Medicine & Science in Sports & Exercise

The Official Journal of the American College of Sports Medicine
www.acsm-msse.org

. . . Published ahead of Print

Pacing Ability in Elite Runners with Intellectual Impairment

Debbie Van Biesen[1], Florentina Hettinga[2], Katina McCulloch[1], and Yves C. Vanlandewijck[1]

[1]KU Leuven, Faculty of Kinesiology and Rehabilitation Sciences, Department of Rehabilitation Sciences, Leuven, Belgium; [2]University of Essex, Centre for Sports and Exercise Science, School of Biological Sciences, Colchester, Essex, United Kingdom

Accepted for Publication: 26 September 2016

Medicine & Science in Sports & Exercise, Publish Ahead of Print
DOI: 10.1249/MSS.0000000000001115

Pacing Ability in Elite Runners with Intellectual Impairment

Debbie Van Biesen[1], Florentina Hettinga[2], Katina McCulloch[1], and Yves C. Vanlandewijck[1]

[1]KU Leuven, Faculty of Kinesiology and Rehabilitation Sciences, Department of Rehabilitation Sciences, Leuven, Belgium; [2]University of Essex, Centre for Sports and Exercise Science, School of Biological Sciences, Colchester, Essex, United Kingdom

Corresponding author:

Katina McCulloch

KU Leuven

Department of Rehabilitation Sciences,

Faculty of Kinesiology and Rehabilitation Sciences

Tervuursevest 101 – box 1500

Leuven, Belgium

Telephone: +32 16 37 65 12, e-mail: katina.mcculloch@kuleuven.be

Running title: **Pacing ability in II-runners**

CONFLICT OF INTEREST AND SOURCE OF FUNDING

The authors have no conflicts of interest

There are no sources of funding for this work

The results of the present study do not constitute endorsement by ACSM

ABSTRACT

Purpose. To understand how athletes invest their energy over a race, differences in pacing ability between athletes with and without intellectual impairment (II) were explored using a novel field test. ***Methods***. Well-trained runners (n=67) participated in this study, including 34 runners with II (age = 24.4 ± 4.5 years; IQ = 63.1 ± 7.7) and 33 runners without II (age = 31.4 ± 11.2 years). The ability to perform at a pre-planned submaximal pace was assessed. Two 400m running trials were performed on an athletics track, with an individually standardized velocity. In the first trial, the speed was imposed by auditory signals given in 20m-40m intervals, in combination with coach-feedback during the initial 200m. The participant was instructed to maintain this velocity without any feedback during the final 200m. In trial 2, no coach-feedback was permitted. ***Results.*** Repeated measures analyses revealed a significant between-groups effect. II-runners deviated more from the target time than runners without II. The significant trial x group interaction effect ($F = 4.15$, $p<.05$) revealed that the ability to self-regulate the pace during the final 200m improved for runners without II (Trial 1: 1.7 ± 1.0s, Trial 2: 0.9 ±0.8s) whereas the II-runners deviated even more in Trial 2 (4.4 ± 4.3s), than in Trial 1 (3.2 ± 3.9s). ***Conclusion.*** Our findings support the assumption that intellectual capacity is involved in pacing. It is demonstrated that II-runners have difficulties maintaining a preplanned submaximal velocity, and this study contributes to understanding problems II-exercisers might experience when exercising. With this field test, we can assess the impact of II on pacing and performance in individual athletes which will lead to a fair Paralympic classification-procedure.

Key words: RUNNING, ATHLETICS, TRACK AND FIELD, INTELLIGENCE

INTRODUCTION

Paragraph Number 1 For optimal athletic performance, athletes must regulate their exercise intensity (1) and decide how and when to invest their energy related to the goal they would like to achieve (25). Poor regulation of exercise intensity is associated with competition failures (7, 29), thereby stressing the importance for athletes to adequately **pace their races** through the use of **pacing strategies.** Previous research has addressed the complexity of pacing (1, 18, 26), and this important skill has been associated with a combination of interoceptive (i.e., physiological, psychological and/or biomechanical) and exteroceptive (i.e., environmental) factors (25). There is growing consensus in the literature about pacing being linked to the brain (1, 6, 9, 10, 21, 22, 23, 25, 26, 28, 31, 32). Factors related to intellectual capacity, such as using previous experiences, knowledge of future physiological requirements, understanding of self-physiology, perceived exertion, deductive reasoning and interactions with external factors all influence this process. However, up until now, the majority of pacing studies have focused on individuals with excellent pacing abilities (elite athletes) while only few studies specifically addressed pacing in relationship with intellectual impairment (II). Previous research on cognitive development (11) and how it affects pacing strategies and motor skills highlight that there is some link, however the specific relationship between cognition and pacing remain unknown (33). Knowing that pacing ability is at least partly influenced by an intellectual component, evidenced by a definite relationship between cognitive development and selecting appropriate pacing strategies in schoolchildren (15), we can assume that this ability is affected in athletes with intellectual impairment, but there is a general lack of evidence and more thorough investigation is required. The in depth understanding of the role cognition plays in regulating exercise intensity (and therefore the balance between exhaustion and successful performance) is of high importance to improve our understanding of the potential problems that exercisers with II might experience when exercising, particularly during middle distance/longer distance running events. Therefore, the goal of this study is to enhance our understanding regarding pacing in elite runners with intellectual impairment.

