Picking up the pace

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Chapter 4

Effects of experience and opponents on the pacing behaviour and 2-km cycling performance of novice adolescents

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Abstract

Purpose: To study the pacing behaviour and performance of novice adolescents in a well-controlled laboratory setting.

Methods: Ten healthy participants (seven male, three female, 15.8 ± 1.0 years) completed four, 2-km trials on a Velotron cycling ergometer. Visit 1 was a familiarization trial. Visits 2 to 4 involved the following conditions, in randomized order: no opponent (NO), a virtual opponent (starting slow and finishing fast) (OP-SLOWFAST), and a virtual opponent (starting fast and finishing slow) (OP-FASTSLOW). Repeated measures ANOVAs ($p<0.05$) were used to examine differences in performance (mean power output, finishing time), pacing behaviour (mean power output per 250m segment), and rate of perceived exertion (RPE) between the four successive visits and the three conditions. The expected performance outcome was measured using a questionnaire.

Results: Power output increased ($F_{3,27} = 5.65$, $p<0.01$, $\eta^2_p = 0.39$) and finishing time decreased ($F_{3,27} = 9.97$, $p<0.001$, $\eta^2_p = 0.53$) between visit 1 and visits 2, 3 and 4. In comparison to the familiarisation visit, the difference between the expected finish time and actual finishing time decreased by 66.2%, regardless of condition. The only significant difference observed in the RPE score was reported at the 500m point, where RPE was higher during visit 1 compared to visits 3 and 4, and during visit 2 compared to visit 4 ($p<0.05$). No differences in pacing behaviour, performance, or RPE were found between conditions ($p>0.05$).

Conclusion: Novice adolescents improved their cycling performance after gaining experience during the first visit, parallel with the capability to anticipate future workload, and independent of a change in pacing behaviour.

Keywords: pacing strategy, adolescence, development, competition.

1. Introduction

Pacing is widely known as the goal-directed distribution of energy over a predetermined exercise task (1, 2). This has been shown to be a decisive component of athletic performance in both time-trial (3, 4) and head-to-head events (5-7). The outcome of decision-making involved in pacing is defined as pacing behaviour (1). Pacing behaviour can be influenced by many aspects including; the perceived level of fatigue throughout the race (8), the competitive environment (9) and sport-specific demands (10). Thus far, most research on pacing behaviour has been conducted in adults, and research on the acquisition of the pacing skill and the development of pacing behaviour in adolescents is surprisingly scarce (11).

Although empirical data on the pacing behaviour of younger individuals is limited, one study of time-trial performances in young children (~5-8 year olds) has suggested it is characterised by an initial all-out use of energy, which thereafter decreases in velocity over the duration of the bout (12). Older children (~10 years old) seem to display a more U-shaped velocity distribution, suggestive of a goal-driven reservation of energy in order to execute an exercise task successfully (12, 13). Furthermore, emerging research from both time-trial and head-to-head events appears to suggest pacing behaviour of younger athletes (12-21 years old) progressively further develops in complexity towards that of adults (14, 15). The proposed theoretical basis behind this development of pacing behaviour is two-fold. First, during adolescence, there are cognitive and physical changes associated with growth and maturation (16, 17). Second, the gathering of experience during exercise tasks, for example by means of training or competition, facilitates the improvement of physical and cognitive performance characteristics. Improvement of performance characteristics in turn facilitates the development of adequate pacing behaviour (11). Therefore, it is likely that the development and maturation of cognitive characteristics mediate the influence of acquired experience on pacing behaviour. As such, cognitive functions relevant to pacing include a progressively accurate self-assessment of physical capability aligned with anticipation of future physiological requirements (18, 19), meta-cognitive functions (11) and deductive reasoning (20). Underdevelopment of these functions may lead to sub-optimal pacing behaviour (12, 20).

