Freestyle Race Pacing Strategies (400m) of Elite Able-Bodied Swimmers and Swimmers with Disability at Major International Championships

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Abstract

Freestyle race pacing strategies (400m) were compared between elite able-bodied swimmers and those with minimal physical (International Paralympic Committee S10 classification) and visual disabilities (International Paralympic Committee S13 classification). Data comprised 50m lap splits and overall race times from 1176 400m freestyle swims from World Championships, European Championships and Olympic/Paralympic Games between 2006 and 2012. Five pacing strategies were identified across groups (even, fast start, negative, parabolic and parabolic fast start), with negative and even strategies the most commonly adopted. The negative pacing strategy produced the fastest race times for all groups except for female S13 swimmers where an even strategy was most effective. Able-bodied groups swam faster than their S10 and S13 counterparts, with no differences between S10 and S13 groups. The results suggest adoption of multiple pacing strategies across groups, and even where impairments are considered minimal they are still associated with performance detriments in comparison to their able-bodied counterparts. The findings have implications for the planning and implementation of training related to pacing strategies to ensure optimal swimmer preparation for competition. Analogous performance levels in S10 and S13 swimmers also suggest a case for integrated competition of these classifications in 400m freestyle swimming.

Key words: pacing, disability, physical impairment, visual impairment, Olympic, Paralympic.

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Pacing has been defined as the distribution of energy during exercise and has physiological and psychological determinants (see Thompson, 2014). Effective pacing is a critical component of sports in which the winner is governed by the time to complete a particular distance (Abbiss & Laursen, 2008; Foster, Schrager, Snyder, & Thompson, 1994). The optimal pacing strategy is deemed to be the one that makes the most efficient use of physiological resources given the constraints of the duration, intensity and environmental factors (Corbett, 2009; Tucker, Lambert, & Noakes, 2006). Shorter events, suggested to be <110 seconds (Tucker et al., 2006), are generally characterised by a maximal start and a progressive slowing of pace whereas longer events tend towards a more consistent pace or a 'negative splitting strategy' in which the second half of an event is performed quicker than the first half (Garland, 2005; Thompson, MacLaren, Lees, & Atkinson, 2003).

Scientific literature relating to pacing in swimming is scarce, with researchers tending to focus upon kinematic variables (e.g., stroke rates, lengths and speeds) or examining temporal elements (e.g., race starts and turns). While pacing is important in all swimming events it is suggested to be most noticeable in events of 400m or longer (Maglischo, 2003). Observations of selected world records in 400m freestyle races have suggested that a fast first 100m, due to the contribution of the dive start (e.g., see Tor, Pease, & Ball, 2014), followed by 200m of relatively even paced swimming, before a final increase in speed during the closing 100m, describes a commonly adopted pacing strategy (Maglischo, 2003). Indeed, this particular pacing strategy was reported to be adopted by the top 16 male and female swimmers competing in 400m freestyle events at nine international swimming competitions over a seven year period (Robertson, Pyne, Hopkins, & Anson, 2009). Robertson et al. (2009) further postulated that substantial improvements in performance could be achieved by making gains within the second and third 100m sections as these lap times were most strongly correlated with overall race time.

Although 400m freestyle pacing can be described in general terms that appear to be supported empirically, idiosyncrasies are evident when the specific approaches adopted by swimmers are examined in more detail. For example, an application of cluster analysis to components of performance at the 2000 Olympic Games 400m freestyle swimming final by Chen, Homma, Jin, and Yan (2007) revealed distinct groupings that reflect differing ‘race patterns’ of the individual swimmer. Further, using a computer algorithm to examine 264 national and international 400m freestyle swims Mauger, Neuloh, and Castle (2012) found that the ‘fast-start-even’ and ‘parabolic’ pacing strategies were most prevalent but did not result in improved performance times when compared to the alternative positive, negative or even pacing strategies. However, from a practical perspective there was evidence of some meaningful differences in the pacing strategies adopted. In particular, the race times of medallists were often <1s apart and the observed difference between the positive and fast-start-even strategies within their study equated to ~1.7s. Lastly, an examination of well-trained junior swimmers (Skorski, Faude, Abbiss, Caviezel, Wengert, & Meyer, 2014a) in simulated 400 m freestyle competitions found that moderate manipulation of pacing in the initial 100 m, through enforcing a fast or slow start (in comparison to self-selected pacing), resulted in overall performance time increasing by >2.5s. Some swimmers also improved their performance time under the manipulated conditions, suggesting that their self-selected pace was not optimal.

