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ORIGINAL ARTICLE

Race development in men's 400 m track and field events

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ABSTRACT

This study aimed to clarify race development in men's 400 m track and field events. We analyzed 457 races involving 155 male long sprinters, including 400 m race records and each 50 m split time. The races were categorized into seven groups based on 400 m race times: 43.0-second (n = 6), 44.0-second (n = 21), 44.5-second (n = 25), 45.0-second (n = 21), 45.5-second (n = 26), 46.0-second (n = 33), and 47.0-second (n = 23). The percentage of each 50 m split time relative to the 400 m race time (%ST) was calculated. Running speeds in all sections were higher in races with faster 400 m times. The %ST in the 0–50 m section was significantly greater in 43.0- and 44.5-second groups than in the 46- and 47-second groups. The %ST in the 0–50 m section showed a negative correlation with the 400 m race time, whereas %ST in the 100–150 m, 150–200 m, and 250–300 m sections exhibited positive correlations. These findings show that faster races were characterized by relatively lower running speeds in the first 50 m and higher speeds in the second 200 m, suggesting strategic race development in faster long sprinters.

Keywords: Performance analysis, Pacing, Pace distribution, Pacing strategy, Sprint.

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INTRODUCTION

In 400 m track and field events, two primary pacing strategies are commonly observed among long sprinters aiming for high performance. Speed-based sprinters prioritize rapidly covering the first 200 m and then strive to sustain their speed for as long as possible. In contrast, endurance-based sprinters may either maintain an even pace, with the second half of the race taking approximately the same time as the first, or accelerate during the latter half after starting at a steady or slow pace (Schiffer, 2008; Smith, 1994). Generally, initiating a fast pace for the first 200 m often leads to a slower pace for the remaining 200 m, and conversely (van Coppenolle, 1980). Sprinters in the 400 m race have the autonomy to choose their pacing strategies based on their preferences, strengths, and tactical considerations.

Regardless of the chosen strategy, it is generally regarded as advantageous to minimize the time difference between the first and second halves of a 400 m race. Some studies have shown that elite sprinters exhibit faster performances in the second half of the race with a reduced time difference between the two halves (Coppenolle, 1980; Hanon & Gajer, 2009). Additionally, elite sprinters have been observed to expend approximately 97.6% of their personal best effort in the first 200 m of a 400 m race and may adopt a more aggressive pacing strategy than sprinters at the national and regional levels (Hanon & Gajer, 2009). Conversely, other studies have proposed that 400 m sprinters should aim to run the first half of their race at approximately 94% of their personal best in the 200 m sprint (Gambetta, 1978; Jarver, 2005). Furthermore, maintaining a slower pace (approximately 93% of the personal best in the 200 m sprint) has been associated with a smaller decrease in step frequency and step length during the second half of the 400 m race, as well as a reduced time difference between the first and second halves compared to a more aggressive pace (98%) (Saraslanidis et al., 2011). These findings suggest that some 400 m sprinters may adopt an endurance-based approach. Ultimately, the optimal race strategy remains a subject of debate.

The development of the 400 m race is quantified using split times for specific distances (for example, 50 m and 100 m) and split times relative to the 400 m record (%ST) (Yoshimoto et al., 2024). Notably, national-class sprinters, compared to the world's top sprinters, make up a smaller proportion in the 0–100 m section and a larger proportion in the 200–300 m section. This finding suggests that male 400 m sprinters need to maintain a heightened speed during the latter 200 m of a 400 m race. Given the precedent that commencing with a rapid pace for the initial 200 m often leads to a decelerated pace for the subsequent 200 m (Coppenolle, 1980), it would be expected that attaining elevated running speeds in the first half of the 400 m may correspond with a reduction in running speed in the latter half of the race.

Little information is available regarding race development in male 400 m races. Given the %ST reported in previous studies, it can be inferred that 400 m sprinters with superior records may adopt an endurance-based approach. Therefore, this study seeks to elucidate the pacing strategies of male 400 m track and field races, leveraging data gleaned from previous research as well as authoritative sources such as the World Association of Athletics Federations and other relevant organizations.

