An Evaluation of 30-km Cycling Time Trial (TT_{30}) Pacing Strategy Through Time-to-Exhaustion at Average TT_{30} Pace

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Abstract

Ham, DJ and Knez, WL. An evaluation of 30 km cycling time trial (TT_{30}) pacing strategy through time-to-exhaustion at average TT_{30} pace. *J Strength Cond Res* 23(3): 1016–1021, 2009—A paucity of research is available on the optimal pacing strategy for cycling events longer than 4 km. Anecdotal evidence suggests that an even pacing strategy is most suitable; however, controlled studies have only determined that a slow start is more suitable than a fast start pacing strategy. Currently, it is unclear which strategy is more effective for endurance cycling time trials. This study sought to identify differences in 30-km cycling time trial (TT_{30}) performance related to pacing strategies by comparing individually chosen pacing strategy with time-to-exhaustion (TE) at the average power output achieved during TT_{30}. Eight moderately trained male cyclists ($\dot{V}O_{2max} = 50.9 \pm 5.2$ ml·kg^{-1}·min^{-1}) performed 2 TT_{30} tests and 2 TE tests at the average power output of TT_{30} on a Velotron cycle ergometer at the same time of day, separated by at least 48 hours. During TT_{30}, participants generally chose to use a 'fast start' pacing strategy, cycling at a speed relative to the TT average (TT_{Avg}) of 103.1 ± 2.2% during the first 5 km. There was no significant difference in performance time between the TE test and TT_{30}. Starting pace (TT_{0-5}) was significantly correlated with finishing pace (TT_{25-30}) ($r = -0.91$; $p < 0.01$) and TE ($r = 0.85$; $p < 0.01$). Subjects cycling at a relative starting speed (RS_{0-5}) >105% had a significantly longer TE than subjects cycling at <105%, whereas TT_{30} performance time was not different between the two groups. The present investigation provided indirect evidence that a fast start pacing strategy decreases finishing speed and overall performance in TT_{30}, and increased TT performance can be achieved by selecting a starting pace no more than 5% above TT_{Avg}.

Key Words endurance performance, measurement, sports

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Introduction

Pacing is the regulation of exercise intensity, and hence energy expenditure, to optimize race performance (16) and is a central component of success in sports, such as running, speed skating, rowing, kayaking, and cycling time trials. The ideal situation for optimum pacing is when both task demand and physiological capacity is known accurately by the athlete, and a pacing strategy can be implemented from the start that allows the task to be completed without surplus energy remaining at the point of task termination (16). Therefore, the intensity of the starting phase during these events needs to be accurately predicted by the athlete to achieve optimum performance. Overestimations (9,14) or underestimations (9,10) of the optimum starting intensity can lead to decreases in performance.

Research suggests that the ideal pacing strategy varies somewhat between the sport, the scenario, and the duration. In some events, optimum performance involves a fast start to either gain a psychological and tactical advantage (11) or to make full use of the kinetic energy generated (9). In cycling time trials, events that benefit from a fast start pacing strategy are short in nature, and the initial acceleration period represents a large portion of the event, such as a 1-km time trial (18). A short and powerful start is also recommended during a 4-km TT [18]. When TT distance is longer than 4 km, it has been suggested that an even distribution of power output is both physiologically and biophysically optimal in conditions of unvarying wind and gradient (2). Foster et al. (9) altered the first half of a 2-km TT and showed that athletes who used an even pacing strategy finished 2.1–2.4% faster, in comparison to those who adopted faster or slower starting strategies. The only study conducted on cycling TTs longer than 4 km failed to show significant differences in performance time between fast start, slow start, and self-selected pace of 20-km TT scenarios, despite 10 of the

13 subjects performing their fastest time during the slow start trial (14). A pacing study of 5-km running TT found no significant difference in performance time between trials with an enforced pace of even, 3% above and 6% above baseline trial speed during the first 1.63 km, despite 8 of the 11 performing the fastest trial during the 6% trial (12).