Although the extant literature regarding pacing strategies adopted within the 400m freestyle swimming event has provided useful insight these conclusions have been based upon elite able-bodied swimmers (Chen et al., 2007; Maglischo, 2003; Mauger et al., 2012; Robertson et al., 2009;). These findings potentially have limited application to other populations, such as Paralympic swimmers, where unique biomechanical and physiological demands can be present (Fulton, Pyne, Hopkins, & Burkett 2009). For example, physical impairments can reduce the co-ordination, range of movement and/or surface area of limbs, subsequently reducing propulsive forces, while an inability to achieve and maintain streamlined positions can increases resistive forces (cf. Daly & Martens, 2011). Consequently, there is a need to extend the growing body of knowledge within Paralympic swimming to provide a more rigorous investigation of the pacing strategies adopted. This will provide an evidence base to assist coaches in the formulation of specific training programmes and underpin the support work of applied sports scientists (Burkett & Mellifont, 2009).

Given the dearth of swimming-based literature relating to pacing, and particularly in relation to elite swimmers with impairments, the aim of this study was to compare the pacing strategies of elite able-bodied swimmers and elite swimmers with minimal physical (International Paralympic Committee S10 classification) and minimal visual (International Paralympic Committee S13 classification) impairment during 400m freestyle races at major international championships. S10 and S13 disability classifications were selected as they signify swimmers with minimal physical and visual impairments and therefore could arguably be expected to adopt similar pacing strategies to able-bodied swimmers. The 400m freestyle is also an event available to both males and females within the S10 and S13 swimmer groups. Based on the existing literature on swimming pacing strategies (e.g., Maglischo, 2003; Mauger et al., 2012; Robertson et al., 2009) we expected that: 1) male swimmers would perform faster 50m lap split and race times than their female counterparts regardless of group (i.e., able-bodied, S10, S13); 2) able-bodied swimmers would perform faster 50m lap split and race times than their gender matched impaired counterparts; 3) the use of multiple pacing strategies would be evident across groups and within each group; and 4) the prevalence of pacing strategies would be similar in all groups.

Methods

Participants and data collection procedures

Following University Research Ethics Board approval race times and associated 50m lap splits were obtained for elite able-bodied swimmers and elite swimmers with minimal physical (International Paralympic Committee S10 classification) and minimal visual (International Paralympic Committee S13 classification) impairments competing in long course 400m freestyle events. Data were sourced from all heats and finals at World Championships, European Championships and Olympic/Paralympic Games between 2006 and 2012 (8 able-bodied meets, 6 Paralympics meets). The dataset comprised 1176 swims; 489 and 312 for able-bodied males and females respectively, 121 and 100 for males and females within the S10 classification respectively, and 96 and 58 swims respectively for males and females within the S13 classification. All data were obtained from official race results (e.g. competition websites), the website of the International Paralympic Committee (www.paralympic.org) and other credible sources (www.omegatiming.com). Where possible, data were validated by triangulating multiple sources.

Data Preparation

Prior to analysis, data were prepared through a process of normalisation and the removal of outliers. Data normalisation was required to facilitate the direct comparison of pacing strategies due to the differences in 50m lap splits and race times between swimmers. For every recorded swim, the difference between each 50m lap time and the mean 50m lap time (derived from overall race time) was calculated and expressed as a time deviation in seconds. For example, if a swimmer performed their 400m race in four minutes then the mean for a 50m lap time would be 30.0s. Consequently a first 50m of 28.0s would represent a deviation of -2.0s. All raw and normalised data were screened using the recommendations of Norusis (2011) and outliers were removed from further analysis. All data were prepared (and subsequently analysed) using Microsoft Excel 2010 (2010, Microsoft Corporation), SPSS 20 (2012, International Business Machines Corporation), and R version 3.0.2 (2013, The R Foundation for Statistical Computing).