Paragraph Number 2 Several elements are crucial within pacing, such as the ability to think in advance how to organize the race but also how to respond to opponents and to correctly judge and react (or not react) to the actions of your opponents (13, 19, 30), and to interpret the signals of fatigue within your own body (7, 16, 27). This study is the first to actually assess one of the core elements of pacing ability, i.e., the ability to maintain a pre-planned submaximal velocity. This is particularly relevant for the middle- and long distance runners with II, and we will focus specifically on the 400m, 800m, 1500m and 5000m runners. The principal research question is whether or not there are differences in this ability to maintain a pre-planned submaximal running velocity in well-trained athletes with and without II. The hypotheses are:

1. Well-trained runners with II are able to run at an imposed submaximal velocity making use of external auditory and visual cues.
2. Runners with II have more problems than equally well-trained runners without II to maintain an imposed submaximal running speed making use of internal information (self-regulation).
3. Well-trained athletes with and without II improve their performance between the first and second trial (learning effect).

METHODS

Participants

Paragraph Number 3 A total sample of 67 middle- and long distance runners participated in this study, of which 34 elite runners with mild II (22 males and 12 females; age = 24,4 ± 4.5; IQ = 63.1 ± 7.7) and a comparison group of 33 runners without impairment (27 males and 6 females; age = 31.4 ± 11.2). The runners with II competed at the 2014 Open European Championship Athletics, in Bergen Op Zoom, The Netherlands, organized by the International Federation for Para-Athletes with Intellectual Impairment (INAS). From here on the sample will be referred to as the II-runners. The II-runners were recruited via personal contact with the coaches before and during the Championship based on the following criteria: competing in long sprint and/or middle and long distance races (400m, 800m, 1500m and 5000m) and meeting the criteria for diagnosis of an intellectual disability as set by the American Association on Intellectual and Developmental Disabilities (2): IQ≤75, significant deficits in adaptive behavior and manifested before the age of 18. None of the participants had severe or moderate II, or a chromosomal disorder (e.g., Down Syndrome). The participants represented 13 countries, of which 11 European and two Asian.

Paragraph Number 4 The selection of the comparison group was based on their principal sport and comparable running experience (9.3 ± 7.4 years) and training volume (8.3 ± 4.0 hours/week) similar to the II-runners (9.6 ± 4.8 years of experience and 9.4 ± 4.0 hours/week training volume). They were recruited by contacting local (Belgian) athletics clubs via e-mail, phone or a personal visit and by posters in the main sport facilities of Leuven's University Sports Center. IQ scores were not available for the comparison group, however, having an II was ruled out by including participants who, at minimum, had graduated from secondary education. All participants and/or their legal guardians signed a written informed consent form prior to participation. The study was approved by the local ethics committee (Commissie Medische Ethiek, KU Leuven).

Procedure

Paragraph Number 5 Each participant performed a running test to assess pacing ability on an official 400m athletics track. The II- runners were tested at the INAS European Athletics Championships track, prior to competition (June 2014). Test sessions of the comparison group took place in and around Leuven, Belgium, between September – December 2014. The study has a cross-sectional design.

Paragraph Number 6 Before the start of the test, 11 cones were placed on the 400m track at marked distances (20m, 40m, 60m, 80m, 120m, 160m, 200m, 250m, 300m, 350m, 400m) as indicated in Figure 1. The target pace for each participant was calculated as 80% of their personal best time (PR) on a 1500m distance using the following formula: [(PR 1500 meter/0.8)/1500]*400. When no PR on 1500m distance was available, it was predicted from the PR on the athlete's preferred distance using following conversion formulas:

1. Lap time = (PR of a certain distance/distance of the PR)*400.
2. Predicted PR on 1500m distance = [(lap time world record 1500m + (lap time PR preferred distance – lap time world record preferred distance))/400]*1500.

This approach was used to extrapolate the use of the pacing test which was originally developed for 1500m runners to other distances. The formula was adapted to gender, by using the male/female world records accordingly.

Paragraph Number 7 After warming up, the test instructions and demonstration were given to the participant. Every test was conducted by two test instructors. Every participant performed two trials of 400m on the track. The required velocity was imposed during the first 200m and the task was to maintain this velocity during the last 200m of the 400m lap without any external feedback. During the first trial, the required velocity was imposed by means of auditory signals (whistle blows) combined with additional feedback of the athlete's personal coach. The first test instructor (T1 in Figure 1) blew the whistle every time the athlete had to pass one of the cones. Hearing the whistle signal before reaching the cone implies the need to speed up. Hearing the whistle signal after having already passed the cone implies the need to slow down. A 5m "run-up" to the start line was foreseen to overcome a velocity of zero and allowing the participant to build up speed to the start line. After the first trial, at least five minutes recovery time was foreseen before executing the second trial. In between trials, no quantitative feedback was given regarding the performance of the athlete, only qualitative feedback about how the athlete followed the instructions during the first 200m part. In the second trial, again, the same required velocity was imposed during the first 200m by means of auditory signals (whistle blows) but this time without additional feedback from the coach. The second test instructor (T2 in Figure 1) was standing in the middle of the infield and used a digital stop watch to register total lap time and split times, each time the participant passed a cone. The total duration of the test was approximately 15 minutes.