Foster et al. (8) suggested that pacing errors in cycling will produce lower decrements in performance than sports, such as swimming and running, because of the more forgiving medium resisting the athlete. This does not mean that pacing strategy is not important during cycling time trials, only that more sensitive ways of measuring these performance differences may be required. Mattern et al. (14) found a significant difference between a fast start and slow start pacing strategy when performance time was expressed as a percentage change from the self-selected trial performance time. Time-to-exhaustion tests are frequently used as a method of measuring small expected increases in performance for various types of interventions and can be more sensitive to performance differences than time trials. For example, the effects of ingesting caffeine and ephedrine have been shown to decrease 10-km run times by 2.1% (4) and increase time-to-exhaustion at 85% $\dot{V}O_{2max}$ by 39% (3).

Pacing studies in cycling generally compare self-selected TT performance with performance during a number of trials with externally selected starting strategies (9,12,14). This type of study aims to determine whether the externally selected pacing strategy produces a better performance than the self-selected pacing strategy of a group of athletes. However, it does not give an indication of the effectiveness of the individual's self-selected pacing strategy and has often failed to find significant differences between groups (12,14). The purpose of this study was to identify differences in TT_{30} performance related to self-selected pacing strategy by comparing individually chosen pacing strategy with a time-to-exhaustion test (TE; essentially an enforced even-paced TT), performed at the average power output achieved during TT_{30}. The aim of this study is to compare the self-selected pacing strategy of moderately trained cyclists during a 30-km TT (TT_{30}) with a TE test performed at the average power output achieved during TT_{30}. It was hypothesized that an even-pace starting strategy would be the most effective TT_{30} pacing strategy and would lead to the shortest TE times. Conversely, longer TE at TT_{Avg} would result from faster TT_{30} starting strategies.

Methods

Experimental Approach to the Problem

Participants were required to complete 5 tests on a cycle ergometer (Velotron; Racermate, Inc., Seattle, Wash.) during a 3-week period of constant training load. The 5 tests were separated by at least 48 hours and comprised (a) a continuous incremental ramp test; (b) 2 TT_{30}, and (c) 2 constant workload TE trials performed at the average power output produced during the faster of the 2 TT_{30}. The faster of the 2 trials was chosen as the intensity for the TE trial to allow participants the chance to familiarize themselves with the protocol and experiment somewhat with their pacing strategy. The second TE trial was used to establish reliability of the TE test and the method for detecting differences in TT performance time. The TE trial represents an enforced even-pacing strategy at the same average intensity as that performed during TT_{30}. This allows TE comparisons to be made between subjects of different performance standards because TE pace is relative to their own TT_{30} pace. This design is limited by the potential for an order effect caused by the requirement for the TT_{30} to occur first.

To ensure adequate hydration levels, participants were asked to arrive in a hydrated state and received 250 mL of water upon entering the laboratory. A further 250 mL was provided during the 10-minute warm-up and 500 mL during the performance trial. If a performance trial exceeded 45 minutes, an extra 250 mL was supplied for every 15 minutes. Urine specific gravity (USG) was taken before each trial, and subjects were not able to begin a trial before registering a USG < 1.02. In the event of a USG ≥ 1.02, the trial start time was postponed by 1 hour, and adequate fluid was provided. Pre- and post-trial body mass (kilograms) was obtained with participants wearing only Lycra cycling shorts using electronic scales accurate to 0.02 kg (Avery Berkel HL120; Avery Berkel, Taiwan, Japan) to estimate the extent of fluid loss attributable to sweating. Urine osmolarity was taken before each trial to ensure adequate hydration levels. Weight loss, as a percentage of body weight, throughout the trials averaged 0.8 ± 0.4 and 0.8 ± 0.3% for TT_{30} and TE, respectively.