MATERIAL AND METHODS

Data collection

We gathered 400 m race records and data for each 50 m section from 457 races involving 155 male long sprinters (Ferro et al., 2001; Mochida et al., 2007; Wanda, 2024; Yamamoto et al., 2016; Yamanaka et al., 2019; Yamanaka et al., 2020; Yamanaka et al., 2017; Yamanaka et al., 2021; Yamanaka et al., 2018). When the same sprinter had multiple race records, we selected his best record. The sprinters were stratified into

distinct groups based on their 400 m records as follows: those achieving times under 44 seconds (T43, n = 6), within the range of 44.00–44.49 seconds (T44.0, n = 21), 44.50–44.99 seconds (T44.5, n = 25), 45.00–45.49 seconds (T45.0, n = 21), 45.50–45.99 seconds (T45.5, n = 27), those with times under 47 seconds (T46, n = 32), and those with times under 48 seconds (T47, n = 23). The experiment was conducted in accordance with the scientific and ethical norms of the Declaration of Helsinki and was approved in advance by the National Institute of Fitness and Sports in Kanoya Ethics Committee (23-1-39).

Data analysis

Time taken for each 50 m section in 400 m races

Split times for each 50 m section in the 400 m race were compiled from prior research (Ferro et al., 2001; Mochida et al., 2007; Wanda, 2024; Yamamoto et al., 2016; Yamanaka et al., 2019; Yamanaka et al., 2020; Yamanaka et al., 2017; Yamanaka et al., 2021; Yamanaka et al., 2018). Ferro et al. (2001) (Ferro et al., 2001) set up video cameras at 50 m intervals along a 400 m track to record the passing times of each sprinter. Other studies were obtained from video footage of the 400 m hurdles between the lines (first hurdle from the start: 45 m, second to tenth hurdle: 35 m, and tenth hurdle to finish line: 40 m), and the split times for each 50 m section were stored and calculated.

The percentage of every 100 m passing time to personal record (%PR)

The %PR was determined by dividing each 100 m passing time by the corresponding personal record. A higher %PR indicates that the sprinter is operating at an effort level closer to their maximum sprinting ability in that section. Owing to the limited opportunities for sprinters specializing in the 400 m race to compete in the 100 m, 200 m, and 300 m races, some of these records may have been established far from the time of their 400 m race personal best. Therefore, %PR was calculated only for sprinters who had recorded times in the 100 m, 200 m, and 300 m races in the year before and after their 400 m race personal record was set. The analysis of %PR was conducted for races comprising 72 participants in the 100 m race, 134 sprinters in the 200 m, and 64 participants in the 300 m.

Relative distribution of each 50 m split time to 400 m race records (% ST)

The %ST was calculated by dividing the time taken for each 50 m section by the corresponding 400 m race records. A higher %ST indicates that the sprinter is relatively slower in that particular section.

Statistical analyses

Descriptive data are presented as means (SDs). The independent variables included the 50 m split time, %ST, %PR, and F-index. To examine group-related differences in 50 m split times, %ST, and %PR, a two-way factorial analysis of variance (ANOVA) (group × section) was employed to examine both main effects and interactions. When no significant interaction was found, post hoc comparisons were conducted using the Bonferroni test. If a significant group by section interaction was identified, a simple main effect test was performed for each factor. To examine group differences in the F-index, a one-way ANOVA was used to confirm the significance of the main effect. When the F-value was significant, post hoc comparisons were conducted using the Bonferroni test. Pearson's correlation coefficient (r) was used to explore the relationships between the 400 m race record and the 50 m split times, %ST, %PR, and F-index. All data analyses were performed using SPSS Statistics (SPSS, version 26.0, for Windows; IBM).

Table 1. Descriptive data on the 400 m personal record, passing times and the percentage of the passing times relative to personal record (% PR).