Paragraph Number 8 After each trial of the pacing test the recorded split times were registered, rounded up to one hundredth of a second. The deviation score for each time point was calculated. The deviation score is the difference between the actual time run until that measure point and the imposed target time for that measure point, which is calculated from the formula mentioned above. Positive deviation scores indicate that the athletes ran too slow, negative deviation scores indicate that they ran too fast during the pacing test.

Data analysis

Paragraph Number 9 The data were analyzed using IBM SPSS Statistics (version 22.0, SPSS Inc., Chicago Ill, USA), with level of significance set at $p<.05$. For the deviation scores both the absolute deviation (AD) and the relative deviation (RD) were used as dependent measures. AD represents the mean deviation from the target time, without taking into account the direction of the deviation and provides information about the absolute size of the deviation. RD provides information about the direction of the deviation (negative values representing running too fast and positive values representing running too slow). For the in-depth analyses of AD and RD, 2 (group: with and without II) x 11 (split time points) analyses of variance were performed for both trials separately with repeated measures on the latter factor. For the comparison of average AD between trials, after the initial 200m and after the final 200m, 2 (group: with and without II) x 2 (Trial 1 versus Trial 2) repeated measures analyses were performed. Effect sizes were calculated for the deviation from the target time (http://www.uccs.edu/~lbecker/). An effect size of 0.2 is small, 0.5 represents a medium effect and 0.8 represents a large effect (4).

RESULTS

Paragraph Number 10 The average absolute deviation from the target time after the initial 200m and after finishing the complete 400m run of both trials is presented in Table 1.

a. Initial 200m: are well-trained runners with II able to run at an imposed submaximal velocity making use of external auditory and visual cues?

Paragraph Number 11 A 2 (group: with and without II) x 2 (Trial 1 versus Trial 2) repeated measures analyses revealed a significant effect for the between factor group (F= 7.58, p<.05, power = 0.77), indicating that II-runners deviate more from the target time, already after 200m, independent of the trial. No significant main effect was found for trial, neither any significant interaction effects.

b. Final 200m: self-regulating pace without any feedback

Paragraph Number 12 The Repeated Measures ANOVA revealed a significant main effect for the between factor group, F(1, 64) = 19.45, p<.001, power = 0.99, with II-runners deviating more from the target time than control group runners. The significant trial x group interaction effect (F = 4.15, p<.05, power = 0.51, Cohen d ES = 1.1) indicated that the differences in absolute deviation between trials were different for II- runners compared to runners without II. Whereas runners without II improve their performance (smaller deviation) between Trial 1 and Trial 2, the II-runners perform worse (larger deviation) in the second trial.

c. Learning effect between first and second trial (absolute and relative deviation)

Paragraph Number 13 Figure 2 presents the mean absolute deviation (AD) and SD's over 11 time points for the two trials and two groups of runners (II versus control) separately.

The 11 time points represent all the split time points during the test. To refresh the readers' memory, split time points are depicted in Figure 1, with 7 time points within the first 200m (with auditory feedback at every time point) and time point 8-11 in the final part of the 400m lap (without any feedback). The Repeated Measures ANOVA yielded a significant main effect for the between factor group ($F = 10.42$, $p<.05$, $\eta 2 = 0.15$, Power = .89). The AD was larger for II-runners than for athletes without II, and this held independent of the trial. The analysis also revealed a significant main effect of the within factor time ($F = 8.79$, $p<.05$, $\eta 2 = 0.63$, Power = 1), indicating that the AD varies over the 11 time points, as visually depicted in Fig. 1. Significant time x group interaction effects ($F=2.89$, $p<.05$, $\eta 2 = 0.36$, Power = .95) and time x trial x group interaction effects ($F=2.01$, $p<.05$, $\eta 2 = 0.28$, Power = .82) revealed that the II-runners start deviating from the target time at earlier time points (cone 5) in trial 2 (without coach feedback) compared to trial 1 (cone 8), but for the control group athletes the deviation from the target time occurs at earlier time points (cone 9) in trial 1 (with coach feedback) compared to trial 2 (cone 11).

