

# Pacing Profiles in Competitive Track Races: Regulation of Exercise Intensity is related to Cognitive Ability

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# Pacing Profiles in Competitive Track Races: Regulation of Exercise Intensity is related to Cognitive Ability.

Running title: pacing profiles and cognitive ability

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## Abstract

Pacing has been defined as the goal-directed regulation of exercise intensity over an exercise bout, in which athletes need to decide how and when to invest their energy. The purpose of this study was to explore if the regulation of exercise intensity during competitive track races is different between runners with and without intellectual impairment, which is characterized by significant limitations in intellectual functioning ( $IQ \leq 75$ ) and adaptive behavioral deficits, diagnosed before the age of 18. The samples included elite runners with intellectual impairment ( $N = 36$ ) and a comparison group of world class runners without impairment ( $N = 39$ ), of which 47 were 400m runners (all male) and 28 were 1500m-runners (15 male and 13 female). Pacing was analysed by means of 100m split times (for 400m races) and 200m split times (for 1500m races). Based on the split times, the average velocity was calculated for four segments of the races. Velocity fluctuations were defined as the differences in velocity between consecutive race segments. A mixed model ANOVA revealed significant differences in pacing profiles between runners with and without intellectual impairment ( $p < .05$ ). Maximal velocity of elite 400m runners with intellectual impairment in the first race segment ( $7.9 \pm 0.3$  m/s) was well below the top-velocity reached by world level 400m runners without intellectual impairment ( $8.9 \pm 0.2$  m/s), and their overall pace was slower ( $F = 120.7$ ,  $p < .05$ ). In addition, both groups followed a different pacing profile and inter-individual differences in pacing profiles were larger, with differences most pronounced for 1500m races. Whereas male 1500m-runners without intellectual impairment reached a high velocity in the first 100m ( $7.2 \pm 0.1$  m/s), slowly decelerated in the second race segment ( $-0.6 \pm 0.1$  m/s), and finished with an end sprint ( $+0.9 \pm 0.1$  m/s); the 1500m runners with intellectual impairment started slower ( $6.1 \pm 0.3$  m/s), accelerated in the second segment ( $+0.2 \pm 0.7$  m/s), and then slowly

43 decreased until the finish ( $F=6.8, p<.05$ ). Our findings support the hypothesis that runners  
44 with intellectual impairment have difficulties to efficiently self-regulate their exercise  
45 intensity. Their limited cognitive resources may constrain the successful integration of  
46 appropriate pacing strategies during competitive races.

47

48 **Key words:** running, 400 meter, 1500 meter, track and field, intelligence

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50

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## 51 **1. Introduction**

52 A vital component for success in running events is the pacing strategy (Abbiss &  
53 Laursen, 2008; Tucker, 2009). The optimal pacing strategy can be a learned pattern, based on  
54 extensive experience gained during training and previous competitions (Foster et al., 2009;  
55 Foster, De Koning, & Thiel, 2014); however, many factors can affect the pacing strategies  
56 adopted during running events. An individuals' pacing strategy is dependent on performance  
57 goals (e.g., world record attempt versus qualification during heats) (Thompson, 2015),  
58 environmental conditions (e.g., temperature) (Tucker, 2009; Roelands, de Koning, Foster,  
59 Hettinga, & Meeusen, 2013) and the presence of opponents (Konings, Noorbergen, Parry, &  
60 Hettinga, 2016; Konings, Schoenmakers, Walker, & Hettinga, 2016). In competition, athletes  
61 must set and adjust their pace based on feelings such as perceived exertion (Abbiss &  
62 Laursen, 2008) or pain (Mauger, 2014). Hence, the actual pacing profile observed during  
63 competition does not always resemble the pre-planned strategy adopted by the athlete and/or  
64 the coach. Competitors need to take into account the distance remaining until finish and also  
65 the actions of their opponents (de Koning et al., 2011; St Clair Gibson et al., 2006; Swart,  
66 Lindsay, Lambert, Brown & Noakes, 2012). When considering an athletic event involving  
67 direct competition between two or more individual athletes, the environment becomes even  
68 more complex (Renfree, Martin, Micklewright & St Clair Gibson, 2014; Konings et al.,  
69 2016a; Konings et al., 2016b).

70

71 Several recent reviews have described pacing as a process of decision-making (Smits,  
72 Pepping & Hettinga, 2014; Renfree et al., 2014). It was recently proposed that effective  
73 cognitive control during performance requires both proactive, goal-driven processes and  
74 reactive, stimulus-driven processes (Brick, MacIntyre and Campbell (2016)). Although the  
75 importance of decision-making upon effort regulation was acknowledged (de Koning et al.,  
76 2011; Renfree & St Clair Gibson, 2013), very little is understood about decision-making  
77 processes involved in pacing or the underlying psychological mechanisms. To understand  
78 how exercisers regulate their exercise capacity, and to identify the role cognition plays in  
79 optimal self-regulation, the study of pacing in athletes with intellectual impairments could be  
80 an interesting design. Although pacing is commonly accepted as an important cognitive  
81 determinant in running (Abbiss & Laursen, 2008; De Koning et al., 2011; Hanon, Leveque,  
82 Thomas, & Vivier, 2008; Hanon & Thomas, 2011; Reardon, 2013; Saraslanidis,  
83 Panoutsakopoulos, Tsalis, & Kyprianou, 2011; St Clair Gibson et al., 2006; Thiel, Foster,  
84 Banzer, & De Koning, 2012; Tucker, 2009; Tucker, Lambert, & Noakes, 2006, Smits et al.  
85 2014, Renfree et al. 2014) only one study has investigated pacing in individuals with  
86 intellectual impairment. Micklewright et al. (2012) demonstrated an explicit link between  
87 pacing and cognitive development by looking into pacing behavior of school children in  
88 different stages of cognitive development. The study confirmed that developing a pacing  
89 strategy is at least in part determined by cognitive mechanisms. In their study, after doing a  
90 control test for age (5 – 14 years), pacing differences were distinguished between groups of  
91 school children in different stages of cognitive development. In another study it was  
92 demonstrated in a large sample of elite swimmers, athletes, basketball- and table tennis  
93 players with intellectual impairment that their cognitive abilities relevant to sport in general  
94 (e.g., visual processing, reaction and decision making speed, short-term memory and fluid

