INTRODUCTION

The 400 m race is a demanding event where athletes literally run themselves to exhaustion in the closing stages of the race. As a consequence, average race speed falls markedly in the last 100 m. (Bruggemann & Glad, 1990; Bruggemann, Koszewski, & Müller, 1999) Yet they seem reluctant to try alternative pacing strategies that offer the prospect of higher velocities as they close in on the finish line. (Anderson, 2002)

The inverse relationship between speed and distance was identified early as a limiting factor to performance. The choice of the initial race speed determines how quickly available energy supplies are utilized and how far you can run at that speed. (Di Prampero, 2003) Race pace strategies must take into account the potential benefits of a fast pace, compared with the likely consequences of misjudging the ability to maintain that pace. (Jones & Whipp, 2002)

400 METRE RACE PACE STRATEGIES: HOW YOUR 200 METRE PERSONAL BEST INFLUENCES YOUR PERFORMANCE OPTIONS

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ABSTRACT

Running the ideal 400 m race strategy is the goal for many athletes, unfortunately the demands of the event often hinder their training performance. The choice of initial race speed has a significant effect on the ability to preserve time during the 3rd 100 m split, which had a very strong correlation with final time ($r=.90, .89, p<.01$) for females and males respectively. Identifying a particular percentage of an athlete’s 200 m personal best has been proposed as a modifier of late race deceleration. Central regulatory control has been implicated as the primary influence in maintaining functional homeostasis during intense exercise. It appears to be regulated by the rate of perceived exertion (RPE) which in turn has been linked to an athlete’s current maximum speed and the percentage of this speed used to maintain race pace. Increasing maximum speed and lowering an athlete’s current 200 m personal best are seen to be the key contributors to continued improvement in 400 m performance.
of motion, (Van Ingen Schenau, de Koning, & de Groot, 1994) or the first law of thermodynamics. (Ward-Smith, 1985) The general consensus is that 400 m is too far to be run entirely at maximum effort. Yet they argue that for elite performers, it is not quite far enough to derive any extra benefit offered by the energetic advantages of even pace running, that is the pre-eminent consideration for longer race distances. (Jones & Whipp, 2002)

Anderson (2002) suggests that the critical factor is how far they continue to run at hard effort. Later models recommend a maximum effort start, but importantly they predict velocity would start to decline after ~30 s, and that improved performances come from minimizing this rate of decline. (Van Ingen Schenau, et al., 1994) Foster et al. (1993) believe that because power output is not constant, maximum available power could be extended to ~40 s, but thereafter some form of pacing would be mandatory.

There are currently no 400 m athletes who integrate these suggestions of a maximum effort start into their race pace strategies. It is suggested the reason for this is that coaches are wary of athletes creating too much muscular tension in their attempts to overcome inertia with maximum effort at the start, and not be able to run without that tension for the rest of the race (personal conversation with the authors). Others too feel it is far better to accelerate smoothly to race velocity as economically as possible, so that the alactic energy reservoir will last longer, and prevent the rapid lactic acid build-up associated with maximum effort, until later in the race. (Arcelli, Manbretti, Cimadora, & Alberti, 2008)

NEW INSIGHTS INTO RACE CONTROL

In the last few years, a new paradigm, based on the regulatory control of the central nervous system, has been advocated as a mediator for numerous metabolic, muscular, psychological, nutritional and respiratory functions that affect athletic performance. (Ansley, Robson, Gibson, & Noakes, 2004; St. Clair Gibson & Noakes, 2004) The suggestion is that ultimate control rests with the central nervous system as it monitors all sensory input and regulates output to maintain homeostasis during bouts of intense exercise via efferent and afferent signalling.

Noakes et al. (2004) argue that these signals are moderated by a pre-set rate of perceived exertion (RPE). As exercise intensity increases, fuel stores decline and metabolic by-products such as lactic acid rise, athletes start to feel fatigue, and the effort to keep going intensifies the RPE. The rising levels of RPE act as a signalling role for the central control to start making changes to allow the athlete to get to the finish line before collapsing, but crucially, the metabolite levels of themselves, do not cause speed to decline.

Further evidence in support of this proposition comes from the recent contentious suggestion that intracellular acidosis actually preserves muscle excitability and therefore has a protective effect against fatigue during intense exercise (Pederson, Nielson, Lamb, & Stephenson, 2004) i.e., it isn’t the lactic acid slowing you down (it’s actually trying to help keep the muscles working), but the central governor reacting to rising RPE and deciding to intercede before you hurt yourself.