The environmental conditions and the athletes' nutritional and training statuses were also controlled. Athletes performed each test in 22°C and 40% relative humidity (RH) and were instructed to abstain from exercise, alcohol, and caffeine for 24 hours before commencement of each trial. They were also asked to consume a high carbohydrate meal the night before testing and arrive at the laboratory in a hydrated and well-rested state, having fasted overnight or for at least 3 hours before the test if the participant was only available for testing during the afternoon.

Subjects

Eight moderately trained male cyclists and triathletes who competed regularly in club-based cycling TT races participated in the study. Participants were 25 ± 7.0 years of age (mean ± *SD*), weighed 77.3 ± 7.9 kg, had a cycling $\dot{V}O_{2peak}$ of 50.9 ± 5.2 ml·kg^{-1}fimin^{-1}, a peak power output (PPO) of 331.9 ± 34.7 W, and had been training for, and competing in cycling or triathlon races, for 5.5 ± 2.8 years. Volunteers completed a medical history questionnaire that sought to determine the presence of cardiovascular disease and diabetes. All risks and benefits of participation in the study were thoroughly explained to the volunteers; each participant provided informed consent, and the investigation was approved by the University Medical Research Ethics Committee.

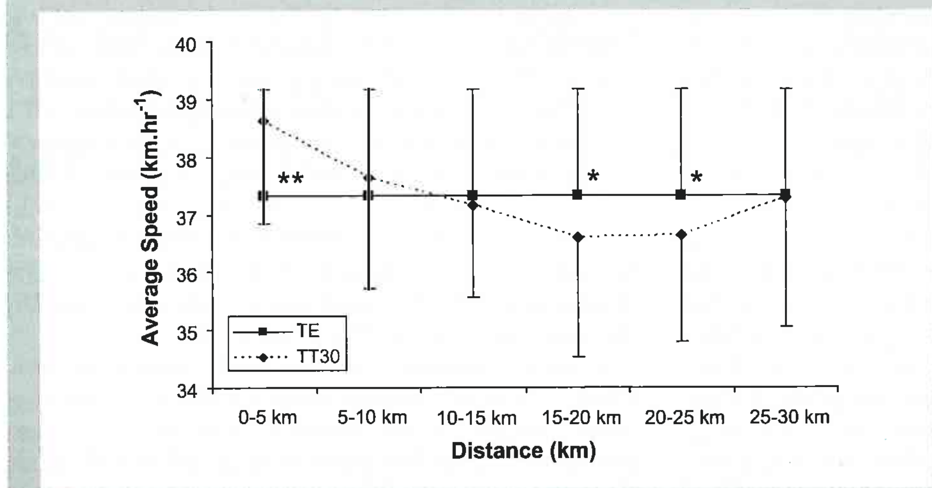

Figure 1. Average speed during each 5-km period of 30-km time trials (TT_{30}) and time to exhaustion (TE). Values are mean ± 95% confidence intervals (CI); *$p < 0.05$ between trials for specific 5-km period; **$p < 0.01$ between trials for specific 5-km period; Significant distance effect ($p < 0.01$); Significant distance × trial interaction ($p < 0.001$); No significant trial effect ($p > 0.05$).

Procedures

The continuous incremental ramp test was used to determine maximal aerobic power ($\dot{V}O_{2peak}$) and PPO and followed the protocol used by Bentley et al. (5). The test was preceded by a 5-minute warm-up at 100 W and a 10-minute rest in which resting levels of expired gases were collected. The initial test workload was set at 100 W for 3 minutes, after which power output was increased by 30 W every 3 minutes until volitional fatigue (5). During the test, expired gases were continuously monitored breath by breath (SensorMedics Vmax 22 series; SensoMedics, Yorba Linda, Calif.) for determination of $\dot{V}O_{2peak}$. The system was calibrated before each test using known volumes and concentrations of gas (O_2 and CO_2). Heart rate (HR) was recorded every 5 seconds during the test using a chest strap and wrist watch receiver (Polar s710; Polar Electro Oy, Kempele, Finland). Peak oxygen uptake was determined as the highest average $\dot{V}O_2$ recorded for any 30-second period of the test.