Paragraph Number 14 The relative deviation from the target time (RD) provides an indication of the direction of the deviation. Figure 3 presents the mean RD and SD's over the 11 time points for both groups in both trials. The Repeated Measures ANOVA yielded a significant between group effect ($F = 11.3$, $p<.001$, $\eta 2 = 0.2$, Power = .90). The direction of the deviation is negative (i.e., acceleration for the II-runners whereas a centering on the axis is observed for the control group runners. A main effect for the within factors time is observed ($F = 8.5$, $p<.001$, $\eta 2 = 0.60$, Power = 1) and also a main effect for the within factor trial ($F=5.6$, $p<.05$, $\eta 2 = 0.1$, power =0.6), indicating that the RD differs between the first and second trial, and this held independent of the group. The significant time x group interaction effect ($F=3.8$, $p<.001$, $\eta 2 =$

0.40, power = 1) indicates that the RD varies differently over time for II-runners compared to control group runners. Figure 3 shows that the majority of the II-runners accelerate in the last 200m of both trials (negative RD), whereas no acceleration is observed in control group runners.

DISCUSSION

Paragraph Number 15 This study was designed to explore pacing ability in elite runners with II evaluating if there was a relation between pacing performance and cognitive development. It was expected that well-trained runners with II would be able to run at an externally imposed submaximal velocity, but that they would have more problems than an equally well-trained group of runners without II to maintain this velocity based on internal information. Our findings confirmed that well-trained runners with II lack the ability to self-regulate their pace when the task is to rely on internal information, and moreover, even during the first 200m when the pace was externally imposed, they had problems with pacing. Whereas athletes without II improved their pacing performance between the first and the second trial, this learning effect was not observed in athletes with II. On the contrary, the absence of any coach feedback in the second trials caused deterioration in performance. Ample literature outlines the requirement of adequate pacing to elicit optimal performance (1) and pacing is commonly described as one of the most important cognitive determinants in running (26, 31). However, not many studies are available that specifically investigate pacing in relation to II. A study of Micklewright et al. (15) has confirmed that forming a pacing strategy is at least in part associated with cognitive mechanisms and pacing differences were distinguished between children (5-14 yrs) in a different stage of cognitive development. The stage of cognitive development was assigned by means of cognitive tests in typically developing schoolchildren, so no individuals with cognitive impairments were included as done in the present study.

Paragraph Number 16 A novel field test was used in this study to assess the ability to maintain a pre-planned velocity. The running speed was imposed by means of auditory signals, respectively with or without additional coach feedback.

a. **Initial 200m: are well-trained runners with II able to run at an imposed submaximal velocity making use of external auditory and visual cues?**

Paragraph Number 17 Already after 200m, II-runners deviated more from the target time than athletes without II. This is remarkable, because in both trials auditory signals were given to impose the required running velocity. The II-runners had the tendency to start too fast. Especially in the second trial, without coach feedback, this trend became more explicit. This means that coaches of II-athletes have an important role in helping their athletes to adequately pace their training sessions and their races. The importance of the coach with respect to pacing for people with an II was also demonstrated by Kunde and Rimmer (14). They found that participants with an II performed better on a one mile walking test when they were accompanied by a person giving constant feedback and encouragement (i.e., coaching). Whereas in this study, athletes had to be tempered in order not to run too fast instead of being encouraged to walk as fast as possible, the positive effect of the coach is common. Individuals with II have problems with self-regulation and perform better with external support. The study of Keary, Godbold, Parenteau and Woods (12) also showed a positive effect of coaching on a 100-meter sprint performance. The ideal profile of a coach for athletes with II is characterized as a calm, balanced and stress-resistant person who has a combination of sport-specific expertise and experience with coaching athletes with intellectual impairment (24). In the control group athletes, we generally observed that the absence of coaching had no negative effect on their performance. On the contrary, the combination of smaller absolute deviation and the smaller variance between trial 1 and trial 2 indicated that a learning process had occurred between the first and second trial, as also observed in other pacing studies (5, 8).

b. Final 200m: self-regulating pace without any feedback

Paragraph Number 18 During the pacing test, the deviations from the target time were significantly larger for II athletes compared to the control group athletes. Whereas after a short learning process, athletes without II were perfectly able to maintain an imposed velocity (without any type of external feedback) in the second part of Trial 2 (only 0.9s deviation); the athletes with II deviated more than 4s from the target time. These findings outline an important problem that athletes with II experience when exercising: the inability of II-runners to self-regulate an imposed pace, which may have major consequences for training (e.g., dosed training sessions) but probably also in competition (e.g., executing a pre-planned strategy), and even in everyday life (e.g., independent living). In general, self-regulation includes abilities of planning, identifying and using adequate resources, evaluating effects of actions, controlling actions, mobilizing attention and motivation to attain a goal (3). Self-regulation develops depending on cognitive resources and studies have identified people with II at different ages and developmental levels as presenting either developmental delay in self-regulation or deficits in self-regulatory strategies in problem solving or in daily life management (17).

c. Learning effect between first and second trial (absolute and relative deviation)

Paragraph Number 19 With further detailed analysis of results, there were clear differences in performance between the first and second trial. For the II-runners, the deviation from the target time started to occur at measure point 8 in the first trial (with feedback from the coach in the first 200m) and even earlier in the exercise bout, at measure point 5, in the second trial (without any external feedback). Whereas the absolute deviation provided insight into the magnitude of the deviation, the relative deviation indicated the direction of the deviation (acceleration or deceleration). The average relative deviation in both groups (runners with and without II) was negative in both trials, meaning they had the tendency to accelerate in the second half of the 400m run. The differences in relative deviation between II- runners and control group runners were only significant for the second trial in which no coach feedback was allowed. When asked afterwards, most of the athletes indicated that the imposed running velocity (80% of the PB on 1500m distance) did not feel very comfortable. It is commonly accepted in sport science literature that the most economical pace is close to the freely chosen pace (20) which may contribute to the findings in our study where a standardized (slow) pace was imposed.

Practical implications

Paragraph Number 20 Pacing is a crucial aspect of running performance; therefore, the results of this study may help coaches and instructors, specifically those involved in elite sports for athletes with II, to improve the quality of their training. The results of this study also had direct practical implications for international sport participation of elite athletes with II, because these findings led to the decision to re-include long distance running as one of the first sports for athletes with II in the Paralympic Games. Based on the differences in one of the crucial elements of pacing ability between runners with and without II, as assessed in this study, the eligibility criteria were developed for II-runners to enter competitive events, sanctioned by the International Paralympic Committee.

Limitations

Paragraph Number 21 Although this study provides new insights regarding pacing in relation with II some shortcomings should not be overlooked. Groups were matched on the basis of their comparable training history and training volume. However, some other aspects (age, cultural differences etc.) may also have contributed to the observed differences. Whereas their training volume was comparable, the control group was on average 7 years older (significant difference), which might be related to a more mature pacing strategy. The control group consisted only of Flemish athletes as opposed to the international base of the INAS group; hence, cultural differences in training for pacing might have impact the findings. In addition, large inter-individual differences are commonly observed when testing a population with II. This was mimicked in this study, where the variation in pacing ability was large, mainly for the II-athletes.

CONCLUSION

Paragraph number 22 A novel field test was applied to investigate pacing ability in persons with intellectual impairment (II) to improve our understanding of the potential problems that runners with II might experience when exercising. Their ability to perform at a pre-planned submaximal velocity, which is an essential aspect of pacing, was assessed and differences between athletes with and without II were evident: athletes with II had difficulties to run at an externally imposed pace, and they were not able to maintain their pace without continued auditory feedback. Learning effects were only observed in runners without II. Knowledge gained from this research outlines that athletes with II have difficulties maintaining a preplanned submaximal velocity. They have the tendency to accelerate and this acceleration starts sooner and is more pronounced when no coach feedback is allowed. The fact that this aspect of pacing ability differs significantly between runners with and without a cognitive impairment supports the assumption that pacing involves a cognitive aspect. Further research is required to determine the relationship between maintaining an imposed submaximal velocity and running performance in competition.

Acknowledgements and Conflict of Interest

The authors would like to thank INAS and IPC for their support to conduct this study, and all members of the INAS-IPC Research Group (Prof. Jan Burns from the University of Canterbury, Prof. Jennifer Mactavish from the Ryerson University in Toronto, Canada, Dr. Peter Van de Vliet, medical and scientific director of IPC, and Nick Parr, executive director of INAS) for their valuable input. No sources of funding were used to assist in the preparation of this study. The authors have no potential conflicts of interest that are directly relevant to the content of this study. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

References

1. Abbiss CR, Laursen PB. Describing and understanding pacing strategies during athletic competition. *Sport. Med*. 2008;38(3):239–52.doi:10.2165/00007256-200838030-00004.
2. American Association on Intellectual and Developmental Disabilities. *Intellectual Disability: Definition, Classification and Systems of Supports.* 11th ed. Washington DC, USA. (n.d.). AAIDD; 2011. 259 p.
3. Boekaerts M. Self-regulated learning at the junction of cognition and motivation. *Eur. Psychol. 1996;*1(2):100–12. http://dx.doi.org/10.1027/1016-9040.1.2.100.
4. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. 567 p.
5. Corbett J, Barwood MJ, Parkhouse K. Effect of task familiarisation on distribution of energy during a 2000 m cycling time trial. *Br. J. Sports Med*. 2009;43(10):770–4.
6. De Koning JJ, Foster C, Bakkum A, et al. Regulation of pacing strategy during athletic competition. *PLoS One 2011;*6(1): e15863. doi:10.1371/journal.pone.0015863.
7. Esteve-Lanao J, Lucia A, de Koning JJ, Foster C. How do humans control physiological strain during strenuous endurance exercise? *PloS One* 2008;3(8): e2943, doi: 10.1371/journal.pone.0002943.
8. Foster C, De Koning JJ, Thiel C. Evolutionary pattern of improved 1-mile running performance. *Int. J. Sports Physiol. Perform.* 2014;9(4):715-719. doi: 10.1123/ijspp.2013-0318.
9. Hanon C, Leveque J-M, Thomas C, Vivier, L. Pacing strategy and VO2 kinetics during a 1500-m race. *Int. J. Sport. Med.* 2008;29(3):206–211. doi:10.1055/s-2007-965109.

10. Hanon C, Thomas C. Effects of optimal pacing strategies for 400-, 800-, and 1500-m races on the VO2 response. *J. Sport. Sci.* 2011;29(9):905–912. doi:10.1080/02640414.2011.562232.

11. Huitt W. & Hummel, J. (2003). Piaget's theory of cognitive development. *Education Psychology Interactive*. Valdosta, GA: Valdosta State University. Retrieved 26.01.15 from http://chiron.valdosta.edu/whuitt/col/cogsys/piaget.html.

12. Keary P, Godbold EN, Parenteau RE, Woods KE. Behavioral coaching of track athletes with developmental disabilities: evaluation of sprint performance during training and Special Olympics competition. *J. Clin. Sport Psychol.* 2013;7(4): 264-74.

13. Konings MJ, Noorbergen OS, Parry D, Hettinga FJ. Pacing Behaviour and Tactical Positioning in 1500 m Short-Track Speed Skating. *Int. J. Sport. Physiol. Perform*. 2015; DOI: http://dx.doi.org/10.1123/ijspp.2015-0137.

14. Kunde K, Rimmer JH. Effects of pacing vs. nonpacing on a one-mile walk test in adults with mental retardation. *Adapt. Phys. Activ. Q.* 2000;17(4):413-20.

15. Micklewright D, Angus C, Suddaby J, St Clair Gibson A, Sandercock G, Chinnasamy C. Pacing strategy in schoolchildren differs with age and cognitive development. *Med. Sci. Sports Exerc.* 2012;44(2): 362–69. doi:10.1249/MSS.0b013e31822cc9ec.

16. Moore RD, Romine MW, O'Connor PJ, Tomporowski PD. The influence of exercise-induced fatigue on cognitive function. *J. Sports Sci.* 2012;30(9),841- 50. doi:10.1080/02640414.2012.675083.

17. Nader-Grosbois N. Self-perception, self-regulation and metacognition in adolescents with intellectual disability. *Res. Dev. Disabil.* 2014;35:1334-48.

18. Noakes TD. The Central Governor Model in 2012: eight new papers deepen our understanding of the regulation of human exercise performance. *Br. J. Sports Med*. 2012;46:1-3.

19. Noorbergen OS, Konings MJ, Micklewright D, Elferink-Gemser MT, Hettinga FJ. Pacing Behaviour and Tactical Positioning in 500m and 1000m Short-Track Speed Skating. *Int. J. Sport. Physiol. Perform*, 2015; in press, DOI: http://dx.doi.org/10.1123/ijspp.2015-0384.

20. Nummela A, Keränen T, Mikkelsson LO. Factors related to top running speed and economy. *Int. J. Sports Med*. 2007;DOI 10.1055/s-2007-964896

21. Reardon J. Optimal pacing for running 400 m and 800 m track races. *Am. J. Phys.* 2013;81(6):1–14. doi:10.1119/1.4803068.

22. Roelands B, De Koning JJ, Foster C, Hettinga FJ, Meeusen R. Neurophysiological determinants of theoretical concepts and mechanisms involved in pacing. *Sports Med*. 2013;43(5):301-11.

23. Saraslanidis PJ, Panoutsakopoulos V, Tsalis GA, Kyprianou E. The effect of different first 200-m pacing strategies on blood lactate and biomechanical parameters of the 400-m sprint. *Eur. J. Appl. Physiol*. 2011;111(8):1579–90. doi:10.1007/s00421-010-1772-4.

24. Schliermann R, Stolz I, Anneken V. The sports background, personality, attitudes, and social competencies of coaches and assistant coaches in the Just Soccer program for pupils with intellectual disabilities. *Hum. Mov.* 2014;15(3):177-85. doi: 10.1515/humo-2015-0009.

25. Smits BLM, Pepping G-J, Hettinga FJ. Pacing and decision making in sport and exercise: the roles of perception and action in the regulation of exercise intensity, *Sports Med.* 2014;44:763-75.

26. St Clair Gibson A, Lambert EV, Rauch LHG, et al. The role of information processing between the brain and peripheral physiological systems in pacing and perception of effort. *Sports Med*. 2006;36(8):705–22.

27. Swart J, Lindsay TR, Lambert MI, Brown JC, Noakes TD. Perceptual cues in the regulation of exercise performance—physical sensations of exercise and awareness of effort interact as separate cues. *Br. J. Sports Med*. 2012;46(1):42–8.

28. Thiel C, Foster C, Banzer W, De Koning JJ. Pacing in Olympic track races: Competitive tactics versus best performance strategy. *J. Sports Sci.* 2012;30(11):1107–15. doi:10.1080/02640414.2012.701759.

29. Thompson KG. *Pacing: Individual Strategies for Optimal Performance*. 1st ed. Champaign (MA): Human Kinetics; 2015. 225 p.

30. Tomazini F, Pasqua LA, Damasceno MV, et al. Head-to-head running race simulation alters pacing strategy, performance, and mood state. *Physiol. Behav*. 2015;149: 39-44.

31. Tucker R. The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *Br. J. Sports Med*. 2009;43(6):392–400. doi:10.1136/bjsm.2008.050799.