Tucker (2009) suggests that central control relies on an anticipatory mechanism or ‘template RPE’, that enables the athlete to control the work rate so as to minimise central control override. This template is based primarily on experience gained either through training or competition. Template RPE allows the athlete to develop an appreciation of how much effort is required, and what levels of fatigue to expect for any particular race distance. It is against this template that the central governor contrasts the time course of energy usage, pulse, respiration rate or body temperature, and calculates the expected depletion point at which time the body could no longer maintain homeostasis. (Ansley, et al., 2004; Noakes, et al., 2004)
If the central governor decides that these usage rates are unsustainable, it will intercede to protect the body from harm, by reducing amongst other things, the level of muscle activation necessary for maintaining stride length, stride frequency and the force production capabilities required for sprinting. (Nummella, Vuorimaa, & Rusko, 1992) Central control will still allow you to get to the finish line, but at a slower speed that is less demanding of the dwindling levels of energy reserves.

The central control approach to evaluating the interaction of performance variables introduces a new hierarchal element to understanding the body’s response to exercise. It shifts the level of influence away from accepted physiological responses (important as they are), to one where the central nervous system assumes primary control for the on-going health and safety of the body when it is undergoing intense stress like that imposed by athletic competition. Failure to allow for this oversight mechanism may go some way to explaining why actual race speed curves in events like the 400 m, differ from those proposed by the mathematical models.

The aim of the present study is to identify the effect pacing strategy choice (expressed as a percentage of their best 200 m performance), has on an athlete’s ability to maintain velocity in the later stages of the 400 m sprint.

**METHOD**

The 100 m and 200 m splits, as well as the 400 m final times, were obtained from the European Cup, US Olympic trials (2008) World Championships and Olympic Games. The data was collated from several different sources including, previously published literature, internet web sites, and video tape analysis of the 400 m finals from the Sydney 2000, Athens 2004 (female only) and Beijing 2008 Olympic Games.

The video tape was analysed for the same split data as had been published. Each athlete was timed three times for intra-operator reliability. (Brown & O’Donoghue, 2007) The data was then compared with the position of the other athletes on the video tape at various check points to verify their respective placing during the race. An error margin of 0.05 s for each 100 m section was accepted. Data for athletes without a published 200 m personal best (PB) were excluded from the analysis.

As well as the first and last 200m splits normally associated with 400m split data analysis, the 2nd and 3rd 100 m splits were added together to create a 3rd or ‘middle’ 200 m split. This was done to determine whether the emphasis on the importance of maintaining ‘preservation time’ on the second curve, as suggested by (Müller, 1991), had significance.

One way analysis of variance with Tukey HSD post hoc test was used to determine differences between the 100 m splits, and the 200 m splits. Correlation analysis was used to determine if there was any relationship between the split times and percentage of 200 m PB, final time, and the time difference between the splits. Significance was set at \( p < 0.05 \) level. Values are shown as mean + SD.

**RESULTS**

The combined data made up a cohort of 50 female and 50 male subjects. Mean final times were 51.00 + 1.19 s and 45.25 + 0.89 s for females and males respectively; 200 m PB 22.95 + 0.52 s and 20.67 + 0.45 s; and the difference between the first and last 200 m splits, 2.35 + 1.18 s and 1.70 + 0.94 s.

**100M SPLITS**

The mean time difference for females (Table 1) between the 1st and 2nd split was significant, as was the difference between the 1st and 4th split (\( p < .05 \)). Reflecting a common observation, the 4th split was significantly slower than the other three splits (\( p < .05 \)).

The percentage of the athlete’s 200 m PB revealed negative correlations throughout, indicative of an inverse relationship between race speed and maximum speed. There was a strong negative
correlation for the 2nd \((r=-.71, p<.01)\) and 4th splits \((r=-.84, p<.01)\). As has been reported elsewhere (Bruggemann, et al., 1999) the 3rd split had the strongest correlation with final time \((r=.90, p<.01)\). The 4th split had the strongest correlation with split difference \((r=.79, p<.01)\).

For the males (Table 1), there was a significant mean time difference between all four 100m splits \((p<.05)\). The 3rd split was significantly faster than the 1st split, and the 4th split was significantly slower than the other three splits \((p<.05)\). They also showed negative correlations as a percentage of 200m PB, but not as high as the females. The 4th split had a strong negative correlation \((r=-.79, p<.01)\). Showing similar traits to the female data, the male 3rd split had the strongest correlation with final time \((r=.89, p<.01)\), and the 4th split had the strongest correlation with split difference \((r=.75, p<.01)\).
The shape of the speed curve for males, depicted in Figure 1b, shows similar traits as the female curve. The one notable difference is that average velocity for the 1st split is slower than the notional even split velocity, and 1.07% slower than the females. This seems to indicate that males allow for a more conservative acceleration phase than the females.

