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

Running head: Effects of experience and opponents on youths

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Purpose: To study the pacing behaviour and performance of novice youth exercisers in a controlled laboratory setting.

Method: 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 measurement ANOVAs ($p<0.05$) were used to examine differences in both pacing behaviour and also performance related to power output, finishing- and split times, and RPE between the four successive visits and the three conditions. Expected performance outcome was measured using a questionnaire.

Results: Power output increased ($F_{3,27}=5.651$, $p=0.004$, $\eta^2_p=0.386$) and finishing time decreased ($F_{3,27}=9.972$, $p<0.001$, $\eta^2_p=0.526$) between visit 1 and visits 2, 3 and 4. In comparison of the first and second visit, the difference between expected finish time and actual finishing time decreased by 66.2%, regardless of condition. The only significant difference observed in 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: Performance was improved by an increase in experience after one visit, parallel with the ability to anticipate future workload.

Keywords: pacing strategy, adolescence, development, competition.

Introduction

Pacing is widely known as the goal-directed distribution of energy over a predetermined exercise task (Edwards & Polman, 2013) and which is a process of decision-making regarding how and when to spend energy (Smits, Pepping, & Hettinga, 2014). This has been shown to be a decisive component of athletic performance in both time-trial (Foster et al., 2003; van Ingen Schenau, De Koning, & De Groot, 1992) and head-to-head events (Edwards, Guy, & Hettinga, 2016; Konings, Noorbergen, Parry, & Hettinga, 2016; Mauger, Neuloh, & Castle, 2012). The outcome of such decision-making involved in pacing is thus defined as pacing behaviour (Smits et al., 2014). Pacing behaviour can be influenced by many aspects including; the perceived level of fatigue throughout the race (De Koning et al., 2011), the competitive environment (Hettinga, Konings, & Pepping, 2017) and sport specific demands (Stoter et al., 2016). 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 youths is surprisingly scarce (Elferink-Gemser & Hettinga, 2017).

Although empirical data on pacing behaviour of youths 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 (Micklewright et al., 2012). Older children (~10 years old) seem to display a more U-shaped velocity distribution, suggestive ofa goal-driven reservation of energy in order to successfully execute an exercise task (Lambrick, Rowlands, Rowland, & Eston, 2013; Micklewright et al., 2012). Furthermore, emerging research from both time-trial and head-to-head events appears to suggest pacing behaviour of youths (12-21 year old) progressively further develops in complexity towards that of that of adults (Menting, Konings, Elferink-Gemser, & Hettinga, 2019; Wiersma, Stoter, Visscher, Hettinga, & Elferink-Gemser, 2017). The suggested theoretical basis behind this development of pacing behaviour is twofold. First, during adolescence there are cognitive and physical changes associated with growth and maturation (Beunen et al., 1992; Blakemore, Burnett, & Dahl, 2010). 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 (Elferink-Gemser & Hettinga, 2017). Therefore, it is likely that the development of 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 (Hettinga, De Koning, & Foster, 2009; Reid et al., 2017), meta-cognitive functions (Elferink-Gemser & Hettinga, 2017) and deductive reasoning (Van Biesen, Hettinga, McCulloch, & Vanlandewijck, 2017). An underdevelopment of these functions may lead to sub-optimal pacing behaviour (Micklewright et al., 2012; Van Biesen et al., 2017).

Recent literature emphasizes the importance of environmental cues in the decision making process of pacing (Hettinga et al., 2017; Konings & Hettinga, 2018; Smits et al., 2014). The anticipation and response to environmental cues (e.g., opponents) has been suggested to be important both in competition and in the development of pacing behaviour (Menting et al., 2019). The study of Lambrick et al. (2013) showed that when inexperienced children (~10 years old), performing an 800m running task, were introduced to opponents, their performance decreased, with no major change in pacing behaviour. The given explanation for this outcome was the relative inexperience of the children in a competitive environment which clearly 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 to competitive environments (Konings, Parkinson, Zijdewind, & Hettinga, 2018; Konings, Schoenmakers, Walker, & Hettinga, 2016; Williams et al., 2015). 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 (Konings et al., 2016). Therefore it would seem the skills that allows an athlete to anticipate, interpret and implement pacing in the presence of an opponent are developed during adolescence (Menting et al., 2019). However, in adolescents, who have not yet developed the accurate pacing behaviour of adults, it is questionable whether performance would be significantly influenced by an opponent to the same extent to that of adults. It is plausible the primary driver of inexperienced young athletes is to properly pace an exercise bout with intrinsic development of their self-paced behaviour, whereas adults who have already developed this pacing skill are more influenced by the behaviour of those around them.

