THE EFFECT OF PACE ON STRIDE CHARACTERISTICS AND VARIABILITY IN SPRINT RUNNING

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The purpose of this study was to investigate the influence of sprint running pace on stride characteristics and their associated variability. Stride characteristics were determined for four experienced male track athletes during sprint running trials at three specified paces. The influence of pace on the stride length and frequency were investigated along with the within subject coefficient of variation for the step frequency / length ratio and the stride velocity. Stride length and stride frequency were shown to influence velocity the greatest at the slowest and fastest paces respectively. Variability of the stride frequency / length ratio was shown to increase with pace whereas the variability of the stride velocity was shown to decrease with pace. Variability within the stride characteristics suggests athletes adopt a flexible control strategy which can adapt to potential perturbations.

KEYWORDS: frequency, length, stride, variability, pace

INTRODUCTION:

Previous research investigating the interaction between stride length and stride frequency in relation to running has generally been inconclusive. Hunter et al. (2004) identified a contrast in findings dependant on whether an intra- (within) or inter- (between) subject approach was adopted. From a inter-subject perspective stride length was significantly related to velocity whereas stride frequency was not. In contrast, when an intra-subject approach was used they found athletes produced their fastest trials with a higher step frequency, not a longer step length. This was in agreement with Weyand et al. (2000) who stated that speed increases were achieved primarily by increases in stride length at lower speeds and stride frequency at higher speeds.

Variability, which is inherent within all biological systems (Newell and Carcos, 1995) has previously been considered in relation to human gait. Specifically, Danion et al. (2003) concluded that stride length and stride frequency are fundamental parameters determining variability. Segers et al. (2007) suggested that running strides are related to a unique step frequency / step length ratio and therefore this may provide a good measure when assessing variability within running technique. Previous investigations into the effect of speed on variability within running gait (Queen et al., 2006) found speed to have little effect on the variability of discrete kinematic variables.

Variability in human movement has been interpreted to be both detrimental and beneficial to overall performance depending on the parameters under investigation (Heiderscheit et al., 2002). The variability of stride characteristics has been shown to increase in subjects with movement disorders (Hausdorff et al., 1997), suggesting the variability present is detrimental to normal healthy function. In contrast, joint coordination variability has been suggested to offer flexibility in adapting to perturbations (Hamill et al., 1999). Limited research has however focussed on variability within stride characteristics in relation to performance, and it may be the case that just as the function of variability changes depending on the variables under investigation, it may also vary according to the nature of the investigation i.e performance or injury related.

The purpose of this study was to gain an initial insight into how sprint running pace influences stride characteristics. Specifically, how sprint running pace influences the variability of the stride characteristics and the implications this has on performance.

METHOD:

Four experienced male track athletes (stature: 1.83 ± 0.08 m; mass 78.0 ± 6.1 kg; age 21.5 ± 2.1 yrs) were recruited for the study. The subjects were all injury free at the time of the study. Institutional ethical approval from the University Research Ethics Committee and subject written informed consent were both obtained. The subjects performed 4 sprint-running trials (60 m) at each of 3 verbally described paces (100 m (maximum velocity), 400 m & 800 m race pace). A standard period of 7 minutes rest was allowed between sprint-running trials. Kinematic data were collected at a sampling rate of 400 Hz using the automatic motion analysis system CODA. For each trial, data were recorded throughout a 6 m collection area (44 m – 50 m of the trial). The average stride velocity for each trial was determined using the kinematic data obtained from CODA. During all trials three-dimensional coordinate data were obtained for markers attached at the second metatarsal tip (2nd TT) and fifth metatarsal-phalangeal joint (5th MTP) on each running spike. Touchdown was defined using the 2ndTT and takeoff was defined using the 5th MTP. These markers were chosen based on the study of Bezodis et al. (2007) which highlighted the benefit of using specific forefoot markers to identify touchdown and toe-off. During dynamic trials touchdown and takeoff were defined by the first and last instants in time respectively, that the marker vertical position data fell below (touchdown) or exceeded (takeoff) a threshold (determined using static trials). A single stride was defined between successive unilateral foot touchdowns. Data were collected for two full strides in each trial resulting in a total of eight strides per subject per pace. Stride characteristics (length (SL), frequency (SF) and velocity (SV)) were determined for each stride analysed, and a stride frequency / stride length ratio (SFLR), defined as the stride frequency divided by the stride length, was subsequently determined. For each pace a mean stride velocity, stride length and stride frequency were determined for each subject. In order to assess the within subject, within pace level of variability the coefficient of variation (CV) was used. The mean coefficient of variation for the group was then determined at each pace.

RESULTS:

The group mean stride velocities for the 400 m and 800 m paces, as a percentage of the maximal stride velocity (group mean 100 m pace stride velocity), were 89 ± 6 % and 77 ± 8 % respectively. The mean stride length and stride data were plotted against the mean stride velocity data for each subject at each pace and fit with a quadratic function (Figure 1). Mean stride length and stride frequencies both increased with pace and therefore stride velocity. Stride length demonstrated larger increases at lower stride velocities compared to higher stride velocities. In contrast stride frequency demonstrated lower increases at lower stride velocities compared to higher stride velocities.