200 M SPLITS

The 200 m split data for the female athletes (Table 2), indicates there was a significant difference between the mean times for the 1st 200 m split and the last 200 m split; and the middle 200 m split and the last 200 m split ($p<.05$). The mean time for the last 200 m split is significantly slower than the 1st and middle 200 m splits ($p<.05$).

There was a strong negative correlation for the last 200 m split ($r=–.70$, $p<.01$), as a percentage of 200 m PB. There was a strong and significant correlation for all three 200 m splits with final time ($r=+.75$, $.85$, $.88$, $p<.01$), and a strong and significant correlation for time difference between the 1st and last 200 m split ($r=.74$, $p<.01$).

Figure 2a illustrates the average velocity of the female 200 m splits expressed as a percentage of their 200 m PB, compared with their notional even split velocity. The 1st and middle splits (significant $p<.05$) are faster than the even split velocity. The last split is both significantly slower than the even split, and significantly slower than the other two splits ($p<.05$).

In the mean times for the male 200 m splits, there was a significant difference between the 1st 200 m split and the last 200 m split, and the middle 200 m split and the last 200 m split ($p<.05$); The mean time for the last 200 m split is significantly slower than the 1st and middle 200 m splits ($p<.05$).

There was a moderate but significant negative correlation for the last 200 m split ($r=–.66$, $p<.01$), as a percentage of 200 m PB. There was a strong and significant correlation for all three 200 m splits with final time ($r=+.72$, .90, .91, $p<.01$), and a strong and significant correlation for time difference between the 1st and last 200 m split ($r=.82$, $p<.01$).

Figure 2b shows that the male results are similar to the female results, except that average velocity for the middle split is not significantly faster than the even split velocity.

### Table 2: 200 m Splits (mean ± SD, correlations)

<table>
<thead>
<tr>
<th></th>
<th>Split</th>
<th>Time (s)</th>
<th>%200 PB</th>
<th>%200 PB correlation</th>
<th>Final time correlation</th>
<th>Difference correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>N=50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1st 200</td>
<td>24.34 ± 0.61</td>
<td>94.35 ± 2.19</td>
<td>–0.55**</td>
<td>0.75**</td>
<td>–</td>
<td></td>
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<tr>
<td>Mid 200</td>
<td>24.53 ± 0.65</td>
<td>96.62 ± 2.25</td>
<td>–0.59**</td>
<td>0.85**</td>
<td>–0.19</td>
<td></td>
</tr>
<tr>
<td>Last 200</td>
<td>26.66 ± 0.84</td>
<td>86.14 ± 2.24</td>
<td>–0.70**</td>
<td>0.88**</td>
<td>0.74**</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>25.17 ± 1.27</td>
<td>91.37 ± 4.33</td>
<td>22.95 ± 0.52</td>
<td>51.00 ± 1.19</td>
<td>2.35 ± 1.18</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>N=50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st 200</td>
<td>21.80 ± 0.40</td>
<td>94.85 ± 1.88</td>
<td>–0.33*</td>
<td>0.72**</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Mid 200</td>
<td>21.59 ± 0.46</td>
<td>95.77 ± 1.95</td>
<td>–0.43**</td>
<td>0.90**</td>
<td>–0.17</td>
<td></td>
</tr>
<tr>
<td>Last 200</td>
<td>23.47 ± 0.66</td>
<td>88.09 ± 2.19</td>
<td>–0.66**</td>
<td>0.91**</td>
<td>0.82**</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>22.28 ± 0.99</td>
<td>92.91 ± 3.97</td>
<td>20.67 ± 0.45</td>
<td>45.25 ± 0.89</td>
<td>1.70 ± 0.94</td>
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</table>

* Correlation significant at 0.05 level (2-tailed)
** Correlation significant at 0.01 level (2 tailed)
DISCUSSION

Conjecture persists as to the most effective pacing strategies for 400 m runners. It has been suggested that a short maximum effort start, followed by even pace until very close to the finish line is the best method for maximizing available energy reserves for short sprint races longer than 291 m. Others recommend that the best approach is to maximise velocity early in the race, then try and minimise the fall off in speed for the remainder of the race. (Van Ingen Schenau, et al., 1994; Ward-Smith, 1985)

The results of the present study of contemporary elite 400 m performances support the latter position. Table 1 indicates that maximum race velocity is achieved in the 2nd 100 m split, and then continues to fall for the reminder of the race. This trend is clearly evident in Figures 1a and 1b.