Distance	50 m		100 m		150 m		200 m		250 m		300 m		350 m		400 m	
Personal best record [s]																
T43	-	-	10.21	(0.24)	-	-	19.88	(0.38)	-	-	31.13	(0.37)	-	-	43.42	(0.27)
T44.0	-	-	10.55	(0.32)	-	-	20.76	(0.45)	-	-	32.91	(2.25)	-	-	44.21	(0.23)
T44.5	-	-	10.71	(0.38)	-	-	20.66	(0.46)	-	-	32.53	(1.12)	-	-	44.54	(0.55)
T45.0	-	-	10.67	(0.35)	-	-	20.85	(0.28)	-	-	33.14	(0.93)	-	-	44.87	(0.33)
T45.5	-	-	10.70	(0.29)	-	-	21.06	(0.44)	-	-	32.92	(0.61)	-	-	45.44	(0.40)
T46	-	-	10.76	(0.31)	-	-	21.24	(0.39)	-	-	33.53	(0.69)	-	-	45.98	(0.52)
T47	-	-	10.93	(0.30)	-	-	21.42	(0.45)	-	-	33.42	(0.55)	-	-	46.72	(0.79)
Passing time [s]																
T43	6.09	(0.09)	10.88	(0.14)	15.76	(0.21)	20.80	(0.29)	26.01	(0.31)	31.40	(0.25)	37.15	(0.19)	43.46	(0.32)
T44.0	6.12	(0.11)	11.05	(0.18)	16.06	(0.25)	21.24	(0.29)	26.62	(0.30)	32.18	(0.29)	38.01	(0.23)	44.30	(0.13)
T44.5	6.12	(0.11)	11.06	(0.13)	16.09	(0.19)	21.33	(0.24)	26.79	(0.28)	32.43	(0.28)	38.36	(0.23)	44.72	(0.16)
T45.0	6.20	(0.10)	11.17	(0.16)	16.28	(0.25)	21.61	(0.32)	27.13	(0.32)	32.83	(0.28)	38.82	(0.21)	45.29	(0.14)
T45.5	6.25	(0.12)	11.30	(0.18)	16.46	(0.24)	21.83	(0.30)	27.40	(0.33)	33.18	(0.29)	39.22	(0.22)	45.73	(0.13)
T46	6.29	(0.12)	11.42	(0.23)	16.67	(0.32)	22.11	(0.38)	27.74	(0.41)	33.62	(0.38)	39.79	(0.32)	46.48	(0.29)
T47	6.40	0.15	11.69	0.29	17.13	0.40	22.79	0.50	28.59	0.51	34.58	0.49	40.81	0.42	47.50	0.29
Pass time relative to personal record [%]																
T43	-	-	93.19	(1.27)	-	-	95.84	(1.07)	-	-	99.17	(1.21)	-	-	-	-
T44.0	-	-	96.88	(2.42)	-	-	97.68	(2.15)	-	-	100.25	(2.52)	-	-	-	-
T44.5	-	-	95.56	(1.16)	-	-	97.04	(1.98)	-	-	99.98	(1.14)	-	-	-	-
T45.0	-	-	95.07	(1.87)	-	-	96.90	(1.84)	-	-	99.79	(0.93)	-	-	-	-
T45.5	-	-	94.40	(1.74)	-	-	96.92	(2.01)	-	-	99.15	(1.79)	-	-	-	-
T46	-	-	93.18	(2.20)	-	-	96.04	(2.01)	-	-	99.15	(1.44)	-	-	-	-
T47	-	-	92.63	(2.12)	-	-	94.88	(2.08)	-	-	96.72	(1.38)	-	-	-	-
Split time [s]																
T43	6.09	(0.09)	4.79	(0.09)	4.88	(0.10)	5.04	(0.11)	5.20	(0.06)	5.40	(0.11)	5.75	(0.17)	6.31	(0.25)
T44.0	6.12	(0.11)	4.93	(0.10)	5.01	(0.10)	5.18	(0.08)	5.38	(0.07)	5.56	(0.08)	5.83	(0.10)	6.29	(0.18)
T44.5	6.12	(0.11)	4.93	(0.09)	5.03	(0.08)	5.24	(0.08)	5.46	(0.08)	5.65	(0.10)	5.92	(0.09)	6.36	(0.19)
T45.0	6.20	(0.10)	4.97	(0.09)	5.11	(0.10)	5.33	(0.09)	5.52	(0.05)	5.71	(0.10)	5.99	(0.13)	6.47	(0.21)
T45.5	6.25	(0.12)	5.04	(0.10)	5.16	(0.09)	5.37	(0.09)	5.57	(0.07)	5.78	(0.08)	6.04	(0.11)	6.50	(0.19)
T46	6.29	(0.12)	5.13	(0.14)	5.25	(0.10)	5.44	(0.09)	5.63	(0.08)	5.88	(0.10)	6.17	(0.14)	6.70	(0.22)
T47	6.40	(0.15	5.29	(0.15	5.44	(0.13)	5.66	(0.13)	5.79	(0.11)	5.99	(0.13)	6.23	(0.16)	6.69	(0.26)
% Split time [%]																
T43	14.01	(0.21)	11.03	(0.26)	11.24	(0.28)	11.60	(0.28)	11.97	(0.13)	12.42	(0.18)	14.01	(0.21)	11.03	(0.26)
T44.0	13.80	(0.26)	11.12	(0.21)	11.31	(0.21)	11.69	(0.18)	12.14	(0.16)	12.54	(0.19)	13.80	(0.26)	11.12	(0.21)
T44.5	13.69	(0.25)	11.03	(0.21)	11.25	(0.17)	11.72	(0.17)	12.20	(0.18)	12.62	(0.21)	13.69	(0.25)	11.03	(0.21)
T45.0	13.69	(0.23)	10.97	(0.22)	11.28	(0.24)	11.76	(0.21)	12.18	(0.10)	12.60	(0.21)	13.69	(0.23)	10.97	(0.22)
T45.5	13.68	(0.27)	11.03	(0.21)	11.29	(0.18)	11.74	(0.19)	12.19	(0.14)	12.65	(0.17)	13.68	(0.27)	11.03	(0.21)
T46	13.54	(0.24)	11.03	(0.28)	11.30	(0.20)	11.70	(0.17)	12.11	(0.16)	12.65	(0.21)	13.54	(0.24)	11.03	(0.28)
T47	13.48	(0.29)	11.14	(0.30)	11.46	(0.25)	11.91	(0.24)	12.20	(0.20)	12.61	(0.26)	13.11	(0.34)	14.09	(0.56)