95 reasoning) were significantly reduced compared to equally well-trained athletes without  
96 impairment (Van Biesen et al., 2016), so it can be assumed that specific cognitive abilities  
97 relevant to pacing and performance in running (i.e., decision making, anticipation) will also  
98 be influenced by having an intellectual impairment. A first study exploring this analyzed the  
99 ability of runners with an intellectual impairment to maintain a pre-planned velocity over  
100 400m, an essential aspect of pacing (Van Biesen, Hettinga, McCulloch, & Vanlandewijck,  
101 2017). It was demonstrated that runners with an intellectual impairment were not able to  
102 maintain the required sub-maximal velocity and accelerated towards the end, in contrast to  
103 athletes without impairment of similar training volume. This provided the first evidence for  
104 the impact of cognitive ability on pacing ability. The present study will now focus on  
105 exploring data of athletes in actual competitions to explore how cognitive ability impacts on  
106 pacing and performance in competition.

107  
108 The purpose of the present study was to explore if the regulation of exercise intensity  
109 during competitive 400m and 1500m track races is different when pacing profiles are  
110 compared between high level runners with and without intellectual impairment. It is  
111 hypothesized that runners with intellectual impairment will have a different, more variable  
112 pacing strategy compared to runners without intellectual impairment. If we detect an effect of  
113 having an intellectual impairment on pacing profiles during the race, this will provide  
114 evidence to support the assumption that the regulation of runners' exercise intensity over the  
115 race is, at least partly, dependent on their cognitive skill level. In addition, a difference in  
116 pacing profiles between the groups will create an evidence-based rationale for organizing  
117 separate competitions for runners with intellectual impairment in the Paralympic Games.

## 118 119 **2. Materials and Methods**

### 120 **2.1 Participants**

121 Data for this study were derived from a sample of 47 400m, and 28 1500m runners, of  
122 which 36 elite runners with mild intellectual impairment (28 males and 8 females) and a  
123 comparison group of 39 runners without impairment (34 males and 5 females). The runners  
124 with intellectual impairment competed at the 2014 Open European Championship Athletics,  
125 in Bergen Op Zoom, The Netherlands, organized by the International Federation for Para-  
126 Athletes with Intellectual Impairment (INAS). They competed in 400m or 1500m races and  
127 all met the criteria for diagnosis of intellectual disability as set by the American Association  
128 on Intellectual and Developmental Disabilities:  $IQ \leq 75$ , significant deficits in adapted behavior  
129 and manifested before the age of 18. More specifically, the IQ scores of the runners with  
130 intellectual impairment were  $64.7 \pm 8.7$  (male 400m),  $59.6 \pm 8.7$  (male 1500m) and  $60.4 \pm 7.9$   
131 (female 1500m). None of the participants had severe intellectual impairment or a genetic  
132 syndrome (e.g., Down Syndrome). The runners with intellectual impairment (aged  $24.4 \pm 4.5$   
133 years) had on average  $9.6 \pm 4.8$  years of experience and  $9.4 \pm 4.0$  hours/week training volume.  
134 The control data was obtained from the International Association of Athletics Federation's  
135 (IAAF) 12th World Championships in Berlin in 2009 (Helmar et al., 2009a, 2009b). For the  
136 1500-meter world record performances of men and women, split times were obtained from  
137 <http://www.iaaf.org/> and <http://wn.com/> respectively. Descriptive information of the

138 participants in the control group (age, training volume, IQ scores) was not available. The  
139 study was approved by the local ethics committee (Commissie Medische Ethiek, KU Leuven).

140

## 141 **2.2 Procedure**

142 Pacing profiles were analysed by means of 100m split times (for 400m races) and  
143 200m split times (for 1500m races). The most recent World Record data were retrieved from  
144 the IAAF book of world records (International Amateur Athletic Federation, 2007; Reardon,  
145 2013). Split times were publically available on the IAAF website for the control group, and  
146 split times were calculated for the runners with intellectual impairment on the basis of video  
147 images recorded during the race. Their races were filmed with three 25 Hz SONY Cameras  
148 for the 400-m race, and one camera for the 1500-m race. The positions of the cameras are  
149 depicted in Figure 1. During the 1500-m race a large cone was placed in view of the camera  
150 as a reference point for the calculation of the 100-m, 500-m, 900-m, and 1300-m split time.  
151 Before the start of every 400-m race, the camera captured the first athlete in starting position  
152 (lane 1 or the most inner athlete). From the moment the athletes took off, the camera was  
153 switched to the designated split time mark to capture every athlete passing by.

154

155 - **Insert Figure 1 about here** -

156

## 157 **2.3 Data reduction and calculation**

158 Based on the split times and distance, the average velocity was calculated for four  
159 segments of the race: 0-100m, 100m-200m, 200m-300m and 300-400m for the 400m races  
160 and 0-100m, 100m-500m, 500m-1000m, and 1000m-1500m for the 1500m races. Velocity  
161 fluctuated within the segments indicating accelerations (i.e., positive fluctuations) or  
162 decelerations (i.e., negative fluctuations).

163

## 164 **2.4 Data analyses**

165 Statistics were performed using SPSS (version 19.0, SPSS Inc., Chicago Ill, USA)  
166 with level of significance set at  $p < .05$ . For the 400m race, a mixed model ANOVA was  
167 performed to analyze the differences in running patterns over different time points during the  
168 race (within factor), between male runners with and without intellectual impairment (between  
169 factor), for heats and finals. The mixed model ANOVA was also performed to analyze the  
170 differences in running patterns over different time points (within) between runners with and  
171 without intellectual impairment (between) in the 1500m finals. Intra-individual coefficients  
172 of variation of running speed within each race were calculated based on 100-m split times (for  
173 the 400m races) and 200-m split times (for the 1500-m races).

