that these moments are not effective. More effective hip extension during initial stance may be beneficial for triathletes to improve their running efficiency and effectiveness.

It is well established that increases in running velocity relate to increased moments and powers at the hip joint (Novacheck, Schache, Belli et al). High hip joint kinetics just prior to (generate hip extension) and during late stance (brake hip extension) enabled the sprinters to achieve higher running velocities. However, the triathletes display the highest hip joint moments between 30-40% of stance, generating a considerable increase in hip extension velocity (acceleration) to extend the hips. Previous research suggests that although the magnitude of hip joint moments increase with increases in running velocity across similar velocity ranges to the present study (3.50 – 8.95 m/s), the underlying kinetic pattern remains consistent (Schache et al., 2011). Thus, it is proposed that although differences in the magnitude of gait kinetics would be seen within each participant at different running velocities, the underlying gait pattern and strategy exhibited would remain stable. Future research investigating gait differences in high level athletes from similar sports across a range of velocities would serve to further validate this contention.

It's suggested that the reduced time spent in braking during stance by sprinters are related to the more effective hip extension prior to and during early stance exhibited by these athletes. The reduction in the percentage of stance spent in braking may also be related to greater leg stiffness and subsequent reduced knee flexion in the sprinters. By experiencing less 'collapse' on the stance leg, sprinters may reduce their braking forces and more effectively utilise the forces applied via the hip joint muscles. Middle distance athletes appear somewhat in the middle of this continuum however reduction in the magnitude and time spent in braking phase may aid in increasing efficiency for these athletes. It may be that for these athletes, the hip kinetics represent the optimal combination of muscular effort and mechanical efficiency.

Although hip joint moments and powers show relatively large intra-sport variation, as indicated by the CI, clear differences in hip joint kinetics are evident across the stance phase, including just prior to and at intitial contact and during the propulsive phase of stance. Comparison of gait parameters across different gait-related sporting populations may provide insight into future technical modifications and coaching that may enhance performance.

CONCLUSION: Differences in joint kinetics and kinematics were identified between elite male triathletes, middle distance runners and sprinters. It is suggested that these differences reflect specific training adaptations and technical strategies specific to each individual discipline. Comparison of gait differences at the hip joint across sporting disciplines may provide coaches and athletes with valuable insight into the limitations and potential performance improvements.

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