A significant finding of this study is that females consistently reveal faster relative 1st 100 m split times than males, expressed as a percentage of their 200 m PB. Table 1 and Figures 1a and 1b indicate that female runners choose an initial race velocity 1.07% faster than males, and nearly 2% faster than their notional even split velocity, yet their average race velocity is much slower, resulting in average race times 5.75 s or 11.25% longer than males. This does not appear to be an isolated occurrence.

A classic example of this trend occurred in the 1st 100 m splits for the respective female and male world records. Marita Koch ran the 1st 100 m of her world record in 11.0 s, whereas Michael Johnson ran his 1st 100 m in 11.1s, (Ferro, Rivera, & Pagola, 2001) not only 0.9% slower than Koch in actual time, but an extraordinary 11.7% slower as a percentage of their respective 200 m PBs. The 100 m split results displayed in Table 1 show there is a significant moderate correlation for females that is 11% higher that males, suggesting these slower speeds for males in the 1st 100 m has less of an impact on the final time than it does for females.

Similarly, Brüggemann and Glad (Bruggemann, et al., 1999) found a very weak correlation with final time (r=.14, p<.01) for males in the 1st 100 m, and (r=.13, p<.01) for another group of males for the 2nd 100 m split; and moderate correlations (r=.51, .50, p<.01) for female athletes for the 1st and 2nd splits. The results from the current study were higher with significant but moderate correlations (r=.55, .66, p<.01) for males and (r=.66, .63, p<.01) for females for the same splits (Table 1). This study also found a much higher correlation for the 3rd 100 m split for males (r=.89, p<.01) compared with Brüggemann and Glad (r=.79, p<.01).
Using a percentage of an athlete’s 200 m PB has been proposed as an appropriate means of determining race speed for the first 200 m of a 400 m race. (Gajer, Hanon, & Thépault-Mathieu, 2007; Müller, 1991) A recent finding, admittedly from a very small sample size (n=5), is that world class 400 m runners can sustain a very high percentage of their 200 m PB (females 96.3% and males 97.6%) in the 1st 200 m. (Gajer, et al., 2007) This suggests that world class male runners are capable of maintaining 93–94% of the average velocity of their 200 m PB. (Brooks, 1977) Even though this data is over 30 years old, it would still appear to be relevant in light of the results displayed in Tables 1 and 2, and would seem to remain a valid standard for assessing current performances.

Brooks (1977) raises an interesting point. She believes that the difference between the average velocities for any one individual’s 200 m and 400 m performances should not exceed 7%. But if the difference is considerably greater than this, it doesn’t necessarily indicate a lack of specific endurance, but more likely is indicative of an as yet unrealised potential in one of the events. According to this approach, the results for the 1st 200 m (Table 2) indicate that the choice of initial pace for males fell within the range of the athlete’s current capabilities.

As mentioned previously, the duration of an event has an inverse relationship with speed. Females in this study had to continue running for a further 5.75 s longer than the males. The significantly longer race times result in lower average velocities. The faster relative 1st 100 m splits for females then would appear to be ill advised. The data (Table 1) indicates that a more conservative acceleration for females to a level of between 90–92% of their 200 m PB for the 1st 200 m split would be a better option.

The correlations for 200 m PB with the 1st 200 m split (Table 2), though only moderate for females, and less so for males, are significant (p<.01), and become increasingly more significant for each successive 200 m split. Where others found no correlation between the 1st 200 m and final time (Van Coppenolle, 1980) for males, this study found a strong and significant correlation between final time and the 1st 200 m split for both females and males (r=.75, .72, p<.01), which suggests that the 1st 200 m, and therefore maximum speed, plays a more important role in final time than had previously been thought. (Schafer, 1989)

Letzelter (cited in Van Coppenolle, 1980) found a strong and significant correlation (r=.74, p<.01) for males between the last 200 m split and final time. The current study (Table 2) found a significant and much stronger correlation (r=.88, .91, p<.01) between the last 200 m and final time, and also a strong correlation (r=.85, .90, p<.01) between the middle 200 m and final time, for females and males respectively. This suggests that speed endurance also plays a critical role in final time, but as indicated by the correlations for the 1st 200 m splits, not at the expense of maximum speed.

