# Pacing and Self-regulation

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# Pacing and Self-regulation: Important Skills for Talent Development in Endurance Sports

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Pacing has been characterized as a multifaceted goal-directed process of decision making in which athletes need to decide how and when to invest their energy during the race, a process essential for optimal performance. Both physiological and psychological characteristics associated with adequate pacing and performance are known to develop with age. Consequently, the multifaceted skill of pacing might be under construction throughout adolescence, as well. Therefore, the authors propose that the complex skill of pacing is a potential important performance characteristic for talented youth athletes that needs to be developed throughout adolescence. To explore whether pacing is a marker for talent and how talented athletes develop this skill in middle-distance and endurance sports, they aim to bring together literature on pacing and literature on talent development and self-regulation of learning. Subsequently, by applying the cyclical process of self-regulation to pacing, they propose a practical model for the development of performance in endurance sports in youth athletes. Not only is self-regulation essential throughout the process of reaching the long-term goal of athletic excellence, but it also seems crucial for the development of pacing skills within a race and the development of a refined performance template based on previous experiences. Coaches and trainers are advised to incorporate pacing as a performance characteristic in their talent-development programs by stimulating their athletes to reflect, plan, monitor, and evaluate their races on a regular basis to build performance templates and, as such, improve their performance.

***Keywords****:* athletic training, coaching, motivation, physical performance, psychology

To perform well in middle-distance and endurance sports, the integration of multiple physiological and psychological systems is required. A multitude of both internal and external factors likely contribute to the successful regulation of exercise intensity.[1] This becomes clear when considering the importance of pacing as a performance characteristic. Pacing is the goal-directed process of decision making in which athletes need to decide how and when to invest their energy during the race.[1] Pacing has been investigated in several time-trial sports, such as cycling, running, swimming, and speed skating; sports in which athletes need to distribute their available energy over the race in such a way that they find an optimal balance between starting fast but preventing negative technical adaptations later on in the race due to early fatigue.[2–4] For example, in speed skating, a technically/biomechanically favorable crouched posture (ie, small knee and trunk angle) leads to a more effective push-off,[5] but at the same time to a physiological disadvantage: a smaller knee angle increases the deoxygenation of the working muscles,[6,7] exacerbating fatigue. This dilemma makes adequate pacing highly challenging and essential. In terms of talent identification and development, it is thus interesting to explore whether this complex and multifaceted skill of pacing can be considered a marker for talent. In youth athletes, data on development of pacing strategies are scarce. So far, only 1 study has focused on the development of pacing in talented youth athletes. This study was performed in speed skating and took the unique approach to explore longitudinally how pacing strategies were developing with age and experience throughout adolescence. The results demonstrated that pacing strategies of the better performing skaters developed toward the pacing strategies observed in world-class senior elite athletes (ie, they were able to maintain their velocity high toward the final stages of the race).[8,9] Lower-ranked skaters did not show this pattern, indicating that pacing skills seem to be a discriminating factor between future top athletes and their lower-ranked peers. Also in swimming, it seems that pacing strategies are developed related to the maturation status and level of performance of the athletes. Although not longitudinally investigated, well-trained adolescent swimmers of on average 15 years appeared unable to regulate their pace adequately[10] whereas another study showed that pacing profiles of high-level swimmers of on average 17 years were stable for the first three-quarters of the race.[11] A study of subelite swimmers showed that swimmers age 12 to 14 and 15 to 18 were unable to stabilize their stroke length between successive race quarters, which the authors contributed to physical immaturity, inexperience in competition pacing and within-race fatigue.[12]

## Pacing and Performance Development in Youth Athletes

As both physiological and psychological characteristics are known to develop with age, it is of interest how youth athletes develop these aspects, and how this impacts on their pacing skills. Since pacing is directly related to an athlete's physical capacity, growth and maturation are expected to play an important role in youth sports. Indeed, the onset of puberty leads to enormous physical changes, such as increases in height, lean body mass and endurance capacity.[13] Although most physical capacities of humans tend to peak around the age of 30,[14] peak performance in middle-distance endurance events is reached at younger ages.[15] Maturing athletes