Data Analysis

Data analysis comprised four stages and was applied across the six swimmer groups (able-bodied males, able-bodied females, S10 males, S10 females, S13 males, S13 females). First, mean time and associated 95% confidence limits for each 50m lap split were calculated for both the raw and normalised data (and also for the overall race time in the raw data). Next, a k-means cluster analysis was applied to the normalised data to evaluate the nature of the pacing strategies used by swimmers within each group. During the third stage of analysis, differences between the final race times for each cluster were compared within swimmer groups via a one-way ANOVA to identify those that were most successful (i.e., resulted in the quickest race time). The alpha value for the one-way ANOVA tests were set at 0.05 with effect size reported using Cohen's *d* (Cohen, 1988). Finally, a chi-square test of independence was used to determine if the incidence of each identified pacing strategy differed across swimmer groups. Standardised residuals for the chi-square test were deemed significant ($p<0.05$) when their absolute value exceeded 1.96 with effect sizes expressed as Cramer's V (Field, 2013; Field, Miles, & Field, 2012).

Results

General characteristics of lap splits and race times of swimmer groups

Visual examination of the descriptive statistics of the raw 50m lap split and overall race time indicated features unique to the typical race profile within each swimmer group. The absence of overlapping confidence intervals (Table 1) suggests that able-bodied, S10 and S13 males swam significantly faster than their respective female counterparts through all 50m race segments and achieved significantly quicker overall race times. Similarly, able-bodied males and females swam significantly faster 50m lap and overall race times than the S10 and S13 swimmers of equivalent gender. In contrast, overlapping confidence intervals showed that overall S10 and S13 males did not differ in the 50m lap times performed or their final race times, this pattern was also apparent for the S10 and S13 females. The normalised data (Table 2) indicated fewer differences between the overall pacing strategies of each swimmer group although able-bodied males and females deviated less from their average race lap time throughout all race sections compared to their S10 and S13 counterparts. This was particularly evident in the first 50m lap split times of the swimmer groups.

Pacing strategies adopted by each swimmer group

Cluster analysis identified five pacing strategies (Figure 2) categorised as ‘even’, ‘fast start’, ‘negative’, ‘parabolic’ and ‘parabolic fast start’ (see Appendix A for descriptions). Both able-bodied males and females’ adopted even, fast start, negative and parabolic pacing strategies. With respect to able-bodied males, differences were observed in the final race times as a function of race strategy ($F(3, 485) = 183.83$, $p < .001$, Cohen's $d = 1.505$) with the negative strategy (mean race time = 230.57s, 95% confidence limits = 229.51 to 231.63) being faster than the even (mean race time = 235.91s, 95% confidence limits = 234.81 to 237.01), fast start (mean race time = 252.66s, 95% confidence limits = 249.26 to 256.06) and parabolic strategies (mean race time = 267.21s, 95% confidence limits = 261.02 to 273.40). Differences were also observed in the race times of able-bodied females as a function of pacing strategy ($F(3, 308) = 61.11$, $p < .001$, Cohen's $d = 0.906$). Similar to the able-bodied males, the negative pacing strategy was fastest for able-bodied females (mean race time = 249.59s, 95% confidence limits = 248.47 to 250.71) followed by the even (mean race time = 253.94s, 95% confidence limits = 252.87 to 255.01), fast start (mean race time = 262.76s, 95% confidence limits = 260.05 to 265.47) and parabolic (mean race time = 263.70s, 95% confidence limits = 260.45 to 266.95) pacing strategies.