The acceptance of the idea of choosing an optimum percentage of your best 200 m time for the initial race speed implies that the best way to keep improving your 400 m is inextricably linked to improving your best 200 m time. Both Müller (1991) Schäfer (1989) advocate this approach to improving 400 m performance, rather than have athletes encroaching on their speed reserve. Speed reserve or saving time, (Van Coppenolle, 1980) is defined as the difference between the best 200 m performance and the 1st 200 m split time during a 400 m race. (Müller, 1991; Schäfer, 1989; Van Coppenolle, 1980)

Another measure of whether the choice of the initial race speed was appropriate is referred to as preservation time (Van Coppenolle, 1980). This measures the decline in speed from 200 m to 300 m, and was the impetus for deciding to create a ‘middle’ 200 m section for this study. As a percentage of 200 m PB (Table 1), mean reduc-
tion of speed between the 2nd and 3rd 100 m split was 5.6% for females and 5.9% for males. These values were considerably greater than the 1–3.5% advocated by Müller (1991).

Even allowing for a larger preservation time than previously reported, Table 2 reveals the middle 200 m split had a very high and significant correlation with final time \((r=0.85, 0.90, p<0.01)\). Importantly, the correlations for the 3rd 100 m split with final time in Table 1 remain very high \((r=0.90, 0.89, p<0.01)\). Any attempt to reduce preservation time requires a speed reserve that only comes from race velocity that is significantly slower than an athlete’s current maximum velocity capability. (Schafer, 1989)

It would seem logical that preservation time is directly related to how much effort is being expended in maintaining velocity, and how much energy was used to get to that point. Both Noakes, et al. (2004) and Tucker (2009) argue that the sensation of fatigue or RPE acts as a signalling agent for central control to start moderating neural, respiratory and energetic supply to reduce velocity to enable the athlete to reach a known endpoint. If you want to avoid central control interceding pre-emptily, you have to have a strategy to be able to mitigate against RPE rising too high, too soon.

The most obvious and easily accessible strategy is to improve your maximum velocity and control how much of it you use in the first half of the race. But if you try and improve endurance through more lactic tolerance training for example, you only reinforce the sensation of fatigue. This will just encourage central control to respond to high levels of RPE and as a result, counterproductively fine tune the pathway for continued motoric inhibition.

Müller (1991) suggests that increased velocity in the first 200 m section is responsible for up to 60% of the improvement in performance, and that this increased velocity is dependent upon improvement in shorter distance races. Furthermore, he suggests that maximum velocity development is the ‘determining criterion’ for improving 400 m performance, and as such should constitute the main emphasis in training. The mean 200 m PB results, 22.95 ± .52 s and 20.67 ± .45 s for females and males respectively (Tables 1 and 2), suggest that there is room for improvement yet when compared with the 200 m PB of the current 400 m world record holders, Marita Koch, 21.71 s and Michael Johnson, 19.32 s.

If on the other hand, the choice of the initial race speed is too slow, performance is compromised by loss of time at the start. In what appears to be a unique result, Singh & Mandal (2003) found evidence of a second, mid-race acceleration phase for 12 female (in the 50 m split from 300 m to 350 m), and 12 male (250 m to 300 m) 400 m runners. This mid-race re-acceleration is suggestive of the consequences of too conservative pacing in the first 200 m, and acts as a cautionary tale against sub-optimal race speed. If you start out too slowly, you can still feel fresh in the later stages of the race, yet the end spurt comes too late to catch the runners who started faster, and built an unassailable lead. (Fukuba & Whipp, 1999)

Throughout this paper, we have been contrasting female and male performances. In reality though, the only difference is the speed at which any individual can run 400 m. Slower athletes have to run for longer durations and the data from this study (Tables 1 and 2) illustrates the need for slower athletes to use a lower percentage of their 200 m PB than faster athletes, to mediate against central governor control interceding too early. It would appear that an athlete’s maximum velocity and the percentage of it they use, is closely linked to RPE and their ability to maintain race pace. Slower 400 m times then simply reflect the fact that the slower the 200 m PB, the slower the potential 400 m performance, irrespective of gender, or whatever training means are utilised.
CONCLUSION

The theoretical optima provided by the power output models and the scope of central governor control, offer suggestions for pacing strategies for the astute coach to exploit performance enhancing variables commonly overlooked by others. Data from the current study support the suggestion that choosing initial race speed based on a percentage of 200 m PB is an approach worth further investigation. Up until now this approach has received too little attention. Having a more defined rationale for choosing the initial race pace lends more certainty to an athlete’s preparation, and critically, offers greater confidence to confront what will always remain a challenging event.

References