Adolescence seems to be an crucial period in the development of establishing pacing behaviour. Nonetheless, most research into pacing has been carried out with adults which is surprising. 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 (Dormehl & Osborough, 2015; Menting et al., 2019; Wiersma et al., 2017). Therefore, an empirical, laboratory controlled study would offer the opportunity to investigate several factors that shape pacing behaviour in youths, without the large variation in environmental circumstances that accompanies measuring athletes in competition. The aims of the current study were therefore to investigate what characteristics the pacing behaviour of novice youth exercisers exhibited during exercise, whether or not their performance and behaviour is influenced by experience gained over successive trials, and if the presence of an opponent influences their pacing behaviour and performance.

Methods

Participants

Ten youth participants (seven males, three females) completed the study (age: 15.8 ± 1.0 years, height: 1.79 ± 0.06m, body mass: 62.0 ± 7.5 kg). All participants were healthy and moderate to highly active, as assessed by respectively the PAR-Q (Shephard, Thomas, & Weiler, 1991) and the short version of the IPAQ (Dinger, Behrens, & Han, 2006). 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.

Experimental procedures

All participants completed four, 2-km cycling time trials over four visits. At the start of each visit, each were 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 ability to anticipate the workload of the exercise ("In what time do you think you will complete the time trial of 2km?"). The participants were not given information on their performance on any of the trials until after the completion all visits, as the knowledge of a previous performance could influence performance on 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 (Andersen, Henckel, & Saltin, 1987; Bishop, 2003), 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 (Astorino & Cottrell, 2012; Hettinga, Schoenmakers, & Smit, 2015). 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 opponent were created individually for each participant on the basis of the performance during the familiarization trial (Konings et al., 2016). 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 were 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 unexperienced children and cycling adults (Konings et al., 2016; Lambrick et al., 2013). 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 the gear throughout the time trial. Power output, velocity, distance, and gearing were monitored during the trial (sample frequency = 25Hz). Rate of perceived exertion (RPE) on a Borg-scale of 6-20 was asked after warming-up, before the start of the trial and at 500m, 1000m, 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.

Data analysis

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 Opponent, OP-SLOWFAST and OP-FASTSLOW) were compared.

Performance was analysed through two outcome variables: finish time and mean power output of the trial. The performance variables and the answers to the questionnaire on motivation, expected performance and expected finishing time, were analysed by a one-way repeated measurement 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, were performed if a significant effect ($p<0.05$) was found. In order to study the ability to anticipate the future workload before exercise, a paired t-test was used to analyse the difference between expected and actual finishing time for each individual visit.

Pacing behaviour of the participants was investigated by analysing the time needed to cover each 250m segment of the 2-km trial. Assessing pacing behaviour through analyses of split times during the course of a trial is a commonly used method in literature (Konings et al., 2016; Lambrick et al., 2013). A two-way repeated measurement analyses ($p<0.05$) 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 measurement analysis ($p<0.05$) to study 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 the RPE score over the segments for either the visits or the conditions, and would be instigate a paired t-test post hoc analyses, including Bonferroni correction.

In anticipation of all previously mentioned repeated measurement ANOVA analyses the sphericity was tested using Mauchly's test. If sphericity could not be assumed a Greenhouse-Geisser correction was used.

Results

Development over successive trials

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 = 0.370, η^2_p = 0.108), expected performance ($F_{3,27}$ = 0.558. p = 0.628, η^2_p = 0.061) or expected finish time ($F_{1.07, 9.61}$ = 2.812, p = 0.125, η^2_p = 0.238). However, a significant difference between expected and actual finishing time was found during visit 1 (t = 2.808, p = 0.020, d = 0.888), but not during visit 2, 3 and 4 (t = 1.686, p = 0.126, d = 0.533; t = 1.987, p = 0.078, d = 0.628; t = 1.893, p = 0.094, d = 0.599; respectively). A significant difference in both performance variables, finish time and mean power output, was found ($F_{3,27}$ = 9.972, p < 0.001, η^2_p = 0.526 and $F_{3,27}$ = 5.651, p = 0.004, η^2_p = 0.386, respectively). The post hoc analyses revealed the finishing times of visits 2, 3 and 4 were significantly lower compared to visit 1 (t = 21.354, d = 1.464, p = 0.001; t = 14.063, d = 1.186, p = 0.005, d = ; t = 13.032, p = 0.006, d = 1.144; respectively). Additionally, the mean power output was significantly higher in visits 2, 3 and 4 compared to visit 1 (t = 11.847, p = 0.007, d = 1.094; t = 9.784, p = 0.012, d = 0.987; t = 7.301, p = 0.024, d = 0.856; respectively).