174

## 175 **3. Results**

### 176 **3.1 400m group differences in race strategy**

177 Figure 2 shows the overall pacing strategy during the men's 400-meter races. Average  
178 velocity plots per segment are shown for the heats and finals. No significant differences in  
179 velocity were found between finals and heats for runners without intellectual impairment,  
180 whereas average velocity at all time-points was higher in the final race than during heats for  
181 runners with intellectual impairment. Both groups initially performed an acceleration

182 followed by a deceleration, however, the pacing strategy significantly differed between both  
183 groups of runners in heats and finals as shown by the significant interaction effect (Table 1).  
184 The runners without intellectual impairment gradually decelerated halfway after a fast start.  
185 The deceleration, traveling between 9.5m/s to 8m/s, concluded with a steeper decline in the  
186 latter part. For the runners with intellectual impairment, the decline occurred with a steep  
187 descent from 8m/s until 7m/s. The result of the post hoc analyses as shown in Table 2  
188 indicated that fluctuations in the final race segment were significantly different between both  
189 groups of runners in the heats ( $F=7.1, p<.05$ ); however, not for the finals ( $F=7.1, p=.1$ ).

190

191 Overall, runners with intellectual impairment demonstrated a slower running speed  
192 than runners without intellectual impairment. The ANOVA showed a significant main effect  
193 of the within factor velocity in the 400m heats and 400m final races (Table 1). In the first race  
194 segment (0-100m) of the final, runners with intellectual impairment accelerated to a velocity  
195 of 7.9m/s, whereas runners without intellectual impairment accelerated to 8.9m/s ( $F=120.7,$   
196  $p<.05$ , Table 2). Another difference between both groups was observed in the second race  
197 segment (100m-200m). In both the final and the heats, runners with intellectual impairment  
198 accelerated ( $0.1 \pm 0.2$  m/s); however, this acceleration was less pronounced than demonstrated  
199 by the runners without intellectual impairment ( $0.6 \pm 0.1$  m/s); The latter group reached their  
200 maximal speed after 200m ( $F=21.4, p<.05$ ).

201

202 - **Insert Figure 2, Table 1 and Table 2 about here -**

203

### 204 **3.2 400m individual differences in race strategy**

205 Coefficients of variance (CV) were calculated as a measure of intra-individual  
206 variance. The average CV of the male runners with intellectual impairment who ran the 400m  
207 final, semi-finals, and/or qualifications in Bergen op Zoom was  $8.1 \pm 2.9\%$  whereas the  
208 coefficient of variation during the World Championships in Berlin was  $6.9 \pm 1.6\%$ .

209

### 210 **3.3 1500m race group differences**

211 Figure 3 and Figure 4 display the pacing strategies applied by respectively male and  
212 female runners during their 1500m final race. The velocity fluctuations within every race  
213 segment are quantified in Table 2. An overall comparison of the distance by velocity plots  
214 (Figure 3) shows that male runners with and without intellectual impairment followed a  
215 different, almost inverse, pacing profile, confirmed by a significant interaction effect (Table  
216 1). After reaching a relatively high velocity in the first 100m (6.1m/s), male runners without  
217 intellectual impairment controlled their pace and slowly decelerated in the second segment of  
218 the race (100m-500m) to finish with an end sprint (1000m-1500m), whereas runners with  
219 intellectual impairment started slower, accelerated in the second segment, and then slowly  
220 decreased velocity until the end ( $F= 6.8, p<.05$ ). The comparison between female 1500m  
221 runners with and without intellectual impairment (Figure 4) also revealed inverse pacing  
222 profiles between both groups of runners, with runners with intellectual impairment  
223 accelerating until 500m, followed by a deceleration until 1100m, and a variable strategy until  
224 finish. The runners without intellectual impairment did the opposite, decelerating between  
225 100-500m, followed by accelerating until 1300m, and then maintaining their velocity until

226 finish. Significant differences were found (Table 1) between the groups in the first three  
227 segments of the race (0-1000m). Only in the final segment (1000m-1500m) both female  
228 groups slightly accelerated.

229

230 - **Insert Figure 3 and Figure 4 about here** -

### 231 **3.4 1500m race intra- and inter-individual differences**

232 In Figure 3 and 4, the individual race velocity profiles during the final 1500m races are  
233 plotted. Based on visual inspection, it can be seen that the inter-individual differences were  
234 large in the group of runners with intellectual impairment compared to the runners without  
235 intellectual impairment. The inter-individual differences were also more pronounced for  
236 runners with intellectual impairment. CV was calculated to express the intra-individual  
237 differences in velocity over the race. However, during the World Championship final male  
238 1500m runners without intellectual impairment demonstrated a CV of  $7.3 \pm 0.5\%$ , and runners  
239 with intellectual impairment had an average CV of  $5.5 \pm 3.1\%$ . Female world championships  
240 finalists had a similar CV ( $6.5 \pm 2.7\%$  for runners with intellectual impairment compared to  
241  $5.8 \pm 0.5\%$  for runners without).

242

## 243 **4 Discussion**

244 The purpose of this study was to explore the differences in pacing strategy between  
245 well-trained middle distance runners with and without intellectual impairment. Clear  
246 differences in pacing profiles were observed between runners with and without intellectual  
247 impairment. Results indicated that runners with intellectual impairment paced their race  
248 differently and with greater variance than runners without intellectual impairment. The  
249 differences were observed in 400m and 1500m races, and for both distances, the differences  
250 were most pronounced in the first half of the race. Our findings largely support the hypothesis  
251 that having an intellectual impairment impacts on the ability of runners with intellectual  
252 impairment to effectively regulate their exercise intensity over the race, supporting the  
253 assumption that this ability is at least partly dependent on cognitive skill level. To our  
254 knowledge, this was the first study to compare pacing profiles during competitive races of  
255 well-trained high level runners with and without intellectual impairment.

256

257 Within the literature, pacing has been described as an important cognitive factor in  
258 middle-distance and endurance performance that is regulated by the brain (St. Clair Gibson et  
259 al., 2006; Tucker, 2009) and has been defined as the goal-directed regulation of exercise  
260 intensity over an exercise bout, in which athletes need to decide how and when to invest their  
261 energy (Smits et al., 2014). The optimal pacing strategies for different running distances were  
262 described extensively in the literature (Thompson, 2015; Reardon, 2013; Tucker, Lambert &  
263 Noakes, 2006; Thiel et al. 2012; Abbiss & Laursen, 2008; Hanon et al., 2008). Thompson  
264 (2015) described that for the 400-meter event, a positive pacing profile is the most optimal  
265 strategy; where the speed of the athlete gradually decreases during the race. Other studies also  
266 suggested a positive pacing profile as the optimal strategy during a 400-meter event (Reardon,  
267 2013; Tucker et al., 2006; Abbiss & Laursen, 2008). Runners are decelerating towards the



268 latter segment of the 400-meter race, primarily due to developing fatigue (Thompson, 2015).  
269 All world records for 400-meter races have been run with a positive pacing strategy (Reardon,  
270 2013), with the results of this study showing that runners with intellectual impairment overall  
271 also use a positive pacing strategy over the 400m running event. Their typical profile of  
272 decline of velocity in the two different segments of the second half of the race (slow  
273 decline/fast decline) was also be observed in the world record race run by Wayde Van  
274 Niekerk in the Olympic Final in Rio 2016 (Vazel, 2016).