Performance trials (TT_{30} and TE) were completed on a Velotron Racermate cycle ergometer (using Coaching Software 1.0.426) fitted with SRM (Schoberer Rad Meßtechnik, Germany) cranks that allow the collection of power at a freely selected pedalling cadence. The participants refrained from any high-intensity or long duration training for at least 48 hours before each test. During each trial, a powerful electronic fan (~15 km·h^{-1}) was directed onto the participant from behind to allow adequate circulation of air. All trials were performed at the same time of day within participants to control for any diurnal variation in performance and were supervised by the same researcher.

Before each test, the participants rested in the seated position in the climatic chamber (22.1 ± 0.6°C; 48.7 ± 6.3% RH) for 10 min while resting HR was recorded. After the rest period, participants completed a 10-minute warm-up that consisted of a 5-minute incremental ramp protocol repeated twice. During each 5-minute ramp, participants cycled at 25% of PPO for the first 2.5 minutes, 60% for the next 90 seconds, and 80% for the final minute. In a 10-minute period after the completion of the warm-up, participants were allowed the final 8 minutes to rest or stretch after being weighed and returning to the ergometer. The trial then commenced, and the participant was free to vary their power output and pedalling frequency at their own discretion during the 2 TT_{30}; the pedalling frequency alone could be varied during the TE trial (because intensity was fixed). Distance was the only feedback given to participants during the TT_{30}, whereas no feedback was received regarding performance during TE trials. The SRM cycle ergometer allows adjustments to be made so that the dimensions of the cyclists own bicycle can be replicated. Clipless pedals were also attached so that the cyclist could wear their own cycling shoes. Mattern et al. (14) defined the start phase of a 20-km TT as the first 15%. Using this logic, the first 4.5 km would be considered the start phase of a TT_{30}. To have even distances for collection periods, and for ease of data collection, time was recorded every 5 km, and hence, the start phase was defined as the first 5 km. In addition, cyclists were asked to rate their perceived exertion (RPE) (6) every 5 minutes during and at the completion of the trial.

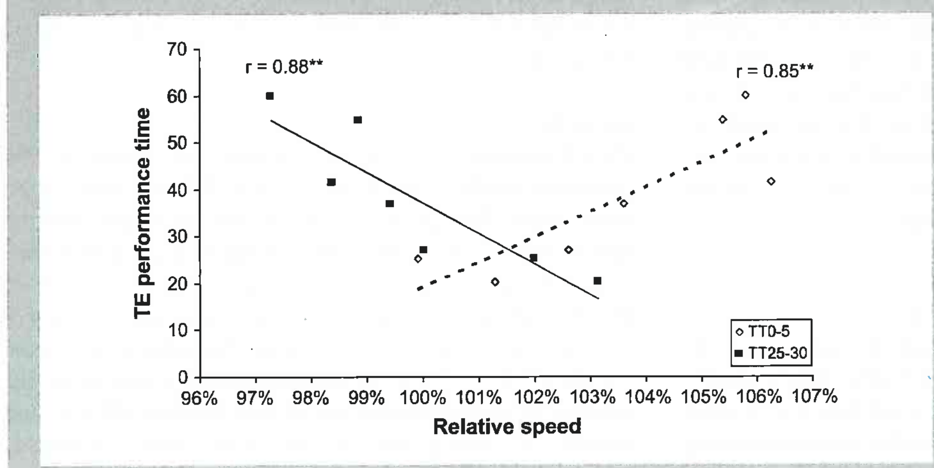

Figure 2. Relative time trial starting pace (RS_{0-5}) and finishing pace (RS_{25-30}) compared with time to exhaustion (TE) performance time. **Significant correlation; $p < 0.01$.