Recent literature emphasizes the importance of environmental stimuli in the pacing process (1, 9, 21). The anticipation and response to environmental stimuli (e.g. opponents) has been suggested to be important both in competition and in the development of pacing behaviour (14). The study of Lambrick *et al.* showed that when inexperienced children (~10 years old) who were performing an 800m running task were introduced to opponents, their performance decreased with no change in pacing behaviour (13). The given explanation for this outcome was the relative inexperience of the children in a competitive environment which increases with exposure to a variety of competitive situations over the life span. Interestingly, when adult athletes were presented with a performance-matched opponent, an improvement in performance was demonstrated, which may be due to the greater familiarity of adults with competitive environments (21-23). Furthermore, it was found that the pacing behaviour of the opponent influenced that of the participant, as a faster-starting opponent evoked a faster (matched) start in the participants (6). Therefore it would seem the skills that allow an athlete to anticipate, interpret and implement pacing in the presence of an opponent are developed during adolescence (14). However, in adolescents, who have not yet fully developed the pacing behaviour of adults, it is questionable whether performance would be significantly influenced by the presence of an opponent and if so, if this influence would be to the same extent to what has been reported in adults. It is plausible that the primary driver of inexperienced young athletes, is to learn how to distribute their efforts over an exercise bout via an intrinsic improvement of their self-regulated behaviour. In contrast, adults who have already developed this pacing skill, might be more influenced by the presence of those around them.

Adolescence seems to be a crucial period in the development of pacing behaviour. Nonetheless, most research into pacing has been carried out in adults. The scarce research that has investigated the subject of pacing behaviour in youth athletes thus far consists mainly of the analysis of split times during competition (14, 15, 24). Therefore, an empirical, well-controlled laboratory study would offer the opportunity to investigate several factors that shape pacing behaviour in adolescents, without the large variation in environmental circumstances that accompanies measuring athletes in competition. The aims of the current study were to investigate what characterises the pacing behaviour of novice adolescents, whether or not their performance and pacing behaviour is influenced by experience gained over successive trials, and if the presence of an opponent influences their pacing behaviour and performance.

2. Methods

2.1. Participants

Ten participants (seven males, three females) completed the study (age: 15.8 ± 1.0 years, height: 1.79 ± 0.06 m, body mass: 62.0 ± 7.5 kg). All participants were healthy and moderately to highly active, as assessed, respectively, by the PAR-Q (25) and the short version of the IPAQ (26). All participants were active partakers in a variety of sports (dance, gym, soccer). None of the participants had any previous experience in performing a (cycling) time trial. Written informed consent was obtained from the participants and their parents or legal guardians at the start of the first visit. The study was approved by the ethical committee of the local university in accordance to the Declaration of Helsinki.

2.2. Experimental procedures

All participants completed four 2-km cycling time trials over four visits. At the start of each visit, each participant was asked two questions about their motivation ("How motivated are you to perform well on the time trial?") and performance ("How do you think you will perform?") concerning the upcoming trial, which were scored on a 5-point Likert scale

(5: very motivated, 1: not motivated at all; 5: very good, 1: not good at all). Additionally, participants were asked to estimate a finishing time for the upcoming trial as an indication of their capability to anticipate the workload of the exercise ("In what time do you think you will complete the time trial of two kilometre?"). The participants were not given information on their performance on any of the trials until after the completion of all visits, as the knowledge of a previous performance could influence performance in upcoming trials. Thereafter, participants performed a five minute warm-up with the instruction to perform an average power output of 150 Watts for males and 115 Watts for females (27), followed by a five minute inactive recovery period before the start of the trial.

All time trials were performed on a cycling ergometer (Velotron Dynafit, Racermate, Seattle, USA), which has been shown to be a reliable and valid tool for testing performance and pacing behaviour (28, 29). Using the Velotron 3D software, a 2-km track was created, which was straight, flat and featured no wind. During trials, the track was projected on a screen. Participants were portrayed by an on-screen avatar. During visit 1, a familiarization trial (FAM) was performed. In this trial, participants performed without the presence of an opponent. During two of the remaining three visits, the participants performed a time trial with an opponent operating different race pacing strategies, and one without an opponent (NO), all in a randomized order. The two styles of opponents were created individually for each participant on the basis of the performance during the familiarization trial (22). One opponent (OP-SLOWFAST) used a slow pace (100% of FAM) between 150-1000m and a fast pace (104% of FAM) between 1000m-2000m. The other opponent (OP-FASTSLOW) adopted a fast pace (104% of FAM) between 150-1000m and a slow pace (100% of FAM) between 1000-2000m. The initial 150m of the race was used to give the virtual opponents a start that was comparable to that of human performers. Both opponents had a total race performance which was two percent faster compared to the FAM to correct for the expected improvement of the participants after the FAM, based on the increase in performances of inexperienced children and adult cyclists (13, 22). During trials with an opponent, two avatars were visible on the screen, portraying the participant and the opponent, providing the participant with the relative distance to the opponent. At the start of each trial, participants were provided with the goal to complete the trial in the fastest possible time and to give maximal effort; whether or not they beat the opponent was not important. When an opponent was present, participants were told the opponent was of a similar performance level as the participants. Participants received no numerical feedback on heart rate, power, velocity, time passed, the distance covered, distance left or relative distance to the opponent. Participants were free to change gear throughout the time trial. Power output, velocity, distance, and gearing were monitored during the trial (sample frequency = 25Hz). The rate of perceived exertion (RPE) on a Borg-scale of 6-20 was asked after warm-up, before the start of the trial and at 500m, 1000m, and 1500m, as well as directly after passing the finish line. The participants were told the RPE collection points were random throughout the trial.