The pacing strategies adopted by swimmers with physical and visual impairments resulted in diverse race times. For S10 male swimmers the negative pacing strategy was found to be quicker (mean race time = 261.94s, 95% confidence limits = 259.10 to 264.78) than the even (mean race time = 263.53s, 95% confidence limits = 261.08 to 265.98) and parabolic fast start (mean race time = 271.11s, 95% confidence limits = 267.53 to 274.69) patterns ($F(2, 118) = 9.83$, $p < .001$, Cohen's $d = 0.557$). An identical trend was observed in S13 males where the race times were fastest ($F(2, 93) = 8.36$, $p < .001$, Cohen's $d = 0.987$) for those swimmers adopting the negative pacing strategy (mean race time = 263.03s, 95% confidence limits = 255.38 to 270.68), compared to the even (mean race time = 268.21s, 95% confidence limits = 265.24 to 271.18) and parabolic fast start (mean race time = 277.44s, 95% confidence limits = 272.61 to 282.27) respectively.

S13 females also adopted the negative, even and parabolic fast strategies but for this cohort, the even pacing strategy was most effective as it resulted in the most competitive race times (mean race time = 288.99s, 95% confidence limits = 283.24 to 294.74) compared to the negative (mean race time = 296.92s, 95% confidence limits = 289.89 to 303.95) and parabolic fast start (mean race time = 307.34 s, 95% confidence limits = 300.98 to 313.70) patterns ($F(2, 55) = 8.55$, $p < .001$, Cohen's $d = 0.618$). The remaining swimmer group, S10 females, adopted a parabolic pacing strategy over a parabolic fast start approach that was a characteristic of the able-bodied but not the impaired groups. However, this strategy was slower (mean race time = 316.03s, 95% confidence limits = 308.63 to 323.43) than the even (mean race time = 295.18s, 95% confidence limits = 291.65 to 298.71) and negative (mean race time = 291.87s, 95% confidence limits = 288.17 to 295.57) pacing strategies ($F(2, 97) = 26.00$, $p < .001$, Cohen's $d = 0.742$).

Prevalence of pacing strategies within and between swimmer groups

The negative pacing strategy was observed to result in the quickest race times overall (except the S13 females) but it was not the most frequently adopted strategy (Table 3). Pacing strategy was found to be dependent on swimmer group ($\chi^2(20) = 427.97$, $p<0.001$, Cramer's V = 0.302). The even and negative pacing strategies were prevalent in all swimmer groups. The fast start and parabolic pacing strategies were predominantly confined to able-bodied swimmers, while the parabolic fast start pacing strategy was only evident for the swimmers with impairments.

Discussion

The aim of this study was to compare the pacing strategies of elite able-bodied swimmers and elite swimmers with minimal physical (International Paralympic Committee S10 classification) and minimal visual (International Paralympic Committee S13 classification) during 400m freestyle races. While existing swimming pacing research has provided preliminary insight into adopted and perceived optimal race strategies for 400m freestyle races these have been restricted to able-bodied swimmers (Chen et al., 2009; Maglischo, 2003; Mauger et al. 2012; Robertson et al., 2009). This study extends the research literature relating to swimmers with disabilities and highlights that even where impairments may be considered minimal, differences exist in the race times achieved and the associated pacing strategies adopted when compared to that of able-bodied swimmers.

The initial hypotheses that male swimmers would perform quicker 50m lap split and race times than female counterparts irrespective of swimmer group (i.e., able-bodied, S10 or S13) was supported. Able-bodied males, S10 males and S13 males swam significantly faster than their respective female counterparts through all 50m race segments and achieved significantly quicker overall race times. Performance based gender differences within sport are long standing and pervasive due to biological and cultural determinants (Seiler, De Koning, & Foster, 2006; Tucker & Collins, 2010). The segregation of athletes by gender is an example, along with variables such as weight and age, of commonly accepted practice that facilitates administration, contributes to athlete safety and underpins attempts to provide parity of performance (Richter, Adams-Mushett, Ferrara, & McCann, 1992). Within disability sport a classification system also exists to primarily ensure parity of performance (Tweedy, Beckman, & Connick, 2014). In specific relation to disability swimming, an ‘integrated’ classification system exists that is intended to provide equitable competition where success is determined by factors such as training, skill and motivation rather than impairment related variables (Richter et al., 1992; Wu & Williams, 1999).