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will continuously need to adapt their pacing strategy to their developing physical abilities. In addition, cognitive changes occur throughout adolescence as well. Extensive structural and functional brain developments take place[16] and metacognitive functions are not fully mature until young adulthood. The classical definition of metacognition is 'knowledge and cognition about cognitive phenomena, generally and broadly understood as cognition about cognition or thinking about thinking.'[17] It reflects the use of strategies that are thoughtfully brought to mind as one prepares to solve a problem, followed by a monitoring of progress toward a specific goal.[18] Lesion studies and functional imaging experiments suggest that the brain areas involved are the frontal lobes.[19,20] During adolescence myelination of these regions continues, increasing speed of information transmission. Furthermore, synaptic pruning takes place, resulting in optimal connections. Metacognitive skills arise as early as at 4 to 6 years of age as a set of domain-specific skills.[21,22] From the age of 12, these skills further develop to a more general repertoire.[23] In a similar way, pacing skills seem to develop with age, as was demonstrated in school children.[24] Younger schoolchildren around the age of 4, with less advanced cognitive development, exhibited a not so optimal negative pacing strategy on a best-effort 4-minute running task, suggesting an inability to anticipate exercise demands. Older schoolchildren, who were at a more advanced stage of cognitive development, exhibited a more traditional U-shaped pacing strategy as seen in adults.[25] In the previously mentioned speed skating study,[8] it was found that also in youth athletes in the age range 13 to 18 years, pacing strategies between younger and older athletes differed. In particular the elite junior speed skaters improved their pacing strategies over time toward a profile observed in elite speed skaters whereas the nonelite skaters did not show similar improvements throughout their adolescent years. Specifically, the development from 16 to 18 years was more pronounced in the better-performing skaters, indicating the relevance of monitoring pacing behavior for talent development particularly in this age group. The findings indicate that junior athletes might benefit from extra support and guidance in the development and training of the complex and multifaceted skill of pacing. Even more, in this longitudinal study it was identified that talented long-track speed skaters discriminated themselves from their peers by their 1500-m pacing profiles. These results highlight the importance of the development of pacing to improve performance toward peak performance. However, up until now, the development of pacing in talented athletes has only been explored in speed skating, and more research is needed.

## Self-regulation of Learning and Training

To reach excellence in endurance sports, it has been suggested that at least 10 years of deliberate practice mounting up to 10,000 hours of training is needed to succeed.[26,27] While the training dose imposed onto a group of youth athletes can be similar in terms of quantity and quality, the response to that training program can vary enormously between athletes.[28] It seems that athletes who exhibit the greatest response to training (ie, those who are most successful in improving their performance over time) are the ones who are eager to learn and train.[29] They take responsibility for their own learning and training process, know which performance characteristics are important for them to develop, are highly motivated to improve, and take action to do so.[30] This goal-driven process is also described as self-regulation of learning and training, consisting of components of metacognition, motivation, and behavior.[31] Self-regulation in general is the extent to which learners exert control over their own learning and training to master a specific task and to excel at it.[32,33]

In terms of pacing, making adequate choices concerning the distribution of the available energy during the race is of utmost importance for success. Self-regulated learners constantly reflect on their learning process to analyze their stronger and weaker skills and reflection may be a marker for talent.[34] This enables them to use prior knowledge and develop strategies for future actions.[33,35] Being able to learn from previous experiences and use them to form and continuously update an adequate performance template has also been mentioned in literature as an important aspect of optimizing pacing behavior.[36] Athletes who are skilled at self-regulation plan their performance in advance, monitor whether they are still on track during the actual performance, and evaluate their performance afterward.[37] This is exactly what is needed for developing a pacing template.[36] We therefore propose that self-regulation is crucial for the development of pacing skills.

## Self-regulation Applied to Pacing: A Proposed Model for Talent Development

To be able to optimally distribute the available energy throughout the race, typical self-regulative skills as described above are important. Therefore, applying the cyclical processes of self-regulation to pacing could provide coaches and athletes with a helpful model to better understand and support the development of the skill of pacing throughout adolescence (Figure 1). It appears that not many coaches have integrated the development of pacing in their programs yet and focus primarily on improving more "overt" performance characteristics in the physiological and technical-skills domains. This also becomes apparent in the complete lack of longitudinal studies focusing on pacing development throughout adolescence in elite talented athletes; there is currently not much scientific knowledge on the development of pacing skills available, that can be used for evidence-based coaching.