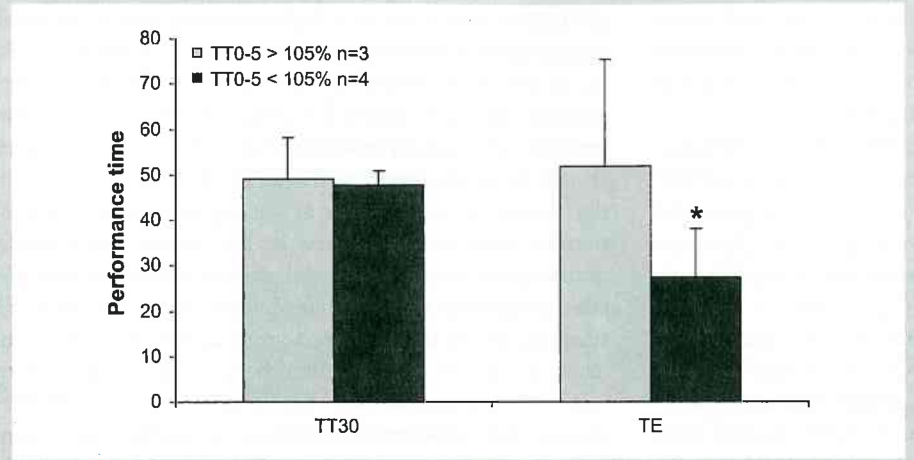

Figure 3. Relative 30-km time trial (TT_{30}) and time-to-exhaustion (TE) performance time for fast-start and even-start groups. Values are mean ± 95% confidence intervals (CI); *$p < 0.05$ between fast-start and even-start performance.

Statistical Analyses

Repeated-measures analysis of variance (ANOVA), paired and independent t-tests, and Wilcoxon's signed rank tests were used, where appropriate, to test for significant difference and interaction between dependent variables. All descriptive statistics are presented as mean ± 95% confidence interval. Pearsons product moment correlation coefficient was also used to detect relationships between TE performance time and speed during different 5-km periods. Data were analyzed using a combination of SPSS (version 11.0; SPSS Inc. Chicago, Ill.) and Statistica (version 7; StatSoft, Tulsa, Okla). The significance level was set at $p \leq 0.05$.

Results

One subject was omitted from the analysis as an outlier on the basis that his RPE during TT_{30} was on average the lowest of the sample group and significantly lower than the group average ($p < 0.01$), indicating a lack of effort in comparison to the rest of the group. One subject did not complete the second TE trial, and reliability data for the TE test was therefore established using 7 of the 8 subjects.

A coefficient of variation of 0.86 ± 0.56% and a significant intraclass correlation ($r = 0.97$; $p < 0.01$) was observed between the 2 TT_{30} performances. A coefficient of variation of 8.9 ± 10.2% and a significant intraclass correlation ($r = 0.90$; $p < 0.01$) was also observed between the 2 TE performances. Furthermore, there was no significant time difference between the 2 TT_{30}s (48.51 ± 2.48 and 48.49 ± 2.66; $p > 0.05$) or the 2 TE tests (43.68 ± 16.41 and 45.36 ± 13.93; $p > 0.05$). TT_{30} time ranged between 44.97 and 53.17 minutes (48.37 ± 2.44), whereas TE time ranged between 20.33 and 59.87 minutes (37.90 ± 13.98). Average power output (270.8 ± 31.4) and speed (37.3 ± 1.5) were identical for TT_{30} and TE, and results for cadence (92.1 ± 5.3 and 88.1 ± 7.0) and heart rate (173.5 ± 4.9 and 166.9 ± 5.6) were not significantly different between trials, respectively. Figure 1 shows the comparison between the average speed for each 5-km period during TT_{30} and TE. A distance effect was observed ($p < 0.01$), with a post-hoc comparison showing significant decreases in average speed during TT_{30} from the 0- to 5-km period (TT_{0-5}) to the 5- to 10-km period (TT_{5-10}) ($p < 0.01$) and then from TT_{5-10} to TT_{10-15} ($p < 0.01$). Speed increased again from TT_{20-25} to TT_{25-30} ($p < 0.01$). Additionally, when TT_{30} was compared with TE, a significant distance-trial interaction ($p < 0.01$) was observed. A post-hoc comparison showed a significantly higher average speed during TT_{0-5} and a significantly lower average speed during TT_{15-20} and TT_{20-25} during the TT_{30} as compared with TE.