Note. The personal best records of the sprinters in this study are the times of only those who hold the record in their respective competitions: T43; 100 m n = 4, 200 m n = 6, 300 m n = 4. T44.0; 100 m n = 7, 200 m n = 19, 300 m n = 8. T44.5; 100 m n = 15, 200 m n = 24, 300 m n = 12. T45.0; 100 m n = 10, 200 m n = 20, 300 m n = 13. T45.5; 100 m n = 24, 200 m n = 26, 300 m n = 19. T46; 100 m n = 33, 200 m n = 30, 300 m n = 32. T47; 100 m n = 20, 200 m n = 21, 300 m n = 10. The % PR for sprinters in this study are based on those who competed in either event within one year before or after the 400 m race data was collected. T43; 100 m n = 2, 200 m n = 4, 300 m n = 4. T44.0; 100 m n = 7, 200 m n = 18, 300 m n = 4. T44.5; 100 m n = 6, 200 m n = 23, 300 m n = 12. T45.0; 100 m n = 8, 200 m n = 18, 300 m n = 6. T45.5; 100 m n = 13, 200 m n = 25, 300 m n = 14. T46; 100 m n = 8, 200 m n = 22, 300 m n = 26. T47; 100 m n = 14, 200 m n = 20, 300 m n = 9.

RESULTS

Group differences in independent variables

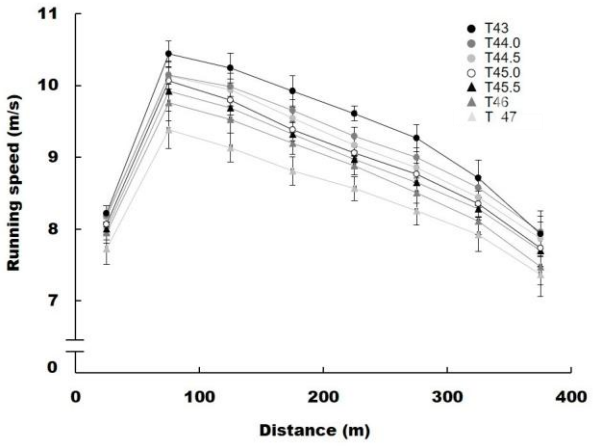
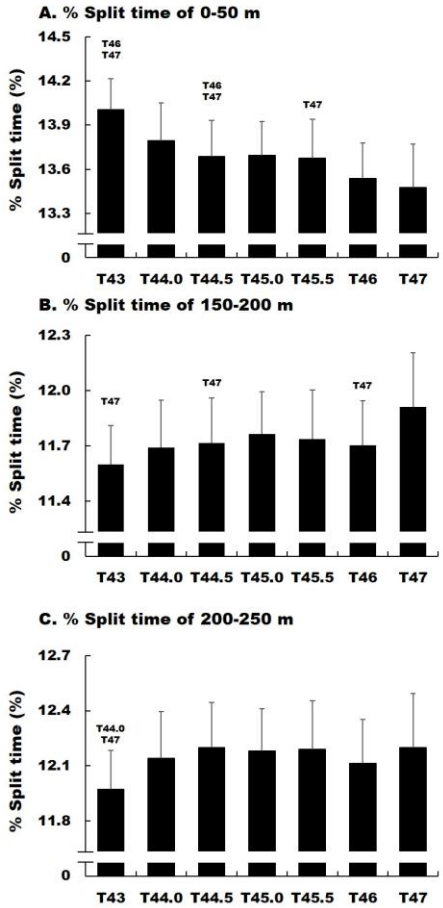


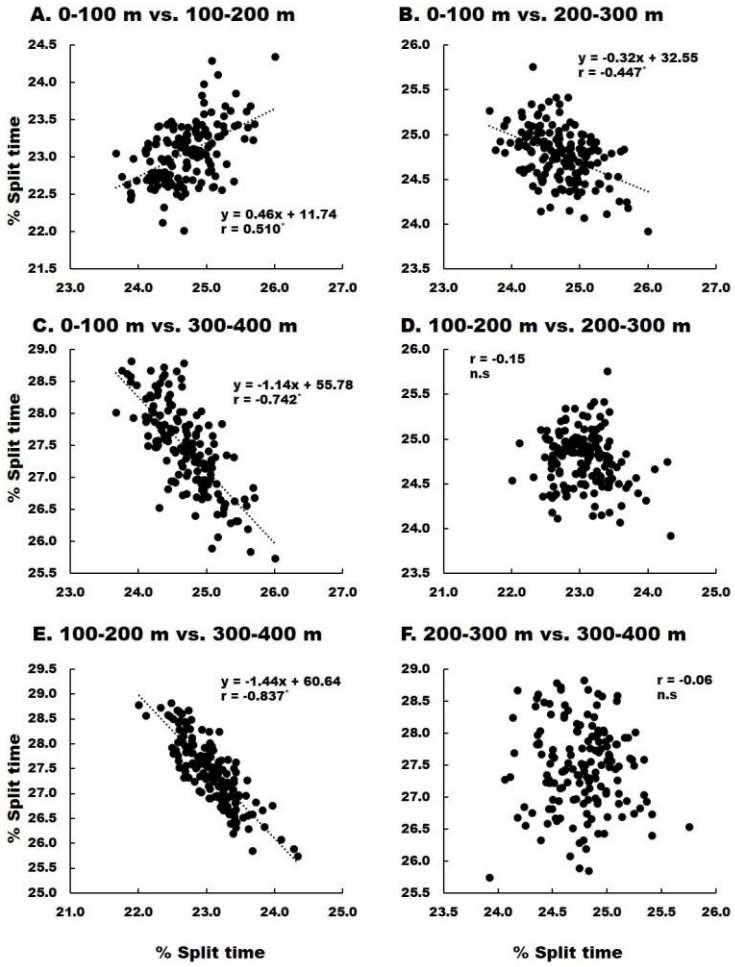
Figure 1. Comparison of running speeds in each 50 m section during the 400 m race across groups.