The second hypothesis that able-bodied swimmers would perform quicker 50m lap split time and race times than gender matched impaired groups was also supported. This finding is unsurprising given that the physical impairments of the S10 swimmers generally include “…the loss of a hand or both feet and a significantly limited function of one hip joint” (http://www.paralympic.org/swimming/classification/), which is likely to impact on a swimmer’s ability to produce the same levels of propulsion as their able-bodied counterparts (Daly & Martens, 2011). Similarly visual impairments within S13 athletes are likely to restrict visual feedback and therefore impact swimmer ability to develop appropriate technique and their potential to monitor personal pacing (Daly & Martens, 2011). The difference in 50m lap splits and overall race time of the S10 and S13 swimmers in comparison to able-bodied swimmers (e.g., >25s in overall race time for men and >30s for females) suggest that even impairments that may be considered minimal are associated with substantial detriments to performance.

Although able-bodied swimmers outperformed their impaired counterparts with respect to 50m lap split and overall race times there was equivalence of performance within the impaired swimmer groups. Both S10 males and S10 females recorded similar lap split and overall race times to their S13 counterparts. These findings, viewed purely from a performance perspective, suggest that elite level S10 and S13 classifications could be combined. Such an action would directly boost swimmer numbers in associated events and improve their sustainability at current and future Paralympic Games and other championships. Furthermore, as there would be no replication of S10 and S13 versions of the same event, space would be created within competition schedules to deliver a wider variety of events across different distances, strokes and classifications. While we acknowledge such a performance-based view does not account for the potential historical, sociological and political factors that have resulted in, or require, visual and physical impairment-specific classifications (Bailey, 2008), our findings do support the contention that the classification system currently employed does not always differentiate clearly between swimmer groups (Oh, Burkett, Osborough, Formosa & Payton, 2013). This reinforces the need for continued development of evidence-based methods to ensure an effective classification system (Tweedy et al., 2014).

The third hypothesis postulated that similar pacing strategies would be adopted by each swimmer group, with multiple strategies evident. No differences were reported in the average pacing strategy employed by the six swimmer groups (e.g., see Table 2), which corresponded to the findings of Maglischo (2003) and Roberston et al. (2009). Specifically, a fast first 100m -due to the contribution of the dive start (cf. Tor et al., 2014) - followed by 200m of relatively even paced swimming, before a final increase in speed during the final 100m, represents the general pacing profile. The presence of this general approach across groups may reflect the fact that the physical and visual impairments within the S10 and S13 classifications respectively are likely to have limited impact on a swimmer’s physiology, enabling similar pacing strategies to be used as those of their able-bodied counterparts. Nevertheless, the observation that able-bodied swimmers maintained a more consistent pace throughout the race distance (i.e., less deviation from the mean race time) is likely to be physiologically advantageous (Abbiss & Laursen, 2008), as slight speed fluctuations may impact upon metabolic demands due to the disproportional increase in energy expenditure with increasing speed in aquatic environments (Thompson, 2014) and may account for some of the difference observed in 50m lap splits and overall race times compared to the impaired swimmer groups.

When comparing the general pacing profile the largest differences between swimmer groups were evident within the first 50 m of the race. In particular, the S10 and S13 swimmers deviated further from their mean swimming speed in comparison to their able-bodied counterparts. This is likely to be indicative of the specific impact of impairment on the start phase of the race. For example, increasing severity of impairment has been shown to be related to a decrease in the time it takes a swimmer to reach 15m following the race start signal (Dingley, Pyne, & Burkett, 2014). This could be due to specific impairments that make it difficult for a swimmer to establish and maintain a streamlined position, thereby minimising passive drag. However, this may be less relevant to the swimmers examined in the current study due to the minimal nature of their impairment. Indeed, direct comparison of Paralympic and Olympic swimmers has shown that S10 swimmers are able to match the underwater speeds of Olympians, but travel less distance beneath the surface, and are unable to transfer the initial speed into their free swimming (Burkett, Mellifont, & Mason, 2010).