Relative speed during the first 5 km (RS_{0-5}) varied between 99.9 and 106.3% (mean, 103.1 ± 2.2%), and relative finishing speed (RS_{25-30}) ranged from 97.3 to 103.1% (99.9 ± 1.9%) of the overall trial average (TT_{Avg}). A strong negative relationship ($r = -0.91$; $p < 0.01$) was observed between RS_{0-5} and RS_{25-30}, indicating that higher starting paces were related to lower finishing paces. The effect of different pacing strategies on TT_{30} performance was investigated indirectly through comparisons between RS during 5-km periods and TE at TT_{Avg}. A positive relationship between RS_{0-5} and TE ($r = 0.85$; $p < 0.05$) and a negative correlation between RS_{25-30} and TE ($r = -0.88$; $p < 0.01$) (Figure 2) was observed. This indicates that 82% of the variation in RS_{25-30} and 72% of the variation in TE can be attributed to RS_{0-5}. RS during all other 5-km periods was not significantly correlated with TE. Analysis of the second TE performed for reliability purposes revealed the same significant correlations between performance time and RS_{0-5} ($r = 0.81$; $p < 0.01$) and RS_{25-30}

($r = -0.89$; $p < 0.01$). The average absolute difference between RS for each 5-km period and TT_{avg} (i.e., root mean square of the error [RMSE]) was also significantly correlated with TE ($r = 0.76$; $p < 0.05$); however, 71% of the variation in the RMSE was attributable to starting pace.

Because of the relationships among RS_{0-5}, RS_{25-30}, variation in pace, and TE time, participants were split up into a number of different groups based on starting pace, finishing pace, and overall variation in pace. Subjects were split into a fast-start group ($RS_{0-5} > 105\%$; $n = 3$) and an even-start group ($RS_{0-5} < 105\%$; $n = 4$); a fast-finish group ($RS_{25-30} > 100\%$; $n = 3$) and a slow-finish group ($RS_{25-30} < 100\%$; $n = 4$); and a low-variation group (RMSE $< 2\%$; $n = 4$) and a high-variation group (RMSE $> 2\%$). Time to exhaustion was significantly shorter in the even-start group (27.30 ± 10.92 minutes) than the fast-start group (52.04 ± 23.61 minutes) (Figure 3), significantly shorter in the fast-finish group (24.17 ± 8.52 minutes) than the slow-finish group (48.21 ± 17.36 minutes), and significantly shorter in the low-variation group (27.30 ± 10.92 minutes) than the high-variation group (52.04 ± 23.61 minutes). It should be noted that the low-variation group and even-start groups represent the same participants. TT_{30} time was not significantly different between any two groups.

Discussion

Participants' self-selected starting speeds were significantly faster than TT_{Avg}, with only one participant selecting a starting speed less than TT_{Avg}. Participants performing a 20-km TT also chose to cycle at a higher speed during the early stages of the trial, as compared with the overall average (14). Both Atkinson et al. [2] and Nikolopoulos et al. (15) noted that it is very difficult for a rider not to start a TT of any distance with a high power output. This is likely because of the fact that higher power outputs at the beginning of a TT are not necessarily accompanied by immediate increases in perceived exertion compared with lower power outputs (1,7). Therefore, when the specific exercise intensity is unknown because of a lack of external feedback, athletes must predict the level of fatigue that they will feel at a future point in time at a given intensity (16).

High initial workloads in endurance events can result in increased blood lactate concentrations (14,17). This seems to be associated with impaired performance during the remainder of the event (14). These findings are supported in the current study by the strong negative relationship observed between RS_{0-5} and RS_{25-30}. This finding indicates that a faster starting pace will result in a slower finishing pace.