275  
276         Regarding the 1500-meter event, an optimal pacing strategy for a 1500m race is even  
277 paced in the middle section; however, overall it is more parabolic according to literature  
278 (Thompson, 2015; Hanon et al., 2008). Thomas, Stone, St Clair Gibson, Thompson, & Ansley  
279 (2013) showed that though even pacing might theoretically be optimal for endurance  
280 performance (de Koning, Bobbert, Foster, J Sci Med Sport., 1999), but in athlete's reality a  
281 parabolic shaped pattern might be more appropriate since the cyclists in their study were not  
282 able to finish the race when forced into an even paced pattern. In addition, it is important to  
283 note that these findings are from cyclists, as differences in optimal pacing might exist between  
284 different sports due to their specific characteristics (Stoter et al., 2016). The male world  
285 record by El Guerrouj however followed the even paced strategy, rather than the parabolic  
286 strategy, with an acceleration at the end (<http://www.iaaf.org/>); whereas the female world  
287 record by Yunxia followed a parabolic pacing strategy (<http://wn.com/>), at overall higher  
288 velocities. In our study, the runners with intellectual impairment adopted different pacing  
289 strategies compared to what is considered optimal in literature, or what is logically assumed  
290 optimal (i.e., world record performance). The male runners with intellectual impairment were  
291 not able to perform an end sprint; which is, probably because they started at very high  
292 velocities. Instead of choosing for a controlled, slower pace during the middle part of the race,  
293 we assume that the runners might have been physiologically forced to slow down making sure  
294 not to deplete energy stores prematurely to the races completion (St. Clair Gibson et al.,  
295 2006). The female runners with intellectual impairment sustained their high start velocity over  
296 a long period during the initial segment of the race, before decelerating in the mid-section.  
297 They were then able to perform an end sprint at the end of the race; although their average  
298 speed overall was lower compared to runners without intellectual impairment.

299  
300         With respect to the individual patterns of runners with intellectual impairment, high  
301 inter-individual variation during the race was observed, with different competitors within the  
302 same race applying different race strategies. Runners with intellectual impairment also  
303 showed more variance in velocity fluctuations during the race compared to the runners  
304 without intellectual impairment. The more consistent strategy applied by runners without  
305 intellectual impairment corresponded with Foster, De Koning and Thiel (2014) who found a  
306 CV of 1.5-3.0% in 1-mile world record performances. In another study by Thiel, Foster,  
307 Banzer & De Koning (2012) the CV during Olympic finals ranged between 3.6 – 11.4 %; and,  
308 in the finals of the long distance races, the pace varied every 100 meter between 1.6 and 2.7 %  
309 (Thiel et al., 2012). In our study, the variation in running speed is large in runners with  
310 intellectual impairment, especially when comparing it to the world records. Using field data,  
311 the present study demonstrated that runners with intellectual impairment race with a larger

312 intra-individual variability. Speed fluctuations result in relatively larger air frictional losses  
313 (Van Ingen Schenau, de Koning, & de Groot, 1992); leading to a decrease in running  
314 economy and a subsequent decrease in performance (Foster et al., 2014). Large velocity  
315 fluctuations of competitors during the races can be related to their inability to control their  
316 own pace and to maintain a preplanned velocity, as we have demonstrated in a previous study  
317 (Van Biesen et al., 2017). It can also be the result of athletes running a very tactical race  
318 (Reardon, 2013), athletes trying to separate themselves from the rest of the athletes when  
319 running in a pack (Foster et al., 2014), or due to specific uncommon events (e.g. the fall of  
320 one or more competitors). The inter-individual variability observed in runners with  
321 intellectual impairment corresponds with findings in many other studies (not only in running)  
322 involving participants with intellectual impairment. It was previously observed that  
323 intellectual impairment is related to larger inter-individual variation in reaction times  
324 (Carmeli, Bar-Yossef, Ariav, Levy, & Liebermann, 2008), physical fitness (Lahtinen, Rintala,  
325 & Malin, 2007; Graham & Reid, 2000), and performance on sport-specific tasks such as table  
326 tennis technical proficiency (Van Biesen et al., 2012).

327  
328 Comparing to what is known from literature and assuming that the world record  
329 pacing patterns are close to optimal, the results of this study indicated that runners with  
330 intellectual impairment adopt non-optimal pacing patterns during their races. This finding  
331 could be explained by numerous external factors which have an influence on the ‘optimal’  
332 distribution of work, such as other competitors (Konings et al., 2016a; Konings et al., 2016b).  
333 Konings et al. (2016b) were the first to show that not only the presence, but also the behavior  
334 of an opponent might affect decisions regarding the regulation of exercise intensity in  
335 laboratory-controlled conditions. As one crucial element in the diagnosis of intellectual  
336 disability is a deficit in adaptive behavior (AAIDD, 2011), the behavior of opponents during  
337 races for runners with intellectual impairment can be even more unpredictable compared to  
338 typical high level races. Also, less accomplished runners can feel forced to stay with the  
339 leading group at a pace markedly faster than their best performance. This increases the risk of  
340 premature excessive fatigue that could result in a decisive drop out later in the race  
341 (Thompson, 2014). An example of this was observed in the 1500m final race for male runners  
342 with intellectual impairment, in which one runner started the race at a very high velocity, but  
343 he was not able to maintain this velocity and ended up finishing last (see Fig. 3). This  
344 behavior is in line with our preceding study, in which athletes with an intellectual impairment  
345 in general were not able to maintain a pre-set sub-maximal velocity (van Biesen et al., 2017),  
346 but accelerated towards the finish line. It is expected based on our previous study that the  
347 behavior of this runner has influenced the profiles of the other finalists, who might have  
348 adapted their own pacing to this occurrence, as has been demonstrated to occur in well-trained  
349 cyclists (Konings et al 2016a). In sports where athletes compete in heats, in direct competition  
350 with their opponents, this is known to influence their pacing as for example has been  
351 demonstrated in 500m, 1000m and 1500m short-track skating competitions (Konings et al.,  
352 2016b, Noorbergen, Konings, Micklewright, Elferink-Gemser, & Hettinga, 2016). Not much  
353 is known yet on how intellectual impaired athletes respond to their opponents, but as athlete-  
354 environment interactions are crucial in pacing (Smits, Pepping, & Hettinga, 2014) we expect  
355 this is an important aspect and future research is needed. Motivational factors are also known