Each consecutive race performance is mediated by the mechanism of self-regulation. Conforming to literature on self-regulation[33] and pacing,[36,38] prior experiences are highly relevant in this model. Information from prior races is used as input for the next race, to anticipate on the exercise demand and divide the available energy optimally. Based on increasing experience with the task, athletes build a "performance template."[36] The 3 phases that have been proposed in pacing literature from a meta-cognitive perspective (ie, preceding the race, during the race, and after the race),[39] as well as the forethought, performance, and self-reflection phase from self-regulation literature,[33] are central to our proposed model for development of pacing skills in youth athletes. Early work of Ulmer[40] indicated that motor-learning during heavy exercise includes not only somatosensory control but also metabolic control. To help athletes in building their performance template, trainers can provide feedback on split times during training sessions on a regular basis, and if possible, also during races. It is hypothesized that in this way athletes can learn to couple bodily sensations (eg, perceived exertion, heart rate frequency, breath frequency, fatigue, and pain) to their performance. However, more research is needed to unravel this mechanism. It has been suggested that humans possess a cortical image of homeostatic afferent activity reflecting the physiological condition of the body tissues, located in the dorsal posterior insula.[41] In the right anterior insula, a meta-representation of the primary interoceptive activity is represented, causing a "feeling" on the basis of the homeostatic condition. In the context

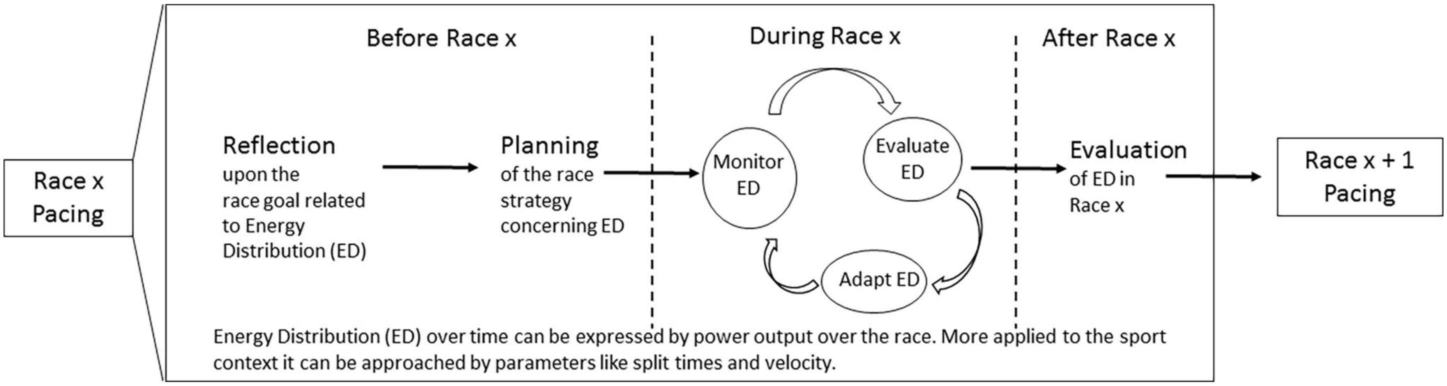


**Figure 1** — The practical model for the development of performance in endurance sports in youth athletes, in which the cyclical process of self-regulation of learning and training is applied to pacing.



of pacing, athletes possibly base part of their pacing decisions on this feeling, that informs them of their momentary homeostatic condition. Brain areas which are subsequently involved in evaluating positive and negative outcomes of behavior engage a specific neural circuitry including the mesencephalic dopamine system and its target areas, the striatum and medial frontal cortex, especially the anterior cingulate cortex (ACC). Feedback expectancy and feedback valence influence the engagement of these brain areas in different ways. Functional magnetic resonance imaging studies show greater ACC activation after unexpected feedback than after expected feedback.[42] This may imply that coaches should offer variation in their feedback. However, more research is warranted to whether this applies to variation in the type of feedback, moment of feedback, et cetera.