32. Tucker R, Lambert MI, Noakes TD. An analysis of pacing strategies during men’s world-record performances in track athletics. *Int. J. Sports Physiol. Perform.* 2006;1(3): 233–45.

33. Van der Fels IMJ, te Wierike SCM, Hartman E, Elferink-Gemser MT, Smith J, Visscher C. The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: a systematic review. *J. Sci. Med. Sport.* 2014;doi:10.1016/j.jsams.2014.09.007.

Table and Figure Captions

Figure 1: Test set-up for the execution of the pacing test

Note. TI 1= Test Instructor 1, TI 2 = Test Instructor 2, distances associated with 11 split-time points.

Table 1: Absolute deviation from the target time after the initial 200m and after the final 200m of both 400m trials

Figure 2: Absolute differences from the target time per split time point

Note. INAS – International Federation for Para-athletes with intellectual impairment

Figure 3: Relative deviation from the target time per split time point

Note. INAS = International federation for para-athletes with intellectual impairment. Negative values on the Y-axis = acceleration, positive values on the Y-axis = deceleration

Figure 1

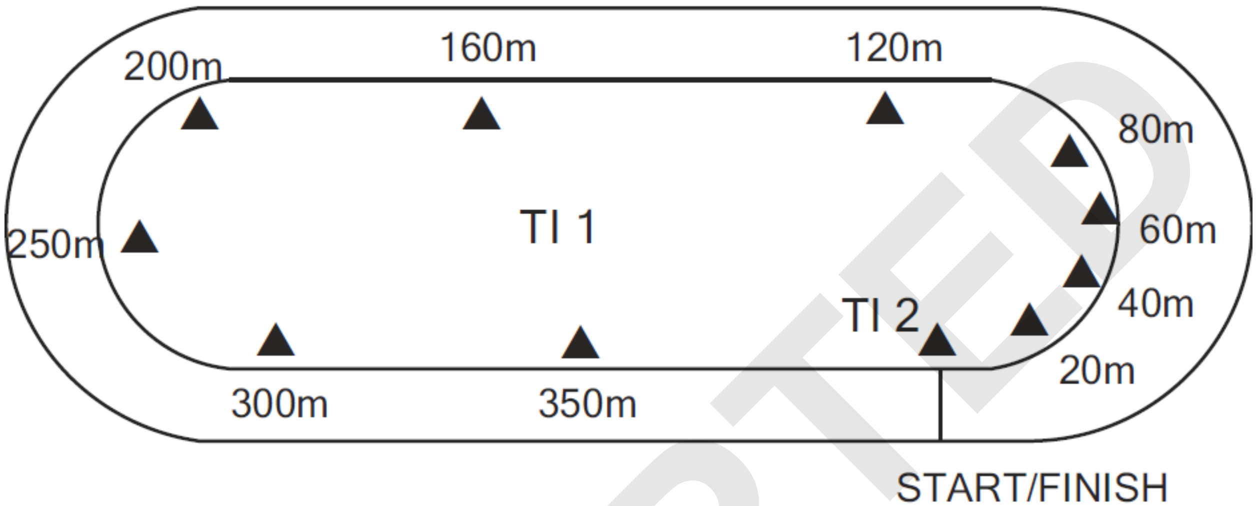
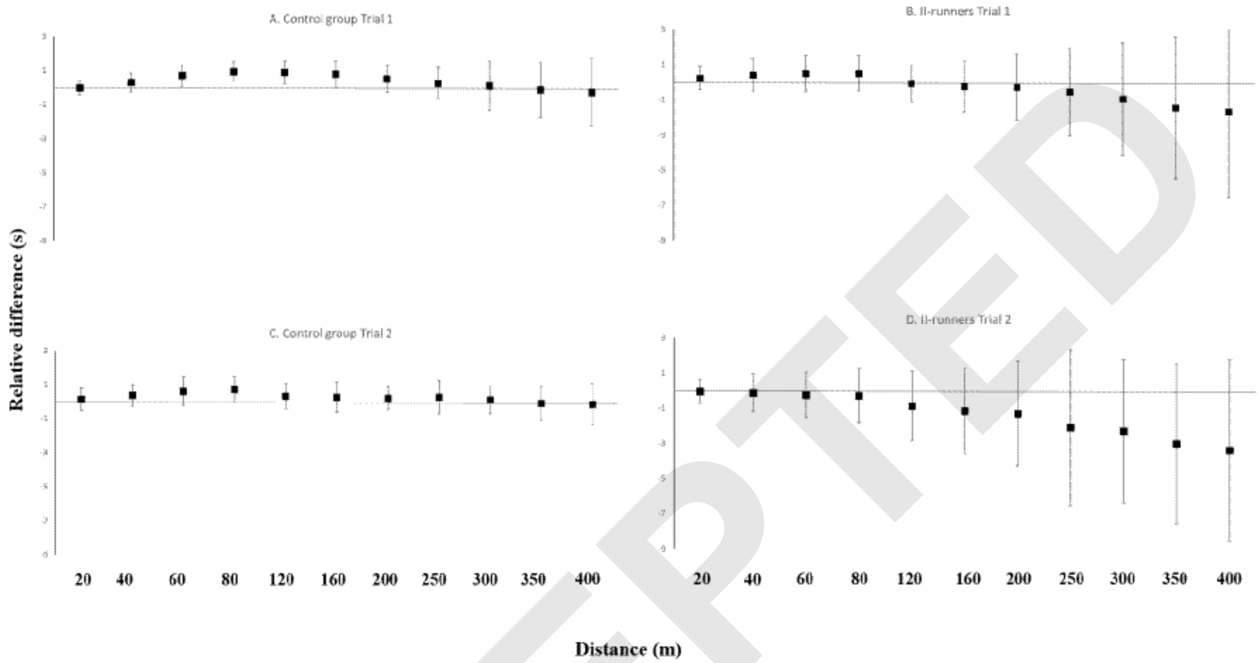
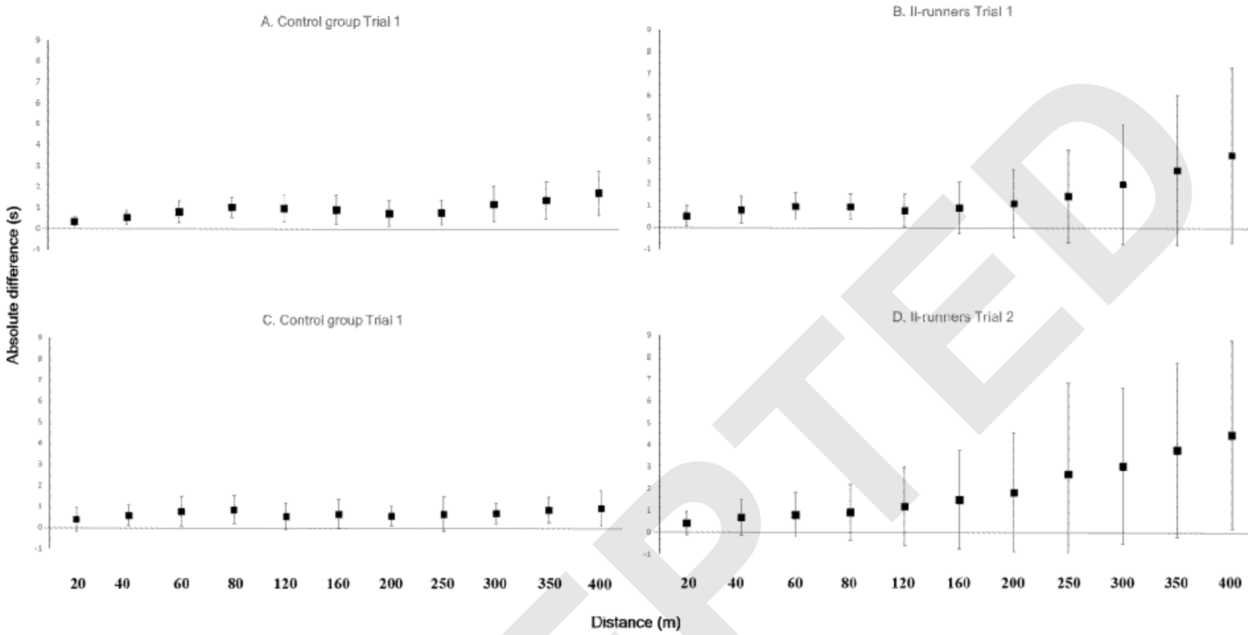