356 to affect optimal pacing (Mauger, 2014). It is known that the increases in motivation and prior  
357 experience will reduce the subjective experience of exercise-induced pain during the race  
358 and/or increase the willingness of the runner to endure it (Mauger, 2014). Reduced levels of  
359 intrinsic motivation are often addressed in research involving participants with intellectual  
360 impairment (Hutzler & Korsensky, 2010), however the sample of participants in this specific  
361 project involved elite athletes and they were observed during competition at the European  
362 Championships, which is a context in which we can assume they perform maximally. Perhaps  
363 a more applicable explanation could be that cognitive control and adequate focus of attention  
364 are important metacognitive skills to successful pacing (Brick, MacIntyre, & Campbell,  
365 2016). These metacognitive skills, and most specifically the proactive cognitive control (i.e.,  
366 anticipatory, goal-oriented processing of information or planning) place a great demand on  
367 cognitive resources (Braver, 2012) and these higher order cognitive skills were previously  
368 demonstrated to be reduced in elite athletes with intellectual impairment (Van Biesen,  
369 McCulloch, Lenaerts, Mactavish, & Vanlandewijck, 2016), who already have, by the nature  
370 of their impairment, limited cognitive resources (Van Biesen, Jacobs, McCulloch, Janssens, &  
371 Vanlandewijck, 2016). People with intellectual impairment are also known to have deficits in  
372 a range of other complex higher-order skills that are relevant to pacing (e.g., problem-solving,  
373 logical reasoning, and language-dependent strategies such as self-talk) (Aitchison et al.,  
374 2013).

375 An interesting finding of the present study is that differences in pacing profiles during  
376 the 400m races were rather small between both group of runners, particularly when compared  
377 to differences in the 1500m. An explanation may be that runners with intellectual  
378 impairment, despite their lower levels of cognitive function (i.e., lower IQ), do have the  
379 relevant skills to adequately perform a 400m race, in which an all-out approach is required.  
380 These findings correspond with the recent findings by Van Biesen, Hettinga, McCulloch, &  
381 Vanlandewijck (2017) that runners with intellectual impairment seem to have difficulties to  
382 self-regulate their pace when they are asked to maintain a submaximal velocity, which is  
383 required for a 1500m. They had the tendency to accelerate, and found it difficult to control  
384 their velocity. The overall IQ scores of 400m runners ( $64.72 \pm 8.71$ ) were somewhat higher  
385 than for 1500m runners ( $59.94 \pm 8.12$ ) but this difference was not statistically significant  
386 ( $p=.09$ ).

387  
388 Overall, velocity of the runners with intellectual impairment is significantly lower  
389 compared to the runners without intellectual impairment, even though both groups consisted  
390 of elite athletes. The race observations of the runners with intellectual impairment took place  
391 at a European Championship, whereas the split times of the runners without intellectual  
392 impairment were obtained from a World Championship. The level at a World Championship  
393 is higher than that on a European Championship; however, the large difference in velocity  
394 between the two groups is probably not caused by the effect of the cognitive impairment on  
395 pacing only. Other aspects may also contribute, for instance the smaller population (i.e., easier  
396 to become a top II-runner), reduced maximal voluntary muscle contraction (Borji, Zghal,  
397 Zarrouk, Sahli, & Rebai, 2014), the lack of motivation to perform maximally (Rimmer, 1994),  
398 reduced leg strength (Fernhall and Pitetti, 2001) or chronotropic incompetence (Dipla et al.,  
399 2013). However, the most important aspect to consider is the training volume. The

400 comparison sample in this study was selected on the basis of comparable competition level  
401 (the highest obtainable). Training volume data were not available but we can assume that it is  
402 higher than the 10 hours per week reported by the runners with intellectual impairment.  
403 Overall, the level of professionalism in sport for elite athletes with intellectual impairment  
404 compared to regular elite sport is not equal. Differences exist in training quality, access to top-  
405 coaches, prize money and sponsorship among other factors (Van Biesen, Mactavish, Pattyn &  
406 Vanlandewijck, 2012).

407  
408         Some other limitations of this study should also be noted. Comparison data was  
409 available for male 400m runners only, not for female 400m runners, and the sample size in the  
410 1500m races was small. In the comparison of data, we were unable to adjust for all potential  
411 confounders that may affect pacing and velocity, such as age and training history. These  
412 limitations, however, do not alter the importance of our findings, as this study was the first to  
413 show a clear difference in pacing strategy during high level running competition between  
414 athletes with and without II, in particular in the longer distances, in which pacing and self-  
415 regulation becomes more crucial. These findings have contributed to the development of sport  
416 specific classification systems and hence created opportunities for athletes with intellectual  
417 impairment the world over to participate at the highest level of competition, i.e., The  
418 Paralympic Games (Kwon and Block, 2012).

419  
420         In conclusion, elite runners with intellectual impairments run at an overall slower  
421 velocity and following a significantly different pacing pattern compared to runners without an  
422 intellectual impairment. For the 400m race, the initial acceleration and the final deceleration  
423 observed in World record and World Championships races (runners without intellectual  
424 impairment) are less pronounced in the finals of high level competitions for runners with  
425 intellectual impairment. During the 1500m race, both group of runners exhibit a seemingly  
426 inverse pacing profile. Large inter and intra-individual variations and fluctuations in velocity  
427 have been observed in runners with intellectual impairment. Our findings support the  
428 assumption that runners with impaired cognitive abilities are less able to regulate their  
429 exercise intensity over the race than typical runners, even if they are equally well trained.

430

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440

441 **Author contributions**

442 DVB: Conceptualizing and drafting the article, revising it critically for important intellectual  
443 content, final approval of the version to be published, and accountability for all aspects of the  
444 work. FH, KM, and YV: Conceptualizing and revising the study critically for important  
445 intellectual content, final approval of the version to be published, and accountability for all  
446 aspects of the work.

447

Provisional

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610

611 **Figure and Table Captions**

612 **Figure 1. Camera positions for split time calculations during 400-m and 1500-m races**

613

614 **Figure 2: Men’s 400-meter pacing profiles** *Note. INAS = International Federation for para-*  
615 *athletes with intellectual impairment. II = intellectual impairment, AB = able bodied.*

616

617 **Table 1: Mixed model Anova results for velocity fluctuations in four races: 400m male**  
618 **final and heats, 1500m male and female final between runners with and without**  
619 **intellectual impairment.** *Note. Df = degrees of freedom, \*p<.05, ME<sub>w</sub> = main effect of the*  
620 *within-subjects factor, ME<sub>b</sub> = main effect of the between subjects factor, IE = interaction*  
621 *effect.*

622

623 **Table 2: Comparison of velocity fluctuations in each race segment between runners with**  
624 **and without intellectual impairment.** *Note. Q1 = first race segment (0-100m), Q2 = second*  
625 *race segment (100m-200m or 100m-500m), Q3 = third race segment (200m-300m or 500m –*  
626 *1000m), Q4 = fourth race segment (300m-400m or 100m-1500m), CI = Confidence interval,*  
627 *SD = standard deviation, \*p<.05, negative velocity fluctuations (= deceleration) is*  
628 *highlighted in bold.*

629

630 **Figure 3: Individual pacing strategies of elite men’s 1500m finalists (II and non-II)**  
631 **versus World Record.** *Note. INAS = International Federation for para-athletes with intellectual*  
632 *impairment*

633

634 **Figure 4: Individual pacing strategies of elite women’s 1500m finalists (II and non-II)**  
635 **versus World Record.** *Note. INAS = International Federation for para-athletes with*  
636 *intellectual impairment*

637

638

639

640

641 **Table 1: Mixed model Anova results for velocity fluctuations in four races: 400m male**  
 642 **final and heats, 1500m male and female final between runners with and without**  
 643 **intellectual impairment.**

644

	df	F	$\eta^2$	p
<b>400m final men</b>				
645 ME <sub>w</sub> Velocity	1, 14	67.23	.95	<.001*
646 ME <sub>b</sub> Impairment	1, 14	241.56	.95	<.001*
647 IE Velocity x Impairment	1, 14	12.50	.79	.001*
<b>400m heats men</b>				
648 ME <sub>w</sub> Velocity	1, 46	333.74	.96	<.001*
649 ME <sub>b</sub> Impairment	1, 46	1265.90	.97	<.001*
650 IE Velocity x Impairment	1, 46	123.33	.63	<.001*
<b>1500m final men</b>				
651 ME <sub>w</sub> Velocity	1, 14	5.25	.61	.02*
652 ME <sub>b</sub> Impairment	1, 14	45.21	.79	<.001*
653 IE Velocity x Impairment	1, 14	35.36	.92	<.001*
<b>1500m final women</b>				
654 ME <sub>w</sub> Velocity	1, 12	10.31	.79	.004*
655 ME <sub>b</sub> Impairment	1, 12	58.94	.86	<.001*
656 IE Velocity x Impairment	1, 12	66.79	.96	<.001*

657 Note. Df = degrees of freedom, \*p<.05, ME<sub>w</sub> = main effect of the within-subjects factor, ME<sub>b</sub> = main effect of the between subjects factor, IE = interaction effect.

658 **Table 2: Comparison of velocity fluctuations over four segments of the races between**  
 659 **runners with and without intellectual impairment**

	With intellectual impairment			Without intellectual impairment			F	ES Cohen d
	Mean (m/s)	SD	95% CI	Mean (m/s)	SD	95% CI		
<b>400m final (men, n=14)</b>								
Q1	7.9	0.3	[7.6, 8.2]	8.9	0.2	[8.7, 9.1]	120.7*	3.9
Q2	0.1	0.2	[-0.1, 0.4]	0.6	0.1	[0.5, 0.7]	21.4*	3.2
Q3	<b>-0.5</b>	<b>0.2</b>	[-0.7, -0.3]	<b>-0.5</b>	<b>0.2</b>	[-0.7, -0.3]	1.2	0
Q4	<b>-0.5</b>	<b>0.3</b>	[-0.8, -0.2]	<b>-0.8</b>	<b>0.2</b>	[-1.0, -0.7]	7.1	1.2
<b>400m heats (men, n=46)</b>								
Q1	7.6	0.4	[7.4, 7.8]	8.9	0.2	[8.8, 8.9]	120.7*	4.1
Q2	0.1	0.3	[-0.1, 0.3]	0.6	0.2	[0.6, 0.7]	21.4*	2.0
Q3	<b>-0.6</b>	<b>0.2</b>	[-0.7, -0.5]	<b>-0.6</b>	<b>0.3</b>	[-0.7, -0.5]	1.2	0
Q4	<b>-0.6</b>	<b>0.2</b>	[-0.7, -0.5]	<b>-0.9</b>	<b>0.3</b>	[-1.0, -0.7]	7.1*	1.2
<b>1500m final (men, n=14)</b>								
Q1	6.1	0.3	[5.9, 6.3]	7.2	0.1	[7.1, 7.3]	-6.8*	5.0
Q2	0.2	0.7	[-0.3, 0.6]	<b>-0.6</b>	<b>0.1</b>	[-0.7, -0.6]	3.8*	1.6
Q3	<b>-0.4</b>	<b>0.3</b>	[-0.6, -0.2]	0.3	0.0	[0.3, 0.3]	-7.6*	3.3
Q4	<b>-0.1</b>	<b>0.4</b>	[-0.3, 0.2]	0.9	0.1	[0.9, 1.0]	-7.6*	3.4
<b>1500m final (women, n=12)</b>								
Q1	4.9	0.1	[4.8, 5.0]	6.5	0.1	[6.3, 6.6]	-28.8*	16.0
Q2	0.3	0.2	[0.1, 0.5]	<b>-0.8</b>	<b>0.1</b>	[-1.0, -0.6]	10.6*	7.0
Q3	<b>-0.5</b>	<b>0.2</b>	[-0.6, -0.3]	0.6	0.0	[0.6, 0.7]	-15.8*	7.8
Q4	0.3	0.6	[-0.1, 0.8]	0.2	0.0	[0.1, 0.3]	0.7	0.2

660 Q1 = first race segment (0-100m), Q2 = second race segment (100m-200m or 100m-500m),  
 661 Q3 = third race segment (200m-300m or 500m – 1000m), Q4 = fourth race segment (300m-  
 662 400m or 1000m-1500m), CI = Confidence interval, SD = standard deviation, \*p<.05, negative  
 663 velocity fluctuations (= deceleration) is highlighted in bold.