While preparing for a race, trainers can stimulate athletes to reflect upon their race goals and plan their strategy beforehand: how to distribute their available energy accordingly? Knowledge of likely demands of the exercise bout, personal goals,[38] and previous experiences[36] are used as input for the next race, to distribute available energy resources over the race most adequately. During the race, the athlete aims to execute the planned pacing strategy but also has to react to unforeseen events. These events can be external environmental factors (ie, changing weather). Also internal factors can have an effect, for example the athlete might feel more fatigued or more pain during the race than expected. Continuously during the race, the athlete monitors and evaluates whether his/her distribution of energy is still optimal for the current situation under the current circumstances. Based on this information, adaptations can be made. In learning how to interpret the rating of perceived exertion (RPE) across the duration of a competition, the product of RPE and the fraction of race distance remaining, also defined as the hazard score, has been suggested to define the likelihood of athletes changing their velocity over the race. It accounts for both the momentary sensations the athlete is experiencing and the relative amount of a competition to be completed.[43] Trainers can make their athletes aware of this.

After the race, a trainer evaluates with the athlete whether energy was distributed optimally, and performance outcomes are considered. This information is the input for the reflection phase of the next race, extending the template. For example, evaluation after race *x* serves as valuable information for the athlete when preparing for race *x* + 1 (see Figure 1). According to this model, competing in multiple races in a variety of environmental circumstances, preferably exploring different pacing strategies, is thus advocated. A study on swimming showed that moderate manipulation of the starting speed during simulated races resulted in positive results in some but not all swimmers.[44] Based on a variety of inputs, the pacing template can be refined by collecting experiences in different situations, which contributes to improvements in performance.

## Pacing and Self-regulation in Head-to-Head Competition

It is important to realize that the proposed model mainly focuses on time-trial events. However, in most middle-distance and endurance events, athletes have to race against opponents to win. Pacing is especially complex in head-to-head competition involving direct opponents. Recent literature has focused on exploring this in several endurance sports: short-track skating,[45,46] rowing,[47] cycling,[48–50] and running.[51] An interdependence between perception and action has been suggested[1,52] that stresses athlete–environment interactions and incorporates the presence of environmental characteristics in decision making and pacing during a race. When competing against direct competitors, where it is first and foremost about winning instead of setting a fastest time, the athlete has to react to unforeseen events: the actions of the opponents. In-competition behavior has been discussed from an ecological perspective,[1,52] but can also be approached using the concept of self-regulation. In the context of self-regulation, it has been suggested that pacing requires both proactive, goal-driven processes and reactive, stimulus-driven processes.[39] This fits with the introduction of deliberate and intuitive processes in the context of pacing and performance.[53] In head-to-head competition, athletes need to learn through experience how to adequately plan their race, but also how to respond to stimuli: Which are the relevant cues from the environment to act upon when unexpected situations emerge? Athletes can benefit from "collecting" experiences such as racing against a variety of opponents, under a variety of different circumstances, that optimally prepare them for adequate actions in the next race. From a proactive, deliberate viewpoint, it could be proposed that athletes can benefit from anticipating the actions of their opponents by preparing for a range of likely scenarios that may occur while racing. Previous evaluations of experiences related to successful or unsuccessful actions associated with the opponent can be used to optimize the planning for the next race.

## Conclusion

With literature on the development of pacing in talented athletes being scarce, there is a need to further explore the suggestion that pacing is a marker for talent. Brain areas relevant for self-regulational aspects of pacing are under development in adolescents, and experience has been determined to be one of the crucial aspects for developing the skill to adequately pace your race. To optimally develop the formation of a pacing template and stimulate the relevant brain areas, coaches are advised to experiment with a variety of pacing strategies and with providing feedback in different ways. Trainers can play an important role in the development of pacing by applying the principles of self-regulation in their programs. We connected literature on pacing to literature on self-regulation of learning resulting in a model for talent development in endurance sports. The model can be used by trainers and coaches to improve talent development programs.