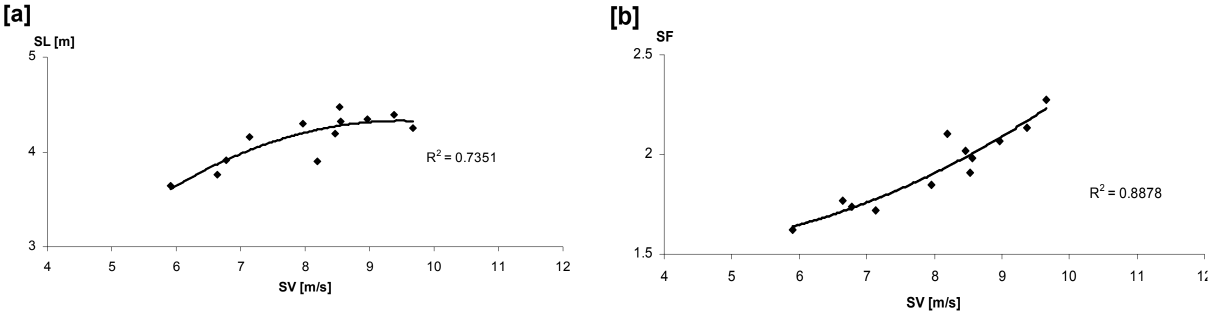

Figure 1: Quadratic relationship between stride velocity and (a) stride length and (b) stride frequency of the individual subject means for each pace.

Within subject variability of the stride velocities decreased with pace from 3.5% to 2.5% to 1.5% in the 800 m pace, 400 m pace and 100 m pace trials respectively. In contrast the variability of the SFLR was lower in the 800 m pace trials (2.2%) compared to both the 400 m pace trials (3.4%) and the 100 m pace trials (3.2%). A more consistent performance outcome was achieved in the higher paced trials, where maximal velocity is achieved, compared to the lower pace (sub-maximal velocity) trials.

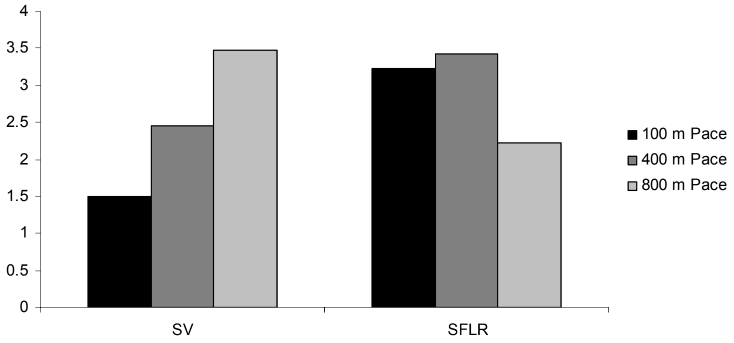

Figure 2: Group mean of within subject coefficient of variation in stride velocity (SV) and stride frequency / stride length ratio (SFLR)

DISCUSSION:

This aim of this study was to investigate how sprint running pace influences stride characteristics and their associated variability and the implications this has on performance.

For the investigated strides, the relationship between stride velocity and both stride length and stride frequency suggests that the stride length is more important at slower sprint running paces (i.e. 800 m pace), whereas stride frequency is more important at faster sprint running paces (i.e. 100 m pace) (Figure 1). That is speed increases are made primarily by increases in the stride length at lower velocities and by increases in stride frequency at higher velocities. On a within subject basis the findings of this study are in agreement with those of Hunter et al. (2004) whereas on a between-subject basis there is disagreement. One explanation for this is the fact that this study considered both maximal and sub-maximal velocities (in order to investigate the influence of pace) whereas Hunter et al. (2004) investigated maximal-velocity sprints only. In addition, the finding are in agreement with Weyand et al. (2000), despite the fact they investigated a much larger range of velocities (3.0 m.s^{-1} to over 9.0 m s^{-1}) compared to this study where only sprint running velocities were considered (6.0 m. s^{-1} to 10.0 s^{-1}). It may therefore be that case that even within the small range of sprint running velocities the same relationship between stride velocity and both stride length and stride frequency exits. It is clear that increases in both stride length and stride frequency are important to sprint running performance but the extent to which they influence performance is determined by the pace.

It has previously been reported that in well learned movements, performance outcome, associated with a consistent performance, is associated with high intra-limb joint coordination variability (Morasso, 1981). This finding suggests that the system provides flexibility such that the search for the optimal solution can be achieved. It may be the case that this is the same with temporal or spatial stride characteristics whereby the higher within subject variability of the SFLR present in maximal velocity sprint running (100 m pace trials) provides a more flexible performance-driven control strategy which produces a consistent maximal performance outcome. During maximal velocity (e.g. 100 m pace trials) athletes utilise this flexible strategy to a greater extent than during sub-maximal velocities (e.g. 800 m pace trials).

The higher variability within the SFLR data and lower variability in the SV data in the 100 m pace trials compared to 800 m pace trials observed in this study may also have injury implications. The reduced variability of the SFLR in the 800 m pace may suggest a reduction in the variability (and therefore flexibility) of the kinematic strategies adopted. According to Hamill et al. (1999) a lack of variability may result in a repeated stress on soft tissue such as cartilage, tendon and ligaments which may subsequently result in pain or injury. The reduced variability in stride characteristics in the 800 m pace may therefore be a contributing factor to the overuse injuries suffered by middle distance runners.

To further investigate the role of variability in sprint running, future research examining the effect of sprint running pace on variability should consider both single joint kinematic and coordination strategies of the lower limb joints using a larger sample and hence allowing effect size statistics to be employed.

CONCLUSION:

The results suggest that pace within sprint running does play an important role in the selection of stride characteristics. Variability within task criterion parameters (e.g. SFLR) appears to be a necessary requirement for producing a consistent performance outcome and this variability is more accessible during maximal rather than sub-maximal velocities.

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