Fast starting paces have also been shown to significantly decrease 2-km TT performance (9) and 20-km TT performance when expressed as a percent change from a self-selected TT [14], as compared with more moderate starting paces. In the current study, indirect evidence of the detrimental effects of high starting paces on performance comes from the significantly higher TEs observed in the fast start group than the even-start group. Furthermore, the strong association between RS_{0-5} and TE at TT_{Avg} represents an indirect indication of a higher starting speed/poorer TT performance relationship. This finding is supported by Foster et al. (9), who found a significant relationship between starting pace and 2-km TT performance, with increasing starting pace leading to a greater decrease in performance. It should be noted that Foster et al. (9) also showed increasing decrements in performance as starting pace decreased to less than an even pace. This may be the reason that significant performance time differences between a fast-start and slow-start group were not found in Mattern et al.'s (14) study. The starting pace in the slow-start group in this study was much closer to the TT average than the fast-pace group (14) and may be responsible for the better results experienced during the slow-start condition. If cyclists are trained to reduce the starting effort of a TT to a pace that represents a more moderate intensity, race times are usually improved (1,7,14).

Higher variation in pace across TT_{30} was associated with poorer TE performance. This is supported by suggestions that an even distribution of power output is both physiologically and biophysically optimal for TTs longer than 4 km in conditions of unvarying wind and gradient (2). Liedl et al. (13) showed no significant differences in physiological strain between an even-pacing strategy and a pacing strategy that consisted of alternate 5-minute periods of 5% more than and 5% less than the mean work rate. Gosztyla et al. (12) reported that 8 of 11 subjects recorded their fastest 5-km running performance when the first 1.63 km were performed 6% more than their fastest baseline 5-km running pace. This was observed despite the fact that 3% more than and even-paced starting strategies were performed (12). The value of 6%, however, should not be taken out of context because the first 1.63 km were only performed at 3.6% more than the average 5-km speed. In the current study, participants who chose a starting speed more than 5% above TT_{Avg}, were able to cycle at TT_{Avg} for a significantly longer period of time. The same group had an average variation in speed from the TT_{Avg} of only 2.5 ± 0.7%. This result is in keeping with the findings of Liedl et al. (13), suggesting that variations from the mean work rate more than 5% can lead to poorer TT performances.

Whereas no differences or associations were evident among TT_{30} performance time and relative starting pace, relative finishing pace, or variation in pace, TE at TT_{Avg} showed significant associations and differences for these factors. As experienced during other studies (3,4), TE in the current study was a more sensitive measure of performance differences and allowed comparisons between subjects of varying performance level.

Whereas TE was not significantly different to TT_{30} performance time for any group, there was a trend towards shorter TE time than TT_{30} time (27.30 ± 10.92 minutes and 47.73 ± 3.21 minutes; $p = 0.13$) for participants in the even-start group. The inability of a number of participants to reach their TT_{30} time during their TE test may be an example of the inherent test differences between a TT and a TE test.

The present investigation provided indirect evidence that a fast-start pacing strategy decreases finishing pace and overall performance in a TT_{30} using a TE at TT_{Avg} to elucidate small TT_{30} performance differences. Findings supported the hypotheses in that an even-paced starting strategy resulted in shorter TE and faster starting strategies led to longer TE. Whether a slower start is a more effective TT pacing strategy than an even start could not be determined because participants did not self select starting paces slower than TT_{Avg}.

Practical Applications

Enhanced endurance cycling TT performance can be achieved by reducing athlete starting pace to less than 5% above the mean trial speed and minimizing changes in pace across the trial during situations of unvarying gradient and wind. A fast-start pacing strategy seems to result in increased levels of anaerobic metabolites, which leads to impaired performance in later parts of the TT and ultimately decreases TT performance. TE at TT_{Avg} can be used to assess the effectiveness of TT pacing between athletes within a group.

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