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Effects of Experience and Opponents on Pacing Behavior and 2-km Cycling Performance of Novice Youths

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

3

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

31

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

34 Method: Ten healthy participants (seven male, three female, 15.8 ± 1.0 years) completed four, 2-km trials
35 on a Velotron cycling ergometer. Visit 1 was a familiarization trial. Visits 2 to 4 involved the following
36 conditions, in randomized order: no opponent (NO), a virtual opponent (starting slow and finishing fast)
37 (OP-SLOWFAST), and a virtual opponent (starting fast and finishing slow) (OP-FASTSLOW).

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

42 Results: Power output increased ($F_{3,27}=5.651$, $p=0.004$, $\eta^2_p=0.386$) and finishing time decreased
43 ($F_{3,27}=9.972$, $p < 0.001$, $\eta^2_p=0.526$) between visit 1 and visits 2, 3 and 4. In comparison of the first and
44 second visit, the difference between expected finish time and actual finishing time decreased by 66.2%,
45 regardless of condition. The only significant difference observed in RPE score was reported at the 500m
46 point, where RPE was higher during visit 1 compared to visits 3 and 4, and during visit 2 compared to
47 visit 4 ($p < 0.05$). No differences in pacing behaviour, performance, or RPE were found between
48 conditions ($p > 0.05$).

49 Conclusion: Performance was improved by an increase in experience after one visit, parallel with the
50 ability to anticipate future workload.

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52 Keywords: pacing strategy, adolescence, development, competition.

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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).

68 Although empirical data on pacing behaviour of youths is limited, one study of time-
69 trial performances in young children (~5-8 year olds) has suggested it is characterised by an
70 initial all-out use of energy, which thereafter decreases in velocity over the duration of the bout
71 (Micklewright et al., 2012). Older children (~10 years old) seem to display a more U-shaped
72 velocity distribution, suggestive of a goal-driven reservation of energy in order to successfully
73 execute an exercise task (Lambrick, Rowlands, Rowland, & Eston, 2013; Micklewright et al.,
74 2012). Furthermore, emerging research from both time-trial and head-to-head events appears
75 to suggest pacing behaviour of youths (12-21 year old) progressively further develops in
76 complexity towards that of that of adults (Menting, Konings, Elferink-Gemser, & Hettinga,
77 2019; Wiersma, Stoter, Visscher, Hettinga, & Elferink-Gemser, 2017). The suggested

78 theoretical basis behind this development of pacing behaviour is twofold. First, during
79 adolescence there are cognitive and physical changes associated with growth and maturation
80 (Beunen et al., 1992; Blakemore, Burnett, & Dahl, 2010). Second, the gathering of experience
81 during exercise tasks, for example by means of training or competition, facilitates the
82 improvement of physical and cognitive performance characteristics. Improvement of
83 performance characteristics in turn facilitates the development of adequate pacing behaviour
84 (Elferink-Gemser & Hettinga, 2017). Therefore, it is likely that the development of maturation
85 of cognitive characteristics mediate the influence of acquired experience on pacing behaviour.
86 As such, cognitive functions relevant to pacing include a progressively accurate self-assessment
87 of physical capability aligned with anticipation of future physiological requirements (Hettinga,
88 De Koning, & Foster, 2009; Reid et al., 2017), meta-cognitive functions (Elferink-Gemser &
89 Hettinga, 2017) and deductive reasoning (Van Biesen, Hettinga, McCulloch, & Vanlandewijck,
90 2017). An underdevelopment of these functions may lead to sub-optimal pacing behaviour
91 (Micklewright et al., 2012; Van Biesen et al., 2017).

92 Recent literature emphasizes the importance of environmental cues in the decision
93 making process of pacing (Hettinga et al., 2017; Konings & Hettinga, 2018; Smits et al., 2014).
94 The anticipation and response to environmental cues (e.g., opponents) has been suggested to be
95 important both in competition and in the development of pacing behaviour (Menting et al.,
96 2019). The study of Lambrick et al. (2013) showed that when inexperienced children (~10 years
97 old), performing an 800m running task, were introduced to opponents, their performance
98 decreased, with no major change in pacing behaviour. The given explanation for this outcome
99 was the relative inexperience of the children in a competitive environment which clearly
100 increases with exposure to a variety of competitive situations over the life span.. Interestingly,
101 when adult athletes were presented with a performance-matched opponent, an improvement in
102 performance was demonstrated, which may be due to the greater familiarity of adults to