*** Please insert Table 1 near here***

The mean (SD) split times of the 250m segments of the trial for each visit are shown in Figure 1. There was a significant difference between the individual 250m segments ($F_{1.268, 11.414}$ = 21.574, p < 0.001, η^2_p = 0.706), and between the average values of the different visits ($F_{3, 27}$ = 9.972, p < 0.001, η^2_p = 0.526). No significant interaction effect, indicating a difference in pacing behaviour between the different visits, was found ($F_{2.99, 26.91}$ = 1.665, p = 0.198, η^2_p = 0.156).

*** Please insert Figure 1 near here***

The mean (SD) RPE scores can be found in Figure 2. The RPE score was significantly different between the different segments ($F_{1.66, 14.937}$ = 159.032, p < 0.001, η^2_p = 0.946). The average RPE score was not significantly different between different visits ($F_{3, 27}$ = 0.847, p = 0.480, η^2_p = 0.086). A significant interaction effect was found, indicating a difference in RPE score over the segments between the visits ($F_{3.30, 29.74}$ = 3.245, p = 0.032, η^2_p = 0.265). The post hoc analysis revealed that the RPE score at the 500m mark was significantly higher during visit 1 compared to visit 3 (t = 7.568, p = 0.022, d = 0.870) and visit 4 (t = 18.688, p = 0.002, d = 1.367). Moreover, the RPE score at the 500m was higher during visit 2 compared to visit 4 (t = 17.047, p = 0.003, d = 1.303). No significant differences in RPE between the visits were found at the start, 1000m, 1500m and finish.

*** Please insert Figure 2 near here***

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-FASTSLOW: 235.35±25.58s.

Between the conditions, there was no significant difference in the scores on motivation ($F_{1.784,16.057}$ = 0.783, p = 0.460, η^2_p = 0.080), expected performance ($F_{1.857,16.711}$ = 0.545, p= 0.577, η^2_p = 0.057) or expected finish time ($F_{1.567,14.101}$ = 0.802, p = 0.440, η^2_p = 0.082) (Table 1). Additionally, no significant difference in finish time or mean power output were found between the trials with different conditions ($F_{1.883,16.48}$ = 0.612, p = 0.544, η^2_p = 0.064 and $F_{1.720,15.484}$ = 0.174, p = 0.811, η^2_p = 0.019, respectively) (Table 1).

The mean (SD) split times of each 250m segment of the trial under different conditions are shown in Figure 3. A significant difference in split time over the different segments was found ($F_{1.378, 12.398}$ = 23.854, p < 0.001, η^2_p = 0.726). No significant difference between the average split time between conditions ($F_{2, 18}$ = 0.612, p = 0.553, η^2_p = 0.064) or interaction effect, indicating a difference in pacing behaviour ($F_{3.606,32.457}$ = 0.1.676, p = 0.184, η^2_p = 0.157), were found. As no significant interaction effect was found, no post hoc analyses was performed.

*** Please insert Figure 3 near here***

Mean (SD) scores for RPE can be found in Figure 4. The RPE score of the individual segments was significantly different ($F_{4, 36}$ = 144.757, p < 0.001, η^2_p = 0.941). Additionally, the average RPE score of the distinct conditions was significantly different ($F_{1.627, 14.643}$ = 4.918, p = 0.029, η^2_p = 0.031). No significant difference in RPE score over the segments between the different conditions was found ($F_{2.131, 19.182}$ = 0.292, p = 0.767, η^2_p = 0.031), therefore, no post hoc analyses was performed.

*** Please insert Figure 4 near here***

Discussion

This study is the first to examine characteristics of pacing behaviour of novice youth exercisers in response to exercise in a controlled laboratory setting. The findings identify that the velocity distribution of the notice youth decrease in velocity between the 250m and 750m mark, and display an increase in velocity at the 1750m to 2000m segment. This is a more complex pacing behaviour than seen previously in young children (~5-8 years) (Micklewright et al., 2012) and the observed overall U-shaped velocity distribution, is generally associated with the goal-directed preservation of energy to successfully execute an exercise task. This suggests increased sophistication of pacing is evident in youths compared to young children, while 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 acquired experience. The finding that the pacing behaviour of youth exhibits characteristics associated the goal-directed reservation of energy during the execution of a novel exercise task, supports the notion that an inherit pacing template is present from a young age (Foster et al., 2009; Lambrick et al., 2013).

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 youth. A similar conclusion was reached in a research in children (aged 9-11 years) performing a running task with a similar duration to the task in the current study (Lambrick et al., 2013). This study found a 2.6-3.1% decrease of finishing time during the second visit and no significant further decrease during a third visit. Moreover, the study did not find significant difference in pacing behaviour between the three visits. These results strengthen the notion that novice performers 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 (Edwards & McCormick, 2018; Hettinga et al., 2009; Reid et al., 2017). In the current study, the ability 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 visit, the gap between the expected finish time and the actual finishing time decreased by 66.2%, suggesting greater awareness of performance capabilities as experience grew. It should be noted that the condition of visit two differed between participants, as 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, in the first visit, the expected and actual finishing time were significantly different. Contrary to this, there was no significant difference between expected and actual finishing time during the other visits. These findings point to an improved ability to anticipate the workload of the exercise as a whole in addition to greater confidence in the performance capability. The increase in the skill 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 (Tucker & Noakes, 2009). The results of the current study present a decrease in RPE score at the 500m mark between visit one and visit three and four, as well as between visit two and four. A decrease in RPE 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 (Faulkner, Parfitt, & Eston, 2008). Therefore, it could be suggested that the skill to anticipate the future workload during exercise takes more than one visit worth of experience to be adapted. This slower change in anticipatory ability could be the underlying mechanism which enabled a change in pacing behaviour over a longer period of time, as seen in previous studies (Menting et al., 2019; Wiersma et al., 2017). Future research, preferably longitudinal, should be performed to gain more insight into the development of pacing behaviour in relation to anticipatory skill.

Influence of opponents

No difference in performance or pacing behaviour was found between the different conditions in the youth athletes in the current study. In contrast, previous studies found a decreased performance in novice children (9-11 years old) facing opponents (Lambrick et al., 2013) and an increase in performance in novice 19 years olds facing opponents (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012). Previous literature states the adaptation of the skill to pace in the presence of opponents is not yet fully developed in youth athletes (Menting et al., 2019), and therefore novice youth 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 (Konings et al., 2018; Konings et al., 2016; Williams et al., 2015). It could be that the attentional needs of youth 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 youth exercisers (15.8±1.0 years old) were in an age range in between the two previous studies in 9-11 year olds (Lambrick et al, 2013) and 19 year olds (Corbett et al, 2012). It is therefore possible that for youth 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 a lesser importance.

Furthermore, previous research pointed to notion that the instructions regarding the presented opponents as well as the behaviour of the opponents, could determine the impact on participant performance (Konings, Schoenmakers, et al., 2016; Williams et al., 2015). In the current study, the participants had the goal of finishing the 2km 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 sport background influences goal-orientation of an athlete, and therefore, impacts the behaviour of athletes to the presence of opponents during exercise performance (van de Pol & Kavussanu, 2012). 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 youth.

Conclusion

The pacing behaviour of novice youth exercisers exhibits characterisations which are associated with goal-directed reservation of energy during novel 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 ability to accurately anticipate the workload of the exercise as a whole. The ability 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 youth exercisers, in which they are more focusing 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 youth exercisers 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.

What does this article add?

The skill to distribute energy over an exercise task is important in both the optimisation of exercise performance and the safeguarding the well-being of exercisers by evading burn-out, dropout and overtraining. Adolescence is an important phase in the development of the pacing skillset. However, there is only a small sum of literature which evaluates the development of performance and pacing behaviour during adolescence. Even less is known on the underlying mechanisms of the development of pacing behaviour and performance during adolescence. The current study made a first step in uncovering these mechanisms by investigating possible underlying factors of pacing behaviour and performance development of youth exercisers in a controlled laboratory setting. This study confirmed the existence of a pacing template in novel youth and emphasizes importance of the gathering of experience with an exercise task for performance development. Additionally, it is suggested that the ability to anticipate workload before and during exercise influences pacing behaviour development both in the short and long term. The lack of behavioural change after introduction of opponents in this stage in the development process, introduces to the idea that novice youth are primarily engaged with properly pacing their exercise bout and are less concerned with the behaviour of opponents.

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Tables

Table 1. Indicators of motivation and expected performance and performance outcome for each visits and the different conditions. * = significant difference between visits, ^{A} = significant difference from visit 1, † = significant difference between expected and actual finishing time within a visit or within a condition.

Figures

Figure 1. Mean (SD) split times of 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.

Figure 3. Split times of 250m segments for each condition.

Figure 4. RPE score at the start, 500m, 1000m, 1500m and finish, for each condition.