Note. Symbols above the bars indicate significant differences between the listed groups. T44.0; 44.0-second races, T46; 46.0-second races, T47; 47.0 second races.

Figure 2. Comparison of percentage of each 50 m split time relative to the 400 m race time (%ST) across groups.

The ANOVAs revealed significant group-by-section interactions in the 50 m split time and %ST. The time for each 50 m section was notably shorter for the faster 400 m records across most sections. As shown in Figure 1, sprinters with better 400 m records had higher running speeds at each distance. Specifically, the %ST in the 0–50 m section was significantly greater in T43 and T44.5 than in T46 and T47 (Figure 2). Moreover, in the 200–250 m section, %ST was significantly lower for T43 than for T44.0 and T47 (Figure 2).



*Note. * Denotes a significant correlation ($p < .05$).*

Figure 3. Correlations between %STs for each 100 m section.

Associations of 400 m race records with independent variables

Table 2. The relationship between 400m race time and 50m split times.

Split time [s]	Significant correlation
0-50m	0.658*
50-100m	0.762*
100-150m	0.840*
150-200m	0.869*
200-250m	0.886*
250-300m	0.855*
300-350m	0.764*
350-400m	0.573*

*Note. * Denotes $p < .05$.*

The 400 m record exhibited significant associations with passing times at the 50 m points. The % ST of the 0–50 m section showed a negative relationship with the 400 m race record, while those of the 100–150 m, 150–200 m, and 250–300 m sections demonstrated positive relationships. On the other hand, the %PR derived from each of the 100 m, 200 m, and 300 m races displayed negative associations with the 400 m race record.

Table 3. The relationship between 400m race time and %ST.

% Split time [%]	Significant correlation
0-50m	-0.427*
50-100m	0.060
100-150m	0.223*
150-200m	0.285*
200-250m	0.092
250-300m	0.160*
300-350m	-0.034
350-400m	-0.061

*Note. * Denotes p < .05.*

Table 4. The relationship between 400m race time, personal record, season record and %PR.

Personal best record [s]	Significant correlation
100m	0.364*
200m	0.607*
300m	0.436*
400m	0.900*
Season record [s]	
100m	0.392*
200m	0.751*
300m	0.728*
400m	0.903*
% Personal record	
100m	-0.265*
200m	-0.364*
300m	-0.275*

*Note. * Denotes p < .05.*

DISCUSSION

The main findings of this study are outlined as follows: (1) there exists a significant positive correlation between the 50 m split times and the 400 m race records across all sections, (2) the association between 400 m race records and %ST displayed a negative correlation for the initial 100 m section, whereas a positive correlation was observed for the subsequent 100–200 m and 250–300 m sections, (3) a significant negative correlation was evident between the initial 100 m section and both the 200–300 m and 300–400 m sections, and (4) sprinters achieving a time under 44 seconds exhibit a larger %ST in the 0–50 m section and a smaller %ST in the 200–250 m section. These findings suggest that achieving a 400 m record requires not only a heightened running speed but also emphasizes the critical role of race development.

As depicted in Figure 1, it is evident that 400 m sprinters with better records consistently exhibited higher running speeds throughout the 400 m race. This observation is consistent with the common understanding that achieving a superior record entail covering the designated distance more rapidly, thus necessitating a

heightened running pace. However, when % ST is considered, a notable distinction emerges. Specifically, the %ST for the sprinters in the T43 was higher in the 0–50 m section compared to those in T44.5–T47 groups but lower in the 200–250 m section compared to the T44.0 group (Figure 2). This implies that the 400 m sprinters with superior records may initially adopt a relatively slow pace. It has been shown that, at the 200 m point in the 400 m race, sprinting at 93% of personal record is better recorded than when sprinting faster than that (Saraslanidis et al., 2011). Combining the current results with those of previous studies, sprinters with better records face challenges in accelerating their pace during the initial stages of the 400 m race despite possessing the capability for higher overall speeds.