All time trials were performed on the same day of the week, with a maximum of six weeks for all the visits. Participants were asked to keep changes in activity and sleep patterns to a minimum during the testing period. Furthermore, participants were asked to abstain from intense physical exercise for 24 hours as well as the consumption of solid food for two hours and caffeine for four hours, before visits. All trials were conducted in ambient temperatures between 18-21°C.

2.3. Data analyses

To investigate the effect of the experience gained over successive trials, the outcome variables of the four consecutive visits (visit 1, visit 2, visit 3 and visit 4) were compared. In order to analyse the influence of the two different opponents, the three different conditions (NO, OP-SLOWFAST and OP-FASTSLOW) were compared.

Performance was analysed through two outcome variables: finish time and mean power output of the trial. Assumption of normality of the continuous outcome variables were checked per visit and condition using Shapiro-Wilk test. The performance variables and the answers to the questionnaire on motivation, expected performance and expected finishing time were analysed by a one-way repeated measures ANOVA to reveal a difference between the visits or conditions ($p<0.05$). A post hoc analysis in the form of paired t-test, including Bonferroni correction, was performed if a significant effect ($p<0.05$) was found. In order to study the capability to anticipate the future workload before exercise, a paired t-test was used to analyse the difference between the expected and actual finishing time for each visit.

The pacing behaviour of the participants was investigated by analysing the mean power output of each 250m segment of the 2-km trial. Assessing pacing behaviour through analyses of power output during the course of a trial is a commonly used method in literature (22). The assumption of normality was checked per visit and condition using the Shapiro-Wilk test. A two-way repeated measures analysis ($p<0.05$) was used to investigate a difference in pacing behaviour between the different visits (segments * visits) and between the different conditions (segments * conditions). If a significant interaction effect ($p<0.05$) was found, indicating a difference in pacing behaviour, a post hoc analysis in the form of paired t-test, including Bonferroni correction, would be performed.

The RPE throughout the trial was analysed using a two-way repeated measures analysis ($p<0.05$) to study the difference in RPE during the different visits (segments * visits) and the difference in RPE between conditions (segments * conditions). A significant interaction effect would indicate a difference in the RPE score over the segments for either the visits or the conditions and would instigate a paired t-test post hoc analyses, including Bonferroni correction.

In anticipation of all previously mentioned repeated measures ANOVA analyses the sphericity was tested using Mauchly's test. If sphericity could not be assumed a Greenhouse-Geisser correction was used. Cohen's d and partial eta squared (η2p) were used to report effect size (small: d = 0.2, η2p = 0.01; medium: d = 0.5, η2p = 0.06; large: d < 0.8, η2p < 0.14).

3. Results

3.1. Repeated trials

The mean (SD) of the questionnaires on motivation, expected performance and expected finishing time, as well as the actual finish time and mean power output of each visit, can be found in Table 1. During the course of the visits, there was no significant difference in the answers to the questions concerning motivation ($F_{3,27} = 1.09$, $p = 0.37$, $\eta^2_p = 0.11$), expected performance ($F_{3,27} = 0.56$, $p = 0.63$, $\eta^2_p = 0.06$) or expected finish time ($F_{1.07, 9.61} = 2.81$, $p = 0.13$, $\eta^2_p = 0.24$). However, a significant difference between expected and actual finishing time was found during visit 1 (t = 2.81, p < 0.05, d = 0.89), but not during visits 2, 3 and 4 (t = 1.69, p = 0.13, d = 0.53; t = 1.99, p = 0.08, d = 0.63; t = 1.89, p = 0.09, d = 0.60; respectively). A significant difference in both performance variables, finish time and mean power output, was found ($F_{3,27} = 9.97$, $p < 0.001$, $\eta^2_p = 0.53$ and $F_{3,27} = 5.65$, $p < 0.01$, $\eta^2_p = 0.39$, respectively). The post hoc analyses revealed the finishing times of visits 2, 3 and 4 were significantly lower compared to visit 1 (t = 21.35, p < 0.01, d = 1.46; t = 14.06, p < 0.01, d = 1.19; t = 13.03, p < 0.01, d = 1.14; respectively). Additionally, the mean power output was significantly higher in visits 2, 3 and 4 compared to visit 1 (t = 11.85, p < 0.01, d = 1.09; t = 9.78, p < 0.05, d = 0.99; t = 7.30, p < 0.05, d = 0.86; respectively).

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The mean (±SD) power output within the 250m segments of the trial for each visit are shown in Figure 1. There was a significant difference between the individual 250m segments ($F_{1.33, 11.95} = 8.28$, $p < 0.01$, $\eta^2_p = 0.48$) and between the mean values of the different visits ($F_{3, 27} = 5.65$, $p < 0.01$, $\eta^2_p = 0.39$). No significant interaction effect, indicating a difference in pacing behaviour between the different visits, was found ($F_{4.56, 40.10} = 2.17$, $p = 0.08$, $\eta^2_p = 0.19$).

The mean (±SD) RPE scores are shown in Figure 2. The RPE score was significantly different between the different segments ($F_{1.66, 14.94} = 159.03$, $p < 0.001$, $\eta^2_p = 0.95$). The average RPE score was not significantly different between different visits ($F_{3, 27} = 0.85$, $p = 0.48$, $\eta^2_p = 0.09$). A significant interaction effect was found, indicating a difference in RPE score over the segments between the visits ($F_{3.30, 29.74} = 3.25$, $p < 0.05$, $\eta^2_p = 0.27$). The post hoc analysis revealed that the RPE score at the 500m mark was significantly higher during visit 1 compared to visit 3 (t = 7.57, p < 0.05, d = 0.87) and visit 4 (t = 18.69, p < 0.05, d = 1.37). Moreover, the RPE score at 500m was higher during visit 2 compared to visit 4 (t = 17.05, p < 0.01, d = 1.30). No significant differences in RPE between the visits were found at the start, 1000m, 1500m and finish.

Table 1. Means (±SD) of the indicators of motivation, expected performance and performance outcome variables for each visit and the different conditions.

	Questioning on motivation (1-5)	Questioning on expected performance (1-5)	Expected finish time (s)	Finish time* (s)	Δ Expected and actual finishing time (s)	Mean power output* (W)
Visit 1	4 ± 1	3 ± 1	453.00±249.18	240.50±27.37	212.50±239.33[†]	181.03±46.36
Visit 2	4 ± 1	3 ± 1	300.00±141.42	228.33±21.12[A]	71.67±134.40	195.70±41.08[A]
Visit 3	4 ± 1	4 ± 1	312.00±142.97	227.69±20.97[A]	84.31±134.21	199.54±43.87[A]
Visit 4	4 ± 1	3 ± 1	297.00±120.37	228.97±18.40[A]	68.03±113.61	193.50±39.84[A]
No Opponent	4 ± 1	4 ± 1	303.00±135.98	227.16±17.17	75.85±129.00	196.73±39.15
OP-SLOWFAST	4 ± 1	3 ± 1	294.00±121.49	228.19±20.39	65.81±114.49	197.33±42.35
OP-FASTSLOW	4 ± 1	4 ± 1	312.00±147.11	229.64±22.61	82.36±138.72	194.68±43.48

Note. * = significant difference between visits, [A] = significantly different from visit 1, [†] = significant difference between expected and actual finishing time within a visit or within a condition.