Moving beyond the general pacing profile, the granular analysis presented in the current study and previous literature (e.g., Chen et al., 2007; Mauger et al., 2012) has identified multiple pacing strategies in 400m freestyle races. The swimmers in our study adopted strategies characterised as even, fast start, negative, parabolic and parabolic fast start (cf. Abbiss & Laursen, 2008; Mauger et al., 2012). Within all swimmer groups the negative pacing strategy resulted in the quickest race times, followed by the even pacing strategy, with the parabolic or parabolic fast start strategies found to be the slowest. Our findings differ from those of Mauger et al. (2012) who reported that no single pacing strategy exerted a significant influence on race time. The reason for these disparate findings are unclear given that both studies examined elite swimmers and therefore may reflect differing methodological approaches in identifying pacing strategies (i.e., the specific algorithms applied). Nonetheless, the successful nature of even and negative strategies within the sample of swimmers analysed in the current study align with the investigation of 400m freestyle swims by Maglischo (2003) and the review of pacing strategies by Abbiss and Laursen (2008).

The final hypothesis predicted that there would be no difference in the prevalence of pacing strategies adopted by the groups of swimmers. In contrast, however, the pacing strategy adopted was found to be dependent on swimmer group. Even and negative pacing strategies were prominent in all swimmer groups, the fast start strategy was used only by able-bodied swimmers, the parabolic fast start strategy only employed by swimmers with impairments, and the parabolic strategy adopted by able-bodied males and females and S10 females. These findings suggest that the adoption of a pacing strategy is likely to be based upon physiological, biomechanical and psychological considerations (Mauger et al., 2012; Thompson, 2014). Further, while the pacing strategy a swimmer adopts may be predetermined before a race it is possible that tactical pacing changes are made during races in response to particular situations, as evident in many sports (cf. Maglischo 2003; Thiel, Foster, Banzer, & De Koning, 2012). This theory has, however, been challenged as reproducible pacing patterns have been observed in junior swimmers with variation suggested to be driven by internal rather than external factors (Skorski, Faude, Caviezel, & Meyer, 2014b).

The results of this study provide several implications for coaches and sports science practitioners working with elite 400m freestyle swimmers. A multitude of pacing strategies exist and while some were found, on average, to be faster than others, this does not exclude the possibility that the optimal pacing strategy for individual swimmers may differ. There is also some suggestion that elite able-bodied swimmers employ pacing strategies that are not observed within elite swimmers with impairments (and vice versa). Consequently, it should not be assumed that pacing strategies used with one population can be effectively employed with another. In particular, coaches and sports science practitioners working with disabled swimmers should evidence their decisions to apply an 'able-bodied model'.

The retrospective and observational nature of this study presents limitations that may impact on interpretation of the results and their implications. First, it is unclear if the pacing strategies adopted were predetermined or a reflection of 'in-race' decision making. Such information would be useful to coaches and sports science practitioners in the development of appropriate race training (e.g., training a swimmer to execute a pre-set plan effectively versus developing a decision maker who can react to developing situations). Subsequent research should interview athletes pre- and post-race, in order to explore the physical, psychological and tactical mechanisms that underpinned their performance. An additional opportunity for researchers is to extend the current work by detailing swimmer training and competition histories to provide an enhanced understanding of potential confounding variables. For example, it is unclear how much of the difference in lap split and race times between able-bodied and impaired swimmers were due directly to impairment and how much was due to other factors, such as number of years training, depth of competition at an elite standard (Makris, Yee, Langefeld, Chappell, & Slemenda, 1993). Finally, while the findings provide insight into 400 m freestyle pacing strategies they are based upon race splits. To more effectively inform interventions and enhance understanding of the potential differences between able-bodied swimmers and those with impairments researchers should also undertake detailed race analysis focusing on specific race components (e.g., start phase, turn phase) including details of stroke parameters such as stroke rates and stroke lengths (cf. Chen et al., 2007, Malone, Daly, Vanderlandewijck, & Steadward, 1998).

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Appendix A - Description of Pacing Strategies

The five pacing strategies observed within this study were assigned descriptions based upon previous reviews of pacing strategies (e.g., Abbiss & Laursen, 2008) and swimming-based research (e.g., Thompson et al., 2003; Mauger et al., 2012).

- A ‘negative’ strategy was characterised by slower 50 and 100m lap splits than other clusters within the swimmer group, followed by a progressive increase in lap times until 200m, and then an increase in lap time for the final half of the race.
- For an ‘even’ strategy the swimmer did not deviate from average lap time by more than one second throughout the race (excluding the first 50m which was faster due to the dive start).
- The ‘fast-start’ strategy consisted of the initial three 50m lap times (i.e., 50m, 100m, and 150m) being faster than the average lap time for the strategy but progressively slowing. This slowing continued throughout the race until an acceleration for the final 50m.
- The ‘parabolic’ strategy was characterised by an ‘inverted-U’. The strategy had the fastest first 50m lap time of all strategies followed by a constant middle section of the race and a subsequent acceleration, leading to progressively quicker 300 to 350m and 350 to 400m race segments.
- A hybrid ‘parabolic fast start’ shared features of both the parabolic and fast start strategies. A fast first 50 m was followed by progressively slower 50 m lap splits with a notable acceleration in the final 50 m lap split where the swimmer recorded a time similar to their mean race split.

Table 1. Descriptive statistics for elite able-bodied swimmers and elite swimmers with a disability (S10 relates to swimmers with minimal physical impairment and S13 to athletes with minimal visual impairment as defined by the International Paralympic Committee).

Gender	Classification	Descriptive Statistic	50 m split	100 m split	150 m split	200 m split	250 m split	300 m split	350 m split	400 m split	Race Time
Male	Able-bodied	Mean time (s)	27.33	29.56	30.03	30.29	30.24	30.47	30.34	29.53	237.80
		Lower 95% confidence limit (s)	26.80	28.86	29.22	29.40	29.31	29.50	29.37	28.59	231.28
		Upper 95% confidence limit (s)	27.87	30.25	30.84	31.17	31.17	31.45	31.32	30.48	244.32
	S10	Mean time (s)	30.01	32.77	33.41	33.82	33.79	34.05	34.06	33.34	265.25
		Lower 95% confidence limit (s)	29.46	32.22	32.78	33.18	33.07	33.32	33.35	32.56	260.45
		Upper 95% confidence limit (s)	30.55	33.33	34.04	34.45	34.51	34.77	34.77	34.12	270.04
	S13	Mean time (s)	29.71	33.17	34.11	34.74	34.70	35.11	34.97	33.81	270.33
		Lower 95% confidence limit (s)	29.02	32.40	33.27	33.87	33.74	34.15	33.93	32.87	263.91
		Upper 95% confidence limit (s)	30.40	33.94	34.94	35.62	35.67	36.08	36.01	34.75	276.75
Female	Able-bodied	Mean time (s)	29.48	31.57	32.04	32.30	32.23	32.49	32.43	31.70	254.24
		Lower 95% confidence limit (s)	29.12	31.10	31.51	31.74	31.64	31.86	31.79	31.04	250.06
		Upper 95% confidence limit (s)	29.85	32.04	32.56	32.86	32.82	33.12	33.07	32.36	258.43
	S10	Mean time (s)	33.64	36.87	37.96	38.28	38.34	38.45	38.29	37.19	299.03
		Lower 95% confidence limit (s)	32.89	35.88	36.89	37.17	37.24	37.35	37.24	36.24	291.21
		Upper 95% confidence limit (s)	34.40	37.86	39.03	39.40	39.45	39.55	39.34	38.15	306.84
	S13	Mean time (s)	33.30	36.87	37.76	38.20	38.21	38.33	38.41	36.88	297.96
		Lower 95% confidence limit (s)	32.55	35.97	36.72	37.18	37.18	37.27	37.27	35.86	290.34
		Upper 95% confidence limit (s)	34.04	37.77	38.79	39.23	39.24	39.39	39.56	37.89	305.58

Table 2. Descriptive statistics for elite able-bodied swimmers and elite swimmers with a disability (S10 relates to swimmers with minimal physical impairment and S13 to athletes with minimal visual impairment as defined by the International Paralympic Committee). Data expressed as deviation from mean lap time/race time where negative values are quicker than average.

Gender	Classification	Descriptive Statistic	50 m split	100 m split	150 m split	200 m split	250 m split	300 m split	350 m split	400 m split
Male	Able-bodied	Mean time (s)	2.39	0.17	-0.30	-0.56	-0.51	-0.75	-0.62	0.19
		Lower 95% confidence limit (s)	1.98	-0.07	-0.48	-0.71	-0.68	-0.96	-0.87	-0.17
		Upper 95% confidence limit (s)	2.80	0.41	-0.13	-0.41	-0.35	-0.54	-0.37	0.55
	S10	Mean time (s)	3.15	0.38	-0.26	-0.66	-0.63	-0.89	-0.90	-0.19
		Lower 95% confidence limit (s)	2.81	0.08	-0.51	-0.87	-0.89	-1.16	-1.18	-0.59
		Upper 95% confidence limit (s)	3.50	0.69	0.00	-0.46	-0.38	-0.62	-0.62	0.22
	S13	Mean time (s)	4.08	0.62	-0.32	-0.95	-0.91	-1.32	-1.18	-0.02
		Lower 95% confidence limit (s)	3.52	0.23	-0.57	-1.15	-1.26	-1.66	-1.60	-0.51
		Upper 95% confidence limit (s)	4.64	1.01	-0.06	-0.75	-0.57	-0.98	-0.76	0.47
Female	Able-bodied	Mean time (s)	2.30	0.21	-0.26	-0.52	-0.45	-0.71	-0.65	0.08
		Lower 95% confidence limit (s)	2.01	0.00	-0.42	-0.65	-0.59	-0.88	-0.86	-0.21
		Upper 95% confidence limit (s)	2.58	0.42	-0.10	-0.39	-0.30	-0.54	-0.44	0.37
	S10	Mean time (s)	3.73	0.51	-0.59	-0.90	-0.96	-1.07	-0.91	0.19
		Lower 95% confidence limit (s)	3.34	0.26	-0.82	-1.14	-1.21	-1.30	-1.20	-0.32
		Upper 95% confidence limit (s)	4.13	0.76	-0.35	-0.67	-0.72	-0.85	-0.62	0.69
	S13	Mean time (s)	3.95	0.37	-0.51	-0.96	-0.96	-1.08	-1.17	0.37
		Lower 95% confidence limit (s)	3.51	0.09	-0.77	-1.17	-1.20	-1.33	-1.49	-0.02
		Upper 95% confidence limit (s)	4.38	0.66	-0.26	-0.74	-0.72	-0.84	-0.85	0.75

Table 3. Frequency of pacing strategies adopted by elite able-bodied swimmers and elite swimmers with a disability (S10 relates to swimmers with minimal physical impairment and S13 to athletes with minimal visual impairment as defined by the International Paralympic Committee). $\chi^2(20) = 427.97$, $p<0.001$; + = observed value significantly greater than expected value (standardised residual > 1.96), - = observed value significantly less than expected value (standardised residual < -1.96).

Gender	Classification	Even	Fast start	Negative	Parabolic	Parabolic fast start
Male	Able-bodied	220	57+	182	30-	0-
	S10	50	0-	36	0-	35+
	S13	49	0-	16-	0-	31+
Female	Able-bodied	105-	23	135+	49+	0-
	S10	41	0-	35	24+	0-
	S13	20	0-	17	0-	21+

Figure Captions

Figure 1. Typical representations of pacing strategies observed in 400 m freestyle swimmers.

Figure 2. Pacing strategies adopted by 400 m freestyle swimmers with no impairment (able-bodied), minimal physical impairment (S10) and minimal visual impairment (S13).