103 competitive environments (Konings, Parkinson, Zijdwind, & Hettinga, 2018; Konings,
104 Schoenmakers, Walker, & Hettinga, 2016; Williams et al., 2015). Furthermore, it was found
105 that the pacing behaviour of the opponent influenced that of the participant, as a faster starting
106 opponent evoked a faster (matched) start in the participants (Konings et al., 2016). Therefore it
107 would seem the skills that allows an athlete to anticipate, interpret and implement pacing in the
108 presence of an opponent are developed during adolescence (Menting et al., 2019). However, in
109 adolescents, who have not yet developed the accurate pacing behaviour of adults, it is
110 questionable whether performance would be significantly influenced by an opponent to the
111 same extent to that of adults. It is plausible the primary driver of inexperienced young athletes
112 is to properly pace an exercise bout with intrinsic development of their self-paced behaviour,
113 whereas adults who have already developed this pacing skill are more influenced by the
114 behaviour of those around them.

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

127

128

Methods

129 **Participants**

130 Ten youth participants (seven males, three females) completed the study (age: 15.8 ± 1.0 years,
131 height: 1.79 ± 0.06 m, body mass: 62.0 ± 7.5 kg). All participants were healthy and moderate to
132 highly active, as assessed by respectively the PAR-Q (Shephard, Thomas, & Weiler, 1991) and
133 the short version of the IPAQ (Dinger, Behrens, & Han, 2006). All participants were active
134 partakers in a variety of sports (dance, gym, soccer). None of the participants had any previous
135 experience in performing a (cycling) time trial. Written informed consent was obtained from
136 the participants and their parents or legal guardians at the start of the first visit. The study was
137 approved by the ethical committee of the local university in accordance to the Declaration of
138 Helsinki.

139

140 **Experimental procedures**

141 All participants completed four, 2-km cycling time trials over four visits. At the start of each
142 visit, each were asked two questions about their motivation (“How motivated are you to perform
143 well on the time trial?”) and performance (“How do you think you will perform?”) concerning
144 the upcoming trial, which were scored on a 5-point Likert scale (5: very motivated, 1: not
145 motivated at all; 5: very good, 1: not good at all). Additionally, participants were asked to
146 estimate a finishing time for the upcoming trial, as an indication of their ability to anticipate the
147 workload of the exercise (“In what time do you think you will complete the time trial of 2km?”).
148 The participants were not given information on their performance on any of the trials until after
149 the completion all visits, as the knowledge of a previous performance could influence
150 performance on upcoming trials. Thereafter, participants performed a five minute warm up with
151 the instruction to perform an average power output of 150 Watts for males and 115 Watts for

152 females (Andersen, Henckel, & Saltin, 1987; Bishop, 2003), followed by a five minute inactive
153 recovery period before the start of the trial.

154 All time trials were performed on a cycling ergometer (Velotron Dynafit, Racermate,
155 Seattle, USA), which has been shown to be a reliable and valid tool for testing performance and
156 pacing behaviour (Astorino & Cottrell, 2012; Hettinga, Schoenmakers, & Smit, 2015). Using
157 the Velotron 3D software, a 2-km track was created which was straight, flat and featured no
158 wind. During trials, the track was projected on a screen. Participants were portrayed by an on-
159 screen avatar. During visit 1, a familiarization trial (FAM) was performed. In this trial
160 participants performed without the presence of an opponent. During two of the remaining three
161 visits the participants performed a time trial with an opponent operating different race pacing
162 strategies, and one without an opponent (NO), all in a randomized order. The two styles of
163 opponent were created individually for each participant on the basis of the performance during
164 the familiarization trial (Konings et al., 2016). One opponent (OP-SLOWFAST) used a slow
165 pace (100% of FAM) between 150-1000m and a fast pace (104% of FAM) between 1000m-
166 2000m. The other opponent (OP-FASTSLOW) adopted a fast pace (104% of FAM) between
167 150-1000m and a slow pace (100% of FAM) between 1000-2000m. The initial 150m of the
168 race were used to give the virtual opponents a start that was comparable to that of human
169 performers. Both opponents had a total race performance which was two percent faster
170 compared to the FAM to correct for the expected improvement of the participants after the
171 FAM, based on the increase in performances of unexperienced children and cycling adults
172 (Konings et al., 2016; Lambrick et al., 2013). During trials with an opponent, two avatars were
173 visible on the screen, portraying the participant and the opponent, providing the participant with
174 the relative distance to the opponent. At the start of each trial, participants were provided with
175 the goal to complete the trial in the fastest possible time and to give maximal effort; whether or
176 not they beat the opponent was not important. When an opponent was present, participants were

177 told the opponent was of a similar performance level as the participants. Participants received
178 no numerical feedback on heart rate, power, velocity, time passed. the distance covered,
179 distance left or relative distance to the opponent.

180 Participants were free to change the gear throughout the time trial. Power output,
181 velocity, distance, and gearing were monitored during the trial (sample frequency = 25Hz). Rate
182 of perceived exertion (RPE) on a Borg-scale of 6-20 was asked after warming-up, before the
183 start of the trial and at 500m, 1000m, 1500m, as well as directly after passing the finish line.
184 The participants were told the RPE collection points were random throughout the trial.

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

191

192 **Data analysis**

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

197 Performance was analysed through two outcome variables: finish time and mean power
198 output of the trial. The performance variables and the answers to the questionnaire on
199 motivation, expected performance and expected finishing time, were analysed by a one-way
200 repeated measurement ANOVA to reveal a difference between the visits or conditions ($p < 0.05$).
201 A post hoc analysis in the form of paired t-test, including Bonferroni correction, were performed

202 if a significant effect ($p < 0.05$) was found. In order to study the ability to anticipate the future
203 workload before exercise, a paired t-test was used to analyse the difference between expected
204 and actual finishing time for each individual visit.

205 Pacing behaviour of the participants was investigated by analysing the time needed to
206 cover each 250m segment of the 2-km trial. Assessing pacing behaviour through analyses of
207 split times during the course of a trial is a commonly used method in literature (Konings et al.,
208 2016; Lambrick et al., 2013). A two-way repeated measurement analyses ($p < 0.05$) was used to
209 investigate a difference in pacing behaviour between the different visits (segments * visits) and
210 between the different conditions (segments * conditions). If a significant interaction effect
211 ($p < 0.05$) was found, indicating a difference in pacing behaviour, a post hoc analysis in the form
212 of paired t-test, including Bonferroni correction, would be performed.

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

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

222

223

Results

224 Development over successive trials

225 Mean (SD) of the questionnaires on motivation, expected performance and expected finishing
226 time as well as the actual finish time and mean power output of each visit can be found in Table

227 1. During the course of the visits, there was no significant difference in the answers to the
228 questions concerning motivation ($F_{3,27} = 1.09$, $p = 0.370$, $\eta^2_p = 0.108$), expected performance
229 ($F_{3,27} = 0.558$, $p = 0.628$, $\eta^2_p = 0.061$) or expected finish time ($F_{1.07, 9.61} = 2.812$, $p = 0.125$, η^2_p
230 $= 0.238$). However, a significant difference between expected and actual finishing time was
231 found during visit 1 ($t = 2.808$, $p = 0.020$, $d = 0.888$), but not during visit 2, 3 and 4 ($t = 1.686$,
232 $p = 0.126$, $d = 0.533$; $t = 1.987$, $p = 0.078$, $d = 0.628$; $t = 1.893$, $p = 0.094$, $d = 0.599$;
233 respectively). A significant difference in both performance variables, finish time and mean
234 power output, was found ($F_{3,27} = 9.972$, $p < 0.001$, $\eta^2_p = 0.526$ and $F_{3,27} = 5.651$, $p = 0.004$, η^2_p
235 $= 0.386$, respectively). The post hoc analyses revealed the finishing times of visits 2, 3 and 4
236 were significantly lower compared to visit 1 ($t = 21.354$, $d = 1.464$, $p = 0.001$; $t = 14.063$, $d =$
237 1.186 , $p = 0.005$; $t = 13.032$, $d = 1.144$, $p = 0.006$; respectively). Additionally, the mean power
238 output was significantly higher in visits 2, 3 and 4 compared to visit 1 ($t = 11.847$, $p = 0.007$, d
239 $= 1.094$; $t = 9.784$, $p = 0.012$, $d = 0.987$; $t = 7.301$, $p = 0.024$, $d = 0.856$; respectively).

240

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

242

243 The mean (SD) split times of the 250m segments of the trial for each visit are shown in
244 Figure 1. There was a significant difference between the individual 250m segments ($F_{1.268, 11.414}$
245 $= 21.574$, $p < 0.001$, $\eta^2_p = 0.706$), and between the average values of the different visits ($F_{3, 27}$
246 $= 9.972$, $p < 0.001$, $\eta^2_p = 0.526$). No significant interaction effect, indicating a difference in
247 pacing behaviour between the different visits, was found ($F_{2.99, 26.91} = 1.665$, $p = 0.198$, $\eta^2_p =$
248 0.156).

249

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

251

252 The mean (SD) RPE scores can be found in Figure 2. The RPE score was significantly
253 different between the different segments ($F_{1.66, 14.937} = 159.032$, $p < 0.001$, $\eta^2_p = 0.946$). The
254 average RPE score was not significantly different between different visits ($F_{3, 27} = 0.847$, $p =$
255 0.480 , $\eta^2_p = 0.086$). A significant interaction effect was found, indicating a difference in RPE
256 score over the segments between the visits ($F_{3.30, 29.74} = 3.245$, $p = 0.032$, $\eta^2_p = 0.265$). The post
257 hoc analysis revealed that the RPE score at the 500m mark was significantly higher during visit
258 1 compared to visit 3 ($t = 7.568$, $p = 0.022$, $d = 0.870$) and visit 4 ($t = 18.688$, $p = 0.002$, $d =$
259 1.367). Moreover, the RPE score at the 500m was higher during visit 2 compared to visit 4 ($t =$
260 17.047 , $p = 0.003$, $d = 1.303$). No significant differences in RPE between the visits were found
261 at the start, 1000m, 1500m and finish.

262

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

264

265 **Influence of opponents**

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

270 Between the conditions, there was no significant difference in the scores on motivation
271 ($F_{1.784, 16.057} = 0.783$, $p = 0.460$, $\eta^2_p = 0.080$), expected performance ($F_{1.857, 16.711} = 0.545$, $p =$
272 0.577 , $\eta^2_p = 0.057$) or expected finish time ($F_{1.567, 14.101} = 0.802$, $p = 0.440$, $\eta^2_p = 0.082$) (Table
273 1). Additionally, no significant difference in finish time or mean power output were found
274 between the trials with different conditions ($F_{1.883, 16.48} = 0.612$, $p = 0.544$, $\eta^2_p = 0.064$ and
275 $F_{1.720, 15.484} = 0.174$, $p = 0.811$, $\eta^2_p = 0.019$, respectively) (Table 1).

276 The mean (SD) split times of each 250m segment of the trial under different conditions
277 are shown in Figure 3. A significant difference in split time over the different segments was
278 found ($F_{1.378, 12.398} = 23.854$, $p < 0.001$, $\eta^2_p = 0.726$). No significant difference between the
279 average split time between conditions ($F_{2, 18} = 0.612$, $p = 0.553$, $\eta^2_p = 0.064$) or interaction
280 effect, indicating a difference in pacing behaviour ($F_{3.606, 32.457} = 0.1676$, $p = 0.184$, $\eta^2_p = 0.157$),
281 were found. As no significant interaction effect was found, no post hoc analyses was performed.

282

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

284

285 Mean (SD) scores for RPE can be found in Figure 4. The RPE score of the individual
286 segments was significantly different ($F_{4, 36} = 144.757$, $p < 0.001$, $\eta^2_p = 0.941$). Additionally, the
287 average RPE score of the distinct conditions was significantly different ($F_{1.627, 14.643} = 4.918$, p
288 $= 0.029$, $\eta^2_p = 0.031$). No significant difference in RPE score over the segments between the
289 different conditions was found ($F_{2.131, 19.182} = 0.292$, $p = 0.767$, $\eta^2_p = 0.031$), therefore, no post
290 hoc analyses was performed.

291

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

293

294

Discussion

295 This study is the first to examine characteristics of pacing behaviour of novice youth exercisers
296 in response to exercise in a controlled laboratory setting. The findings identify that the velocity
297 distribution of the notice youth decrease in velocity between the 250m and 750m mark, and
298 display an increase in velocity at the 1750m to 2000m segment. This is a more complex pacing
299 behaviour than seen previously in young children (~5-8 years) (Micklewright et al., 2012) and
300 the observed overall U-shaped velocity distribution, is generally associated with the goal-

301 directed preservation of energy to successfully execute an exercise task. This suggests increased
302 sophistication of pacing is evident in youths compared to young children, while it is also
303 interesting that during the first visit, a significant difference was found between the amount of
304 time participants thought was needed to finish the trial and the actual completion time of the
305 trial. The variety in expected finishing time among the cohort during the first visit was also
306 substantially larger (SD of visit 1: 249.18s) compared to other visits (average SD visits 2-4:
307 134.74s) . Both findings attest to the novelty of the activity for the participants before the first
308 visit and the potential impact of acquired experience. The finding that the pacing behaviour of
309 youth exhibits characteristics associated the goal-directed reservation of energy during the
310 execution of a novel exercise task, supports the notion that an inherit pacing template is present
311 from a young age (Foster et al., 2009; Lambrick et al., 2013).

312
313 The secondary aim of this research was to investigate the influence of the experience gained
314 over successive trials on pacing behaviour and performance. However, no change in pacing
315 behaviour was found throughout the visits. Nevertheless, the 8.1% increase in power output and
316 5.1% decrease in finishing time during the second visit indicate an improvement in performance
317 after gaining experience during the first visit. The observation that there was no significant
318 increase in performance during visits two, three and four suggests that a single familiarization
319 trial was sufficient to heighten the performance in novice youth. A similar conclusion was
320 reached in a research in children (aged 9-11 years) performing a running task with a similar
321 duration to the task in the current study (Lambrick et al., 2013). This study found a 2.6-3.1%
322 decrease of finishing time during the second visit and no significant further decrease during a
323 third visit. Moreover, the study did not find significant difference in pacing behaviour between
324 the three visits. These results strengthen the notion that novice performers can increase
325 performance after gaining experience in only a single trial.

326 It has previously been proposed that the anticipation of workload, and the adjustment of
327 workload anticipation during exercise, form part of the underlying mechanism of the regulation
328 of energy (Edwards & McCormick, 2018; Hettinga et al., 2009; Reid et al., 2017). In the current
329 study, the ability to anticipate the workload of the exercise was measured by analysing the
330 difference between the expected finish time and the actual finishing time of each visit. By
331 comparing the first and second visit, the gap between the expected finish time and the actual
332 finishing time decreased by 66.2%, suggesting greater awareness of performance capabilities
333 as experience grew. It should be noted that the condition of visit two differed between
334 participants, as result of the randomisation of conditions between visits two, three and four.
335 However, there was no significant difference in expected or actual finishing time between the
336 conditions, indicating that the increase in awareness of performance capabilities was not
337 influenced by the condition of the second visit. Moreover, in the first visit, the expected and
338 actual finishing time were significantly different. Contrary to this, there was no significant
339 difference between expected and actual finishing time during the other visits. These findings
340 point to an improved ability to anticipate the workload of the exercise as a whole in addition to
341 greater confidence in the performance capability. The increase in the skill to anticipate the total
342 workload might be the underlying mechanism of the increase in performance after the first visit.

343 In literature, RPE has been proposed as a mediating factor in the regulation of energy
344 distribution by the cognitive anticipatory skill (Tucker & Noakes, 2009). The results of the
345 current study present a decrease in RPE score at the 500m mark between visit one and visit
346 three and four, as well as between visit two and four. A decrease in RPE during the initial phase
347 of the race may well indicate that the participants were actively changing their anticipation of
348 the future workload during the exercise (Faulkner, Parfitt, & Eston, 2008). Therefore, it could
349 be suggested that the skill to anticipate the future workload during exercise takes more than one
350 visit worth of experience to be adapted. This slower change in anticipatory ability could be the

351 underlying mechanism which enabled a change in pacing behaviour over a longer period of
352 time, as seen in previous studies (Menting et al., 2019; Wiersma et al., 2017). Future research,
353 preferably longitudinal, should be performed to gain more insight into the development of
354 pacing behaviour in relation to anticipatory skill.

355

356 **Influence of opponents**

357 No difference in performance or pacing behaviour was found between the different conditions
358 in the youth athletes in the current study. In contrast, previous studies found a decreased
359 performance in novice children (9-11 years old) facing opponents (Lambrick et al., 2013) and
360 an increase in performance in novice 19 years olds facing opponents (Corbett, Barwood,
361 Ouzounoglou, Thelwell, & Dicks, 2012). Previous literature states the adaptation of the skill to
362 pace in the presence of opponents is not yet fully developed in youth athletes (Menting et al.,
363 2019), and therefore novice youth might not yet be able to use the presence of opponents to
364 increase their performance, as seen in adults who have been found to perform better when
365 opponents are present (Konings et al., 2018; Konings et al., 2016; Williams et al., 2015). It
366 could be that the attentional needs of youth exercisers in the adolescence development phase
367 are more aimed at properly pacing an exercise bout and internally developing their self-paced
368 behaviour and that they therefore consider opponents to a lesser extent, and for the very young
369 it might therefore be detrimental to performance. The current group of novice youth exercisers
370 (15.8±1.0 years old) were in an age range in between the two previous studies in 9-11 year olds
371 (Lambrick et al, 2013) and 19 year olds (Corbett et al, 2012). It is therefore possible that for
372 youth exercisers in this specific age range, an increase in performance through the gathering of
373 experience as discussed previously seems more important for performance improvements,
374 while the presence of opponents seems of a lesser importance.

375 Furthermore, previous research pointed to notion that the instructions regarding the
376 presented opponents as well as the behaviour of the opponents, could determine the impact on
377 participant performance (Konings, Schoenmakers, et al., 2016; Williams et al., 2015). In the
378 current study, the participants had the goal of finishing the 2km trial as fast as possible,
379 regardless of beating the opponent. It seems plausible that the lack of influence of the opponent
380 could be caused by a lack of engagement with the opponent. It should also be acknowledged
381 that the participants in the current study were active in a variety of both individual and team
382 sports. Previous research has pointed out that sport background influences goal-orientation of
383 an athlete, and therefore, impacts the behaviour of athletes to the presence of opponents during
384 exercise performance (van de Pol & Kavussanu, 2012). It would therefore be interesting for
385 future studies to investigate the effect of different exercise backgrounds, goal-orientations and
386 instruction regarding opponents, on performance and pacing behaviour in youth.

387

388

Conclusion

389 The pacing behaviour of novice youth exercisers exhibits characterisations which are associated
390 with goal-directed reservation of energy during novel exercise, attesting to the existence of a
391 pacing template in this population. The experience gained during a single trial seems sufficient
392 to cause an improvement in performance, but not a change in underlying pacing behaviour. The
393 large increase in performance after only one visit is theorized to be caused by an improved
394 ability to accurately anticipate the workload of the exercise as a whole. The ability to anticipate
395 future workload during exercise, and regulate the energy distribution accordingly, might be
396 among the underlying mechanisms of the long term changes in pacing behaviour that occur
397 throughout adolescence. The lack of influence from the presence of opponents could be
398 appointed to the development phase of the youth exercisers, in which they are more focusing
399 on developing the self-regulated pacing of a bout of exercise and to a lesser extent on the

400 presence of opponents. As the current study is the first to analyse the performance and pacing
401 behaviour of novice youth exercisers in a controlled environment, future research should be
402 conducted to further investigate the factors underlying the development of pacing behaviour
403 and performance in this age group. A suggested starting point for this research is to further
404 explore the influence of self-regulatory skills and anticipation of workload on the development
405 of pacing behaviour and performance.

406

407

What does this article add?

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

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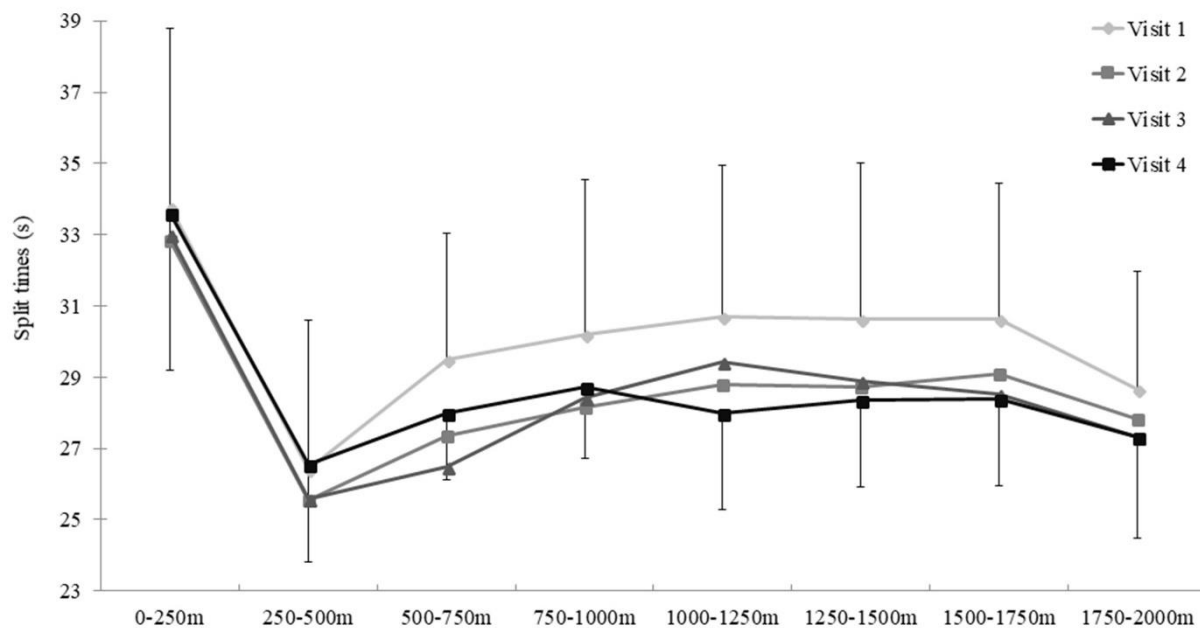
519

520 Table 1.

521 Means (\pm SD) of the indicators of motivation, expected performance and performance outcome variables for each
 522 visits 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* (Watt)
Visit 1	4 \pm 1	3 \pm 1	453.00 \pm 249.18	240.50 \pm 27.37	212.50 \pm 239.33 [†]	181.03 \pm 46.36
Visit 2	4 \pm 1	3 \pm 1	300.00 \pm 141.42	228.33 \pm 21.12 ^A	71.67 \pm 134.40	195.70 \pm 41.08 ^A
Visit 3	4 \pm 1	4 \pm 1	312.00 \pm 142.97	227.69 \pm 20.97 ^A	84.31 \pm 134.21	199.54 \pm 43.87 ^A
Visit 4	4 \pm 1	3 \pm 1	297.00 \pm 120.37	228.97 \pm 18.40 ^A	68.03 \pm 113.61	193.50 \pm 39.84 ^A
No Opponent	4 \pm 1	4 \pm 1	303.00 \pm 135.98	227.16 \pm 17.17	75.85 \pm 129.00	196.73 \pm 39.15
OP-SLOWFAST	4 \pm 1	3 \pm 1	294.00 \pm 121.49	228.19 \pm 20.39	65.81 \pm 114.49	197.33 \pm 42.35
OP-FASTSLOW	4 \pm 1	4 \pm 1	312.00 \pm 147.11	229.64 \pm 22.61	82.36 \pm 138.72	194.68 \pm 43.48

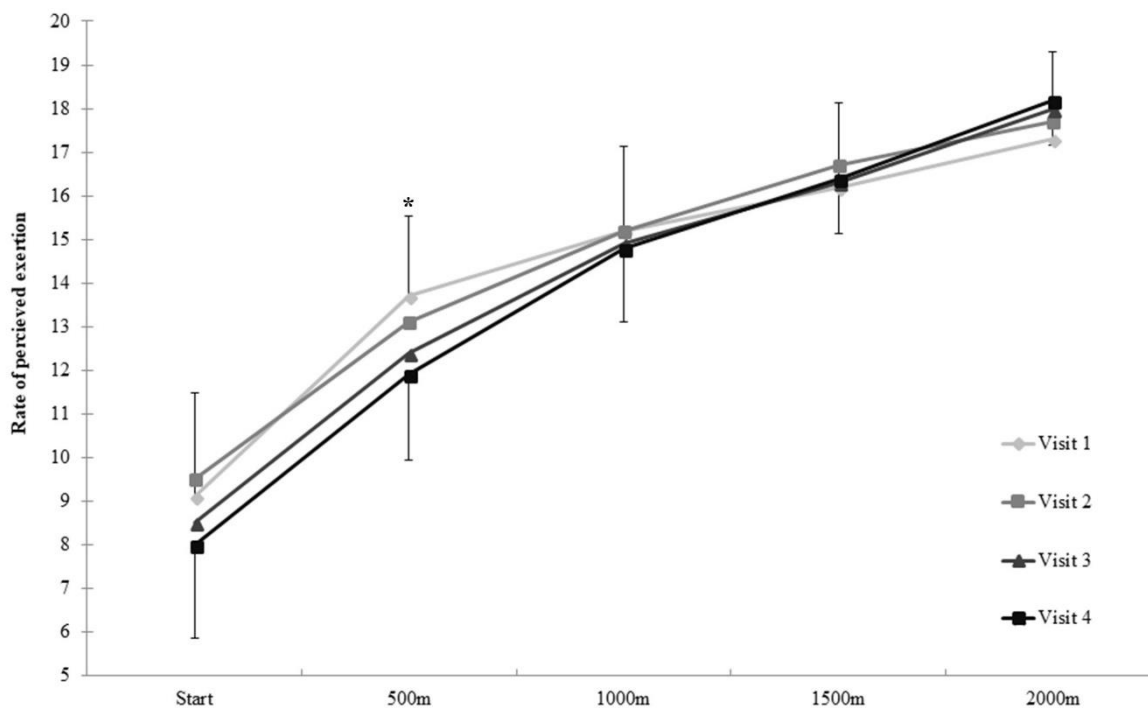
523 Note. * = significant difference between visits, ^A = significantly different from visit 1, [†] = significant difference
 524 between expected and actual finishing time within a visit or within a condition.



525

526 Figure 1. Mean (SD) split times of 250m segments for each visit.

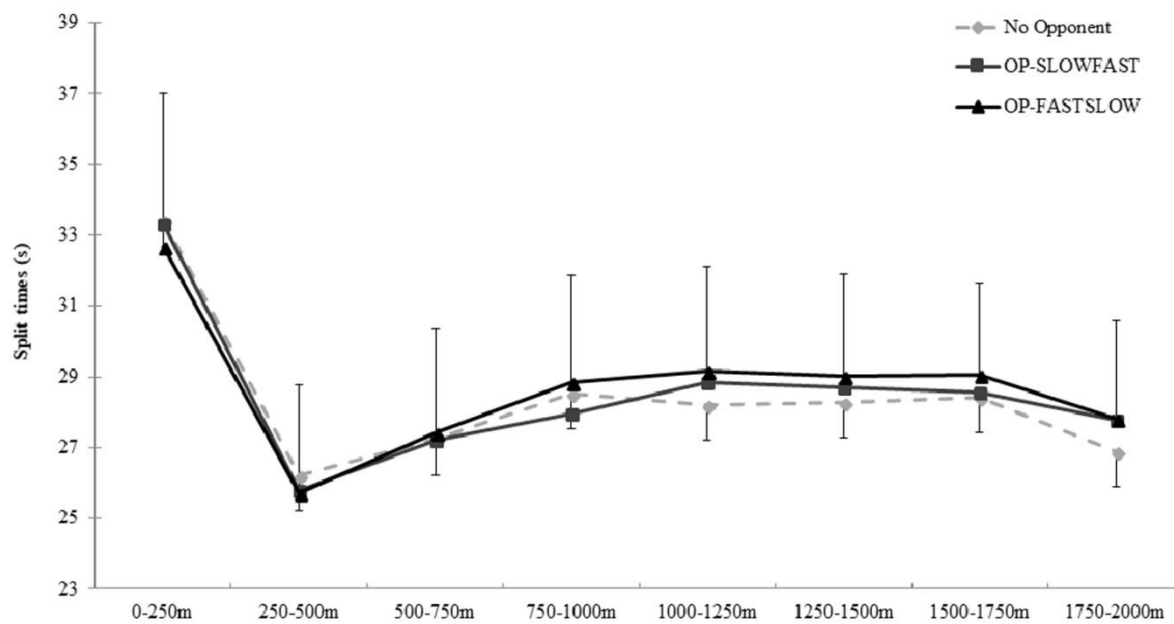
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529 Figure 2. RPE score at the start, 500m, 1000m, 1500m and finish, for each visit. * a significant

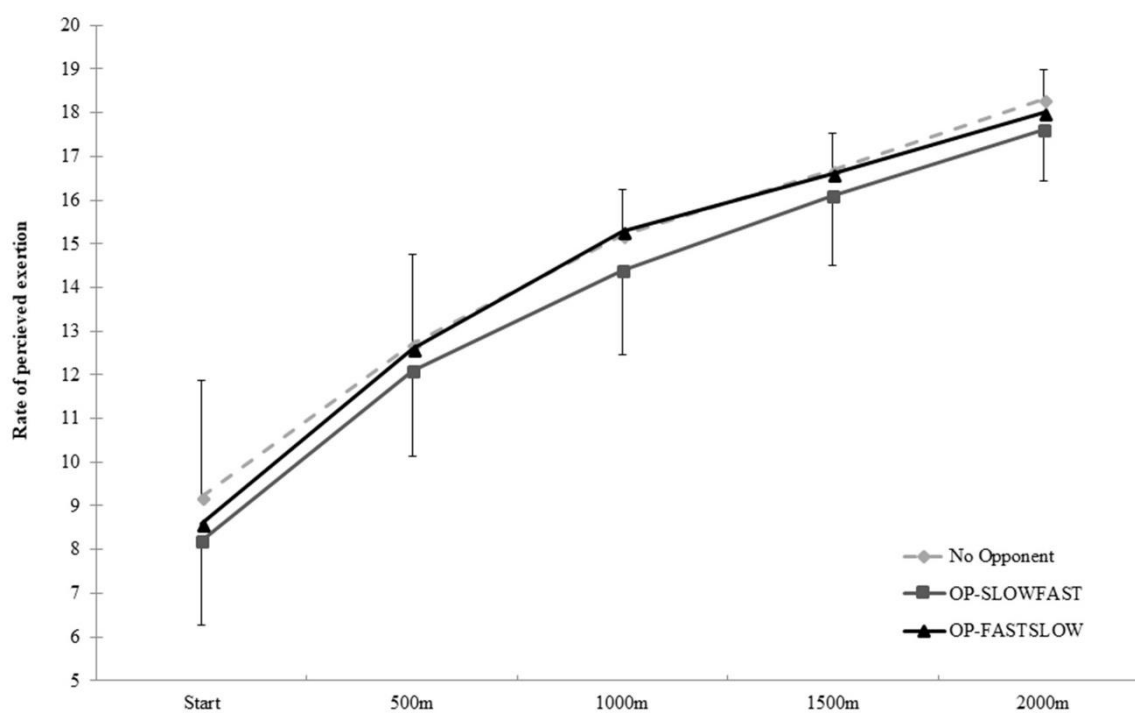
530 difference in RPE ($p < 0.05$) between: visit 1 and visit 3 & 4, visit 2 and visit 4.



531

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

533



534

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