160m
120m
200m
80m
TI 1
250m
60m
40m
TI 2
20m
300m
350m
START/FINISH

Figure 2



A. Control group Trial 1
B. Il-runners Trial 1
C. Control group Trial 2
D. Il-runners Trial 2
Relative difference (s)
20
40
60
80
120
160
200
250
300
350
400
Distance (m)

Figure 3



A. Control group Trial 1
B. II-runners Trial 1
C. Control group Trial 1
D. II-runners Trial 2
Absolute difference (s)
20
40
60
80
120
160
200
250
300
350
400
Distance (m)

Table 1: Absolute deviation from the target time after the initial 200m and after the final 200m of both 400m trials

	With intellectual impairment (N=34)			Without intellectual impairment (N=33)		
	M	SD	95% CI	M	SD	95% CI
Absolute deviation (s) after initial 200m						
Trial 1 (with coach feedback)	1.1	1.6	[0.6, 1.6]	0.7	0.6	[0.5, 0.9]
Trial 2 (no coach feedback)	1.8	2.7	[0.9, 2.7]	0.5	0.4	[0.4, 0.6]
Absolute deviation (s) after end of trial (400m)						
Trial 1 (with coach feedback)	3.2	3.9	[1.8, 4.6]	1.7	1.0	[1.3, 2.1]
Trial 2 (no coach feedback)	4.4	4.3	[2.9, 5.9]	0.9	0.8	[0.6, 1.2]

Note. CI = confidence interval