A previous study showed that increasing running speed in the 200–300 m section can reduce the overall time in the 400 m race (Stoyanov, 2016), which was also observed in this study with the highest correlation coefficient in that section. Interestingly, the %ST for the 0–100 m section had a negative correlation with the %ST for the 200–300 m and 300–400 m sections (Figure 3), suggesting that acquiring a relatively higher speed in the first half of 400 m may lead to lower running velocity in the latter half. From this, it can be inferred that world-class athletes, in addition to having high running capabilities, plan their pacing to suppress speed acquisition in the first half and increase their running velocity in the 200–300 m section.

Furthermore, the proportion of split times at various points during the race relative to personal records in 100 m, 200 m, and 300 m races had a significant negative correlation with the 400 m race records. This indicates that athletes with better 400 m records pass each point at a speed closer to their short-distance event records. This finding aligns with previous knowledge that the %PR calculated from the 200 m personal record is larger for world-class athletes (average 44.43 s) than for average athletes (average 48.24 s) (Hanon & Gajer, 2009). Considering the results of %ST, it is necessary to plan pacing strategies by integrating each athlete's %PR and %ST for the 400 m race distribution.

Limitation

The differences observed between the %ST and %PR results can be attributed to the fact that athletes with higher performance levels are more likely to specialize in and compete in the 400 m race. Athletes who compete and place in high-level competitions (such as the Olympics or World Championships) in the 400 m are thought to tailor their periodization to coincide with their peak performance periods and fine-tune their peaking process more delicately. Athletes who participate in international competitions are likely peaking specifically for the 400 m race and may not implement peaking strategies as intensely for events other than the 400 m. As a result, it is speculated that the times for multiple events tend to be relatively slower compared to the 400 m race, leading to a tendency toward higher %PR.

Practical applications

The results of this study showed that sprinters who performed better in the 400 m race achieved a higher running velocity throughout the race. Personal records in the 100 m, 200 m, and 300 m races were significantly positively correlated with personal records in the 400 m race. This indicates that sprinters should improve their 400 m personal records by increasing their sprint performance in races shorter than 400 m. Furthermore, this study found that sprinters with better 400 m race records were relatively slower in the 0–50 m section and relatively faster in the 100–300 m section. Thus, it is possible that 400 m sprinters with higher levels of performance execute a pacing strategy in which they reduce their running velocity in the early phase of the 400 m race and maintain a higher running velocity until the latter half of the race. With regard to practical application, coaches should train sprinters to focus on a balanced pace, emphasizing not overexerting themselves during the early phases of the race. Training programs could include drills that simulate race conditions and teach sprinters to distribute their efforts evenly across the race. This could

involve specific workouts aimed at maintaining a steady pace for the first 200 m, and then progressively increasing velocity in the later phases.

CONCLUSION

This study aimed to aggregate and analyse data on split times for every 50 m section in past 400 m races to elucidate the differences in pacing distribution by level and the relationship between each sprinter's record and pacing distribution. The results revealed that athletes with faster 400 m times maintained higher running velocities throughout the race while running relatively slower in the 0-50 m section. From these findings, it is evident that, in the 400 m race, controlling excessive speed in the early sections and acquiring and maintaining a high level of speed after the 200 m point are crucial.

AUTHOR CONTRIBUTIONS

TY, YC, KS, and YT conceived the idea of the study. TY drafted the original manuscript. TY developed the statistical analysis plan and conducted statistical analyses. TY, YC, KS, and YT contributed to the interpretation of the results. All authors reviewed the manuscript draft and revised it critically on intellectual content. All authors approved the final version of the manuscript to be published.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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