664

Figure 01.JPEG

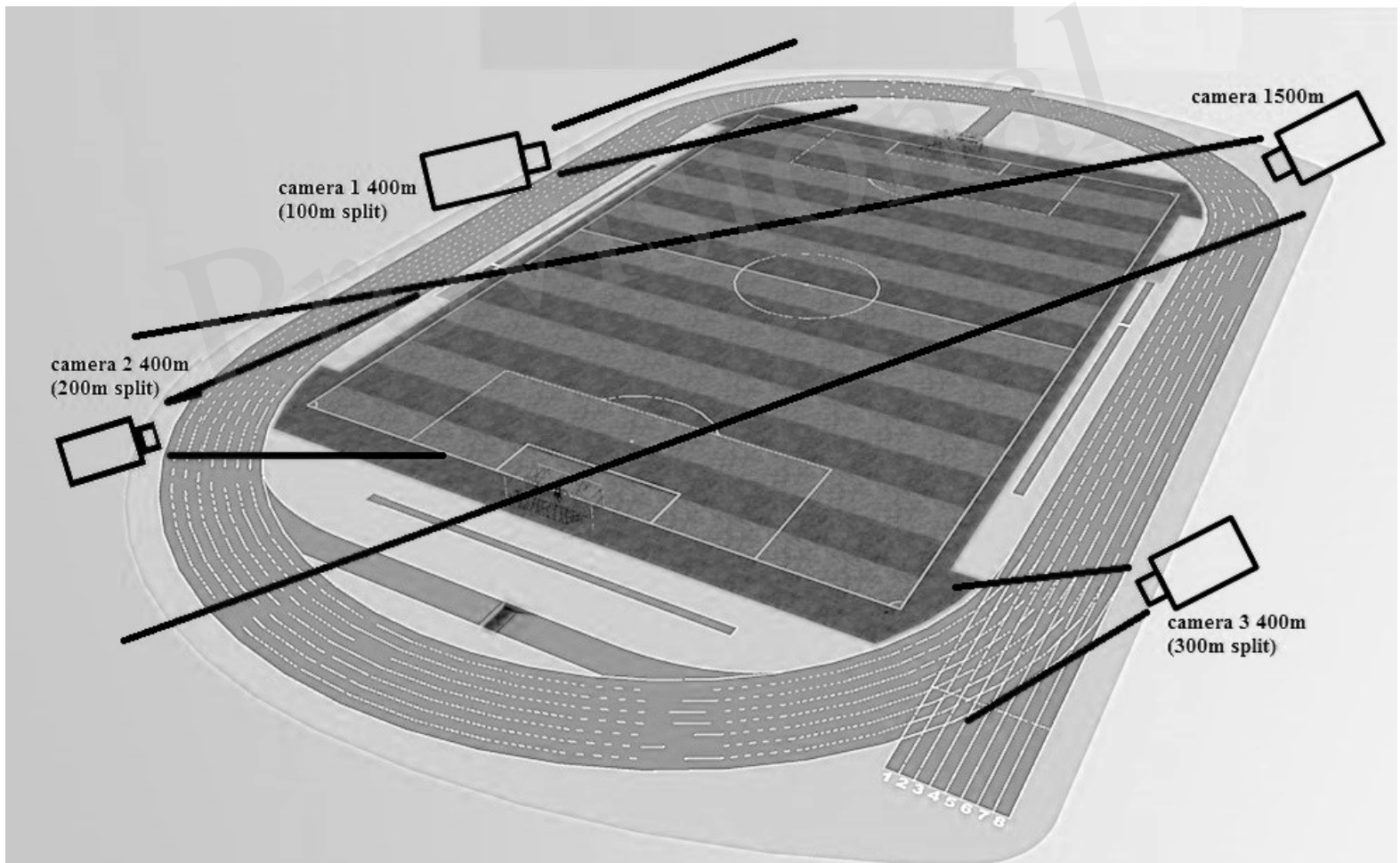


Figure 02.JPEG