## References


1. Smits BL, Pepping GJ, 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;44:763–775. PubMed doi:10.1007/s40279-014-0163-0
2. Foster C, de Koning JJ, Hettinga FJ, et al. Pattern of energy expenditure during simulated competition. *Med Sci Sports Exerc*. 2003;35(5):826–831. PubMed doi:10.1249/01.MSS.0000065001.17658.68
3. Stoter IK, MacIntosh BR, Fletcher JR, Pootz S, Zijdewind CAT, Hettinga FJ. Pacing strategy, muscle fatigue and technique in 1500m speed skating and cycling time-trials. *Int J Sports Physiol Perform*. 2016;11:337–343. PubMed doi:10.1123/ijspp.2014-0603
4. Hettinga FJ, de Koning JJ, Schmidt LJI, Wind AC, MacIntosh B, Foster C. Optimal pacing strategy: From theoretical modelling to reality in 1500-m speed skating. *Br J Sports Med*. 2011;45(1):30–35. PubMed doi:10.1136/bjsm.2009.064774
5. Van Ingen Schenau GJ, De Groot G. On the origin of differences in performance level between elite male and female speed skaters. *Hum Mov Sci*. 1983;2:15l–159. doi:10.1016/0167-9457(83)90013-1
6. Konings MJ, Elferink-Gemser MT, Stoter IK, van der Meer D, Otten E, Hettinga FJ. Performance characteristics of long-track speed skaters: a literature review. *Sports Med*. 2015;45(4):505–516. PubMed doi:10.1007/s40279-014-0298-z
7. Foster C, Rundell KW, Snyder AC, et al. Evidence for restricted muscle blood flow during speed skating. *Med Sci Sports Exerc*. 1999;31(10):1433–1440. PubMed doi:10.1097/00005768-199910000-00012
8. Wiersma R, Stoter IK, Visscher C, Hettinga FJ, Elferink-Gemser MT. Development of 1500m pacing behavior in junior speed skaters: a longitudinal study [advance online publication March 2, 2017]. *Int J Sports Physiol Perform.* https://doi.org/10.1123/ijspp.2016-0517 PMID:28253043
9. Muehlbauer T, Schindler C, Panzer S. Pacing and performance in competitive middle-distance speed skating. *Res Q Exerc Sport*. 2010;81(1):1–6. PubMed doi:10.1080/02701367.2010.10599622
10. Scruton A, Baker J, Roberts J, Basevitch I, Merzbach V, Gordon D. Pacing accuracy during an incremental step test in adolescent swimmers. *Open Access J Sports Med*. 2015;6:249. PubMed
11. Skorski S, Faude O, Rausch K, Meyer T. Reproducibility of pacing profiles in competitive swimmers. *Int J Sports Med*. 2013;34(2):152–157. PubMed
12. Dormehl S, Osborough C. Effect of age, sex, and race distance on front crawl stroke parameters in subelite adolescent swimmers during competition. *Pediatr Exerc Sci*. 2015;27(3):334–344. PubMed doi:10.1123/pes.2014-0114
13. Malina RM, Bouchard C, Bar-Or O. *Growth, Maturation, and Physical Activity*. Champaign, IL: Human Kinetics; 2004.
14. Gabbard C. *Lifelong Motor Development*. San Francisco: Benjamin Cummings; 2004.
15. Allen SV, Hopkins WG. Age of peak competitive performance of elite athletes: a systematic review. *Sports Med*. 2015;45:1431–1441. PubMed doi:10.1007/s40279-015-0354-3
16. Crone EA, Dahl RE. Understanding adolescence as a period of social–affective engagement and goal flexibility. *Nat Rev Neurosci*. 2012;13(9):636–650. PubMed doi:10.1038/nrn3313
17. Strle T. Metacognition and decision making: between first and third person perspective. *Interdisc Description of Complex Systems*. 2012;10(3):284–297. doi:10.7906/indecs.10.3.6
18. Tomporowski PD, McCullick B, Pendleton DM, Pesce C. Exercise and children's cognition: the role of exercise characteristics and a place for metacognition. *J Sport Health Sci*. 2015;4(1):47–55. doi:10.1016/j.jshs.2014.09.003
19. Bourgeois JP, Goldman-Rakic PS, Rakic P. Synaptogenesis in the prefrontal cortex of rhesus monekeys. *Cereb Cortex*. 1994;4:78–96. PubMed doi:10.1093/cercor/4.1.78
20. Rubia K, Russell T, Overmeyer S, et al. Mapping motor inhibition: conjunctive brain activation across different versions of go/no-gp and stop tasks. *Neuroimage*. 2001;13:250–261. PubMed doi:10.1006/nimg.2000.0685
21. McCabe LA, Cunnington M, Brooks-Gunn J. The development of self-regulation in young children: individual characteristics and environmental contexts. In: Baumeister RF, Vohs K, eds. *Handbook of Self-regulation: Research, Theory and Applications*. New York: Guilford Press; 2004:340–356.
22. Veenman VJ, Spaans MA. Relation between intellectual and metacognitive skills: age and task differences. *Learn Individ Differ*. 2005;15:159–176. doi:10.1016/j.lindif.2004.12.001
23. van der Stel M, Veenman MVJ. Relation between intellectual ability and metacognitive skillfulness as predictors of learning performance of young students performing tasks in different domains. *Learn Individ Differ*. 2008;18:128–134. doi:10.1016/j.lindif.2007.08.003
24. 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):362–369. PubMed doi:10.1249/MSS.0b013e31822cc9ec
25. Abbiss CR, Laursen PB. Describing and understanding pacing strategies during athletic competition. doi:10.2165/00007256-200838030-00004
26. Ericsson KA. Development of elite performance and deliberate practice: an update from the perspective of the expert performance approach. In: Starkes JL, Ericsson KA, eds. *Expert Performance in Sports: Advances in Research Expertise*. Champaign, IL: Human Kinetics; 2003:49–87.
27. Ericsson KA, Krampe RT, Tesch-Römer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev*. 1993;100:363–406. doi:10.1037/0033-295X.100.3.363
28. Elferink-Gemser MT, Visscher C, Lemmink KAPM, Mulder T. Multidimensional performance characteristics and performance level in talented youth field hockey players: a longitudinal study. *J Sports Sci*. 2007;25:481–489. PubMed doi:10.1080/02640410600719945
29. Elferink-Gemser MT, Jordet G, Coelho-E-Silva MJ, Visscher C. The marvels of elite sports: How to get there? *Br J Sports Med*. 2011;45(9):683–684. PubMed doi:10.1136/bjsports-2011-090254
30. Toering TT, Elferink-Gemser MT, Jordet G, Visscher C. Self-regulation and performance level of elite and non-elite youth