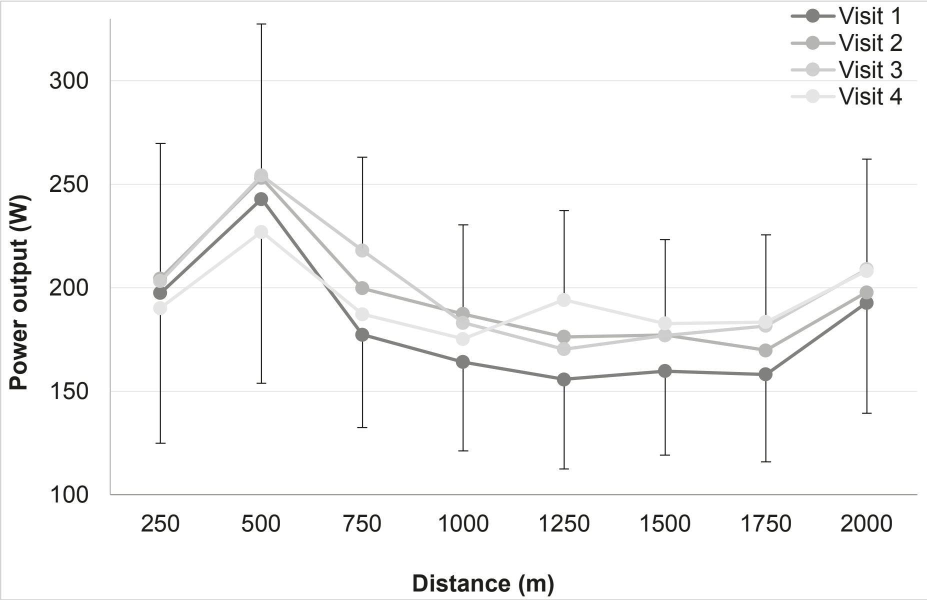

Figure 1. Mean (±SD) power output in each 250m segments for each visit.

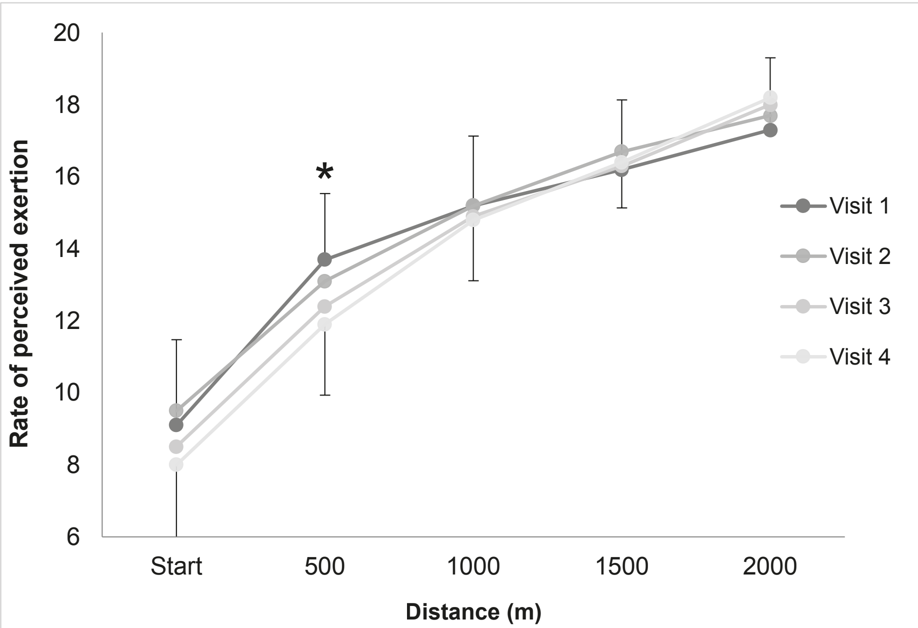

Figure 2. RPE score at the start, 500m, 1000m, 1500m and finish, for each visit. * a significant difference in RPE ($p < 0.05$) between: visit 1 and visit 3 & 4, visit 2 and visit 4.

3.2. Influence of opponents

The difference in finishing time between the opponents calculated from the FAM and the constructed opponents which participants faced was: 0.33±0.07s. The mean (±SD) finishing times of the constructed opponents were OP-SLOWFAST: 235.39±25.44s and OP-FAST-SLOW: 235.35±25.58s.

Between the conditions, there was no significant difference in the scores on motivation ($F_{1.78,16.06} = 0.78$, $p = 0.46$, $\eta^2_p = 0.08$), expected performance ($F_{1.86,16.71} = 0.55$, $p= 0.58$, $\eta^2_p = 0.06$) or expected finish time ($F_{1.57,14.10} = 0.81$, $p = 0.44$, $\eta^2_p = 0.08$) (Table 1). Additionally, no significant difference in finish time or mean power output was found between the trials with different conditions ($F_{1.88,16.48} = 0.61$, $p = 0.54$, $\eta^2_p = 0.06$ and $F_{1.720,15.484} = 0.17$, $p = 0.81$, $\eta^2_p = 0.02$, respectively) (Table 1).

The mean (±SD) power output within each 250m segment of the trial under different conditions are shown in Figure 3. A significant difference in power output over the different segments was found ($F_{1.47, 13.23} = 6.87$, $p < 0.05$, $\eta^2_p = 0.43$). No significant difference between the mean values between conditions ($F_{2, 18} = 0.17$, $p = 0.81$, $\eta^2_p = 0.02$) or interaction effect, indicating a difference in pacing behaviour ($F_{2.90,26.08} = 1.32$, $p = 0.29$, $\eta^2_p = 0.13$), were found.

Mean (±SD) scores for RPE can be found in Figure 4. The RPE score of the individual segments was significantly different ($F_{4, 36} = 144.76$, $p < 0.001$, $\eta^2_p = 0.94$). Additionally, the average RPE score of the distinct conditions was significantly different ($F_{1.63, 14.64} = 4.92$, $p < 0.05$, $\eta^2_p = 0.03$). No significant difference in RPE score over the segments between the different conditions was found ($F_{2.13, 19.18} = 0.29$, $p = 0.77$, $\eta^2_p = 0.03$).

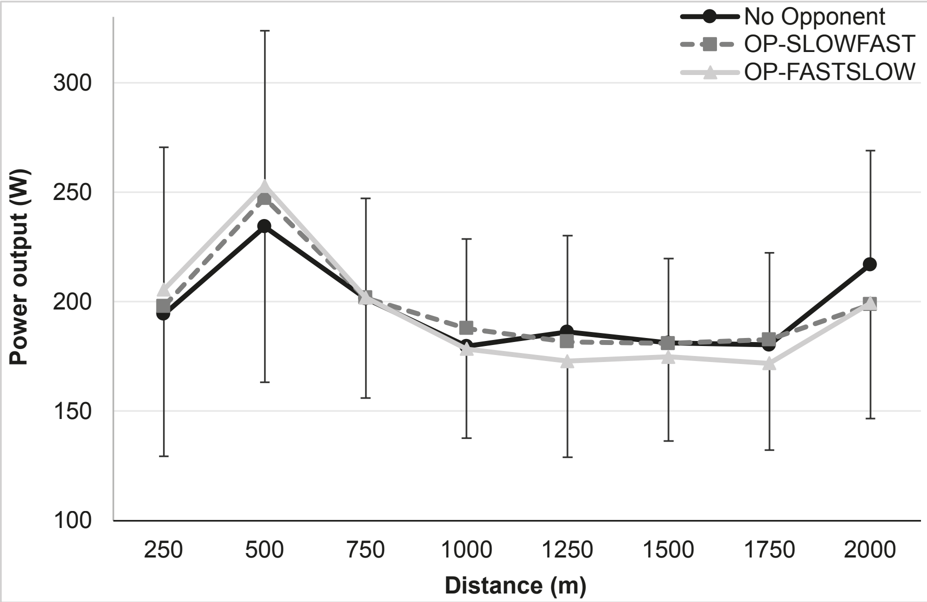

Figure 3. Mean (±SD) power output in each 250m segments for each condition.

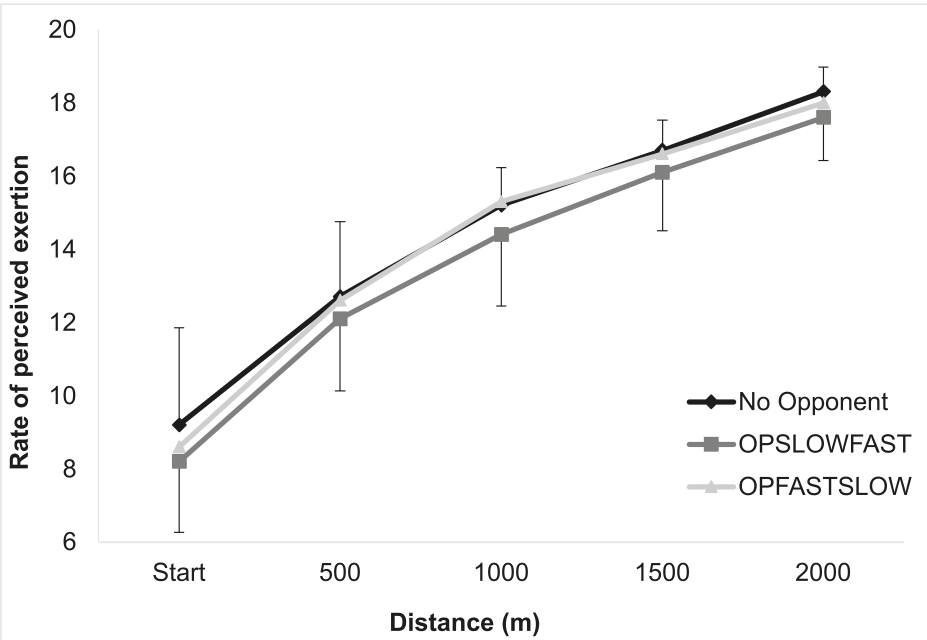

Figure 4. Mean (±SD) RPE score at the start, 500m, 1000m, 1500m and at the finish, for each condition.

4. Discussion

This study is the first to examine characteristics of the pacing behaviour of novice adolescents in a controlled laboratory setting. The findings identify that the power output of the novice adolescents decreases between the 500m and 1000m mark, and increases at the 1750m to 2000m segment. This is a more complex pacing behaviour than seen previously in young children (~5-8 years) (12), and the observed overall U-shaped effort distribution is generally associated with the goal-directed preservation of energy to execute an exercise task successfully. This suggests that increased sophistication of pacing behaviour is evident in adolescents compared to young children. It is also interesting that during the first visit, a significant difference was found between the amount of time participants thought was needed to finish the trial and the actual completion time of the trial. The variety in expected finishing time among the cohort during the first visit was also substantially larger (SD of visit 1: 249.18s) compared to other visits (average SD visits 2-4: 134.74s). Both findings attest to the novelty of the activity for the participants before the first visit and the potential impact of the acquired experience. The finding that the pacing behaviour of adolescents exhibits characteristics associated with the goal-directed reservation of energy during the execution of a novel exercise task supports the notion of an inherit pacing template already being present from a young age (13, 30).

The secondary aim of this research was to investigate the influence of the experience gained over successive trials on pacing behaviour and performance. However, no change in pacing behaviour was found throughout the visits. Nevertheless, the 8.1% increase in power output and 5.1% decrease in finishing time during the second visit indicate an improvement in performance after gaining experience during the first visit. The observation that there was no significant increase in performance during visits two, three and four suggests that a single familiarization trial was sufficient to heighten the performance in novice adolescents. A similar conclusion was reached in research on children (aged 9-11 years) performing a running task with a similar duration to the task in the current study (13). This study found a 2.6-3.1% decrease in finishing time during the second visit and no significant further decrease during the third visit. Moreover, the study did not find a significant difference in pacing behaviour between the three visits. These results strengthen the notion that novices can increase performance after gaining experience in only a single trial.

It has previously been proposed that the anticipation of workload, and the adjustment of workload anticipation during exercise form part of the underlying mechanism of the regulation of energy (18, 19, 31). In the current study, the capability to anticipate the workload of the exercise was measured by analysing the difference between the expected finish time and the actual finishing time of each visit. By comparing the first and second visits, the gap between the expected finish time and the actual finishing time decreased by 66.2%, suggesting greater awareness of task demands as experience grew. It should be noted that the condition of visit two differed between participants, as a result of the randomisation of conditions between visits two, three and four. However, there was no significant difference in expected or actual finishing time between the conditions, indicating that the increase in awareness of performance capabilities was not influenced by the condition of the second visit. Moreover, on the first visit, the expected and actual finishing times were significantly different. Contrary to this, there was no significant difference between the expected and actual finishing times during the other visits. These findings point to an improved capability to anticipate the workload of the exercise as a whole, in addition to greater confidence in the performance capability. The increase in the capability to anticipate the total workload might be the underlying mechanism of the increase in performance after the first visit.

In literature, RPE has been proposed as a mediating factor in the regulation of energy distribution by the cognitive anticipatory skill (32). The results of the current study present a decrease in RPE score at the 500m mark between visits one and visit three and four, as well as between visits two and four. A lower RPE score during the initial phase of the race may well indicate that the participants were actively changing their anticipation of the future workload during the exercise (33). Therefore, it could be suggested that the capability to anticipate the future workload during exercise takes more than one visit worth of experience to be adapted. This slower change in anticipatory capability could be the underlying mechanism which enabled a change in pacing behaviour over a longer period of time, as seen in previous studies (14, 15). Future research, preferably longitudinal, should be performed to gain more insight into the development of pacing behaviour in relation to anticipatory capability.

4.1. Influence of opponents

No difference in performance or pacing behaviour of novice adolescents was found between the different conditions in the current study. In contrast, previous studies found a decreased performance in novice children (9-11 years old) facing opponents (13) and an increase in performance in novice 19-year-olds facing opponents (34). Previous literature states the adaptation of the skill to pace in the presence of opponents is not yet fully developed in young athletes (14), and therefore novice adolescents might not yet be able to use the presence of opponents to increase their performance, as seen in adults who have been found to perform better when opponents are present (21-23). It could be that the attentional needs of young exercisers in the adolescence development phase are more aimed at properly pacing an exercise bout and internally developing their self-paced behaviour and that they, therefore, consider opponents to a lesser extent, and for the very young, it might therefore be detrimental to performance. The current group of novice adolescents (15.8±1.0 years old) were in an age range in between the two previous studies in 9-11 year-olds (13) and 19-year-olds (34). It is, therefore, possible that for young exercisers in this specific age range, an increase in performance through the gathering of experience, as discussed previously, seems more important for performance improvements, while the presence of opponents seems of lesser importance.

Furthermore, previous research pointed to the notion that the instructions regarding the presented opponents as well as the behaviour of the opponents, could determine the impact on participant performance (21, 23). In the current study, the participants had the goal of finishing the 2-km trial as fast as possible, regardless of beating the opponent. It seems plausible that the lack of influence of the opponent could be caused by a lack of engagement with the opponent. It should also be acknowledged that the participants in the current study were active in a variety of both individual and team sports. Previous research has pointed out that sports background influences the goal orientation of an athlete, and therefore, impacts the behaviour of athletes to the presence of opponents during exercise performance (35). It would therefore be interesting for future studies to investigate the effect of different exercise backgrounds, goal orientations and instruction regarding opponents, on performance and pacing behaviour in adolescents.

5. Conclusion

The pacing behaviour of novice adolescents exhibits characterisations which are associated with goal-directed reservation of energy during exercise, attesting to the existence of a pacing template in this population. The experience gained during a single trial seems sufficient to cause an improvement in performance, but not a change in underlying pacing behaviour. The large increase in performance after only one visit is theorized to be caused by an improved capability to accurately anticipate the workload of the exercise as a whole. The capability to anticipate future workload during exercise, and regulate the energy distribution accordingly, might be among the underlying mechanisms of the long-term changes in pacing behaviour that occur throughout adolescence. The lack of influence from the presence of opponents could be appointed to the development phase of the adolescents, in which they are more focused on developing the self-regulated pacing of a bout of exercise and to a lesser extent, on the presence of opponents. As the current study is the first to analyse the performance and pacing behaviour of novice adolescents in a controlled environment, future research should be conducted to further investigate the factors underlying the development of pacing behaviour and performance in this age group. A suggested starting point for this research is to further explore the influence of self-regulatory skills and anticipation of workload on the development of pacing behaviour and performance.

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