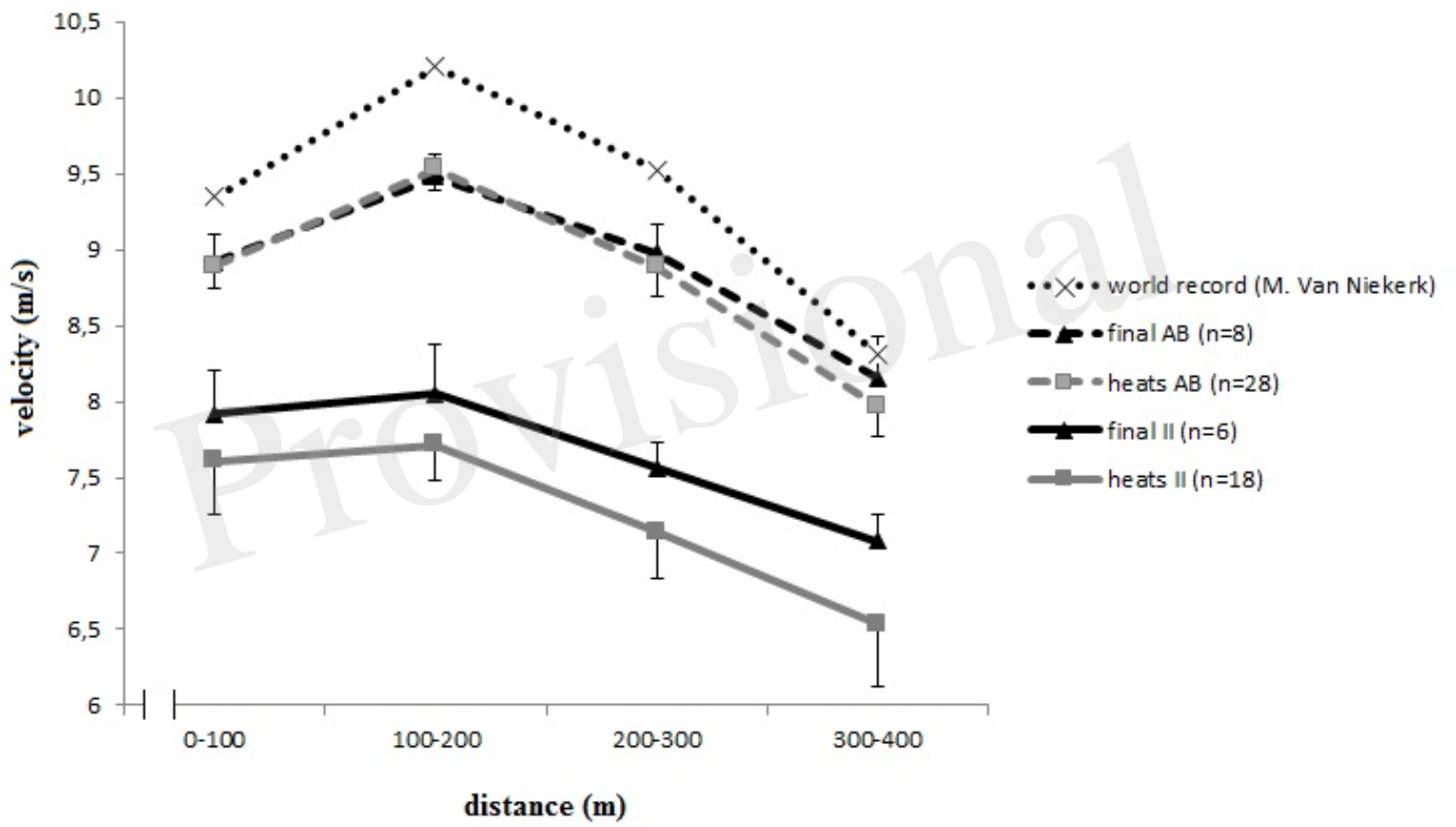


Figure 03.JPEG

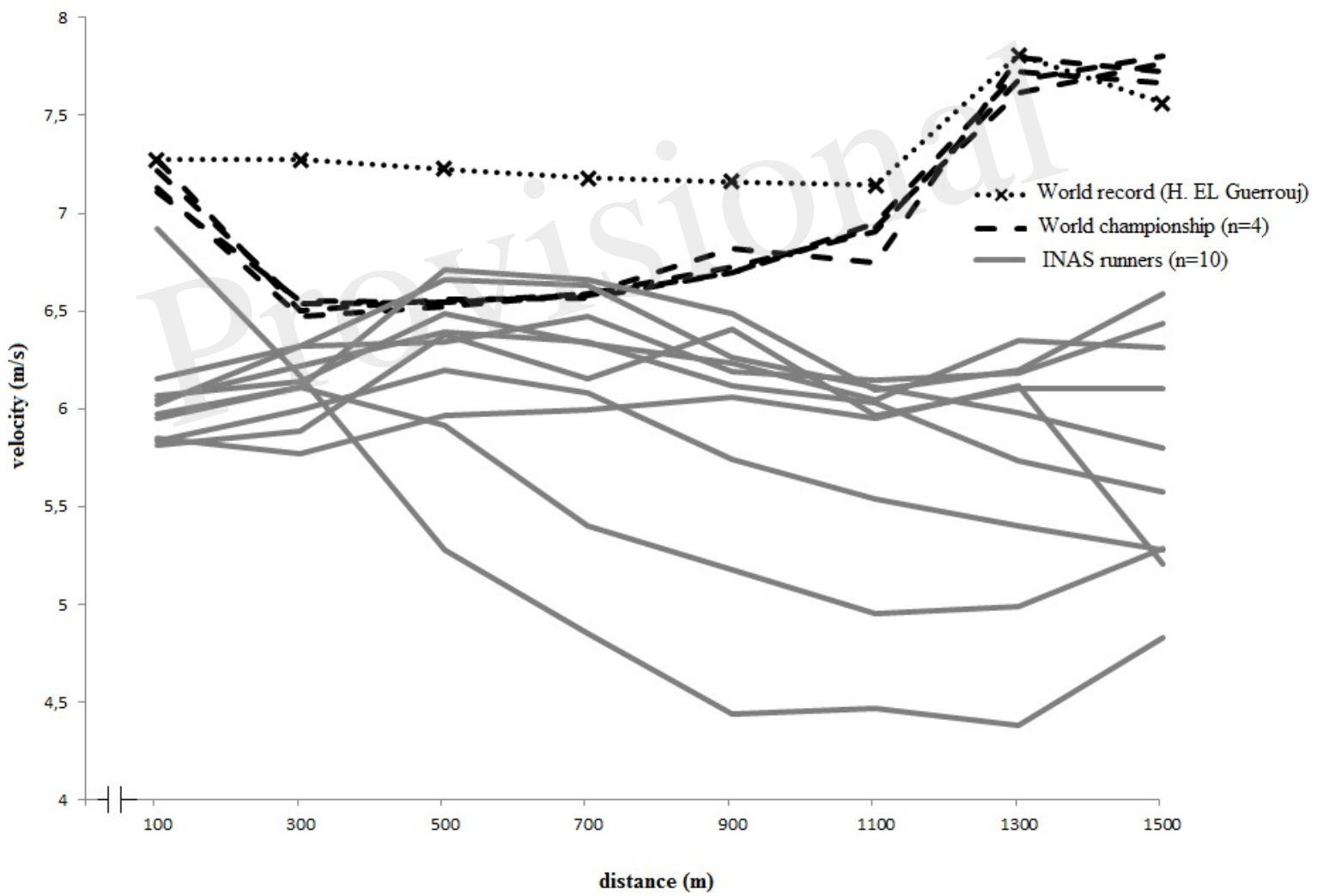


Figure 04.JPEG