soccer players. *J Sports Sci*. 2009;27:1509–1517. PubMed doi:10.1080/02640410903369919

31. Jonker L, Elferink-Gemser MT, Tromp EJY, Baker J, Visscher C. Psychological characteristics and the developing athlete. the importance of self-regulation. In: Baker J, Farrow D, eds. *Routledge Handbook of Sport Expertise*. London, New York: Routledge Taylor & Francis Group; 2015:317–328.
32. Zimmerman BJ. Becoming a self-regulated learner: Which are the key subprocesses? *Contemp Educ Psychol*. 1986;11:307–313. doi:10.1016/0361-476X(86)90027-5
33. Zimmerman BJ. Development and adaptation of expertise: the role of self-regulatory processes and beliefs. In: Ericsson KA, Charness N, Feltovich PJ, Hoffman RR, eds. *The Cambridge Handbook of Expertise and Expert Performance*. New York: Cambridge University Press; 2006:705–722. doi:10.1017/CBO9780511816796.039
34. Toering TT, Elferink-Gemser MT, Jordet G, Pepping GJ, Visscher C. Self -regulation of Learning and performance level of elite youth soccer players. *Int J Sport Psychol*. 2012;43:312–325.
35. Ertmer PA, Newby TJ. The expert learner: strategic, self-regulated, and reflective. *Instr Sci*. 1986;24:1–24. doi:10.1007/BF00156001
36. Foster C, Hendrickson KJ, Peyer K, et al. Pattern of developing the performance template. *Br J Sports Med*. 2009;43:765–769. PubMed doi:10.1136/bjsm.2008.054841
37. Jonker L, Elferink-Gemser MT, Visscher C. Differences in self-regulatory skills among talented athletes: the significance of competitive level and type of sport. *J Sports Sci*. 2010;28:901–908. PubMed doi:10.1080/02640411003797157
38. Edwards AM, Polman RC. Pacing and awareness: brain regulation of physical activity. *Sports Med*. 2013;43:1057–1064. PubMed doi:10.1007/s40279-013-0091-4
39. Brick NE, MacIntyre TE, Campbell MJ. Thinking and action: a cognitive perspective on self-regulation during endurance performance. *Front Physiol.* 2016;27,7:159. doi:10.3389/fphys.2016.00159
40. Ulmer HV. Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psychophysiological feedback. *Experientia*. 1996;52(5):416–420. PubMed doi:10.1007/BF01919309
41. Craig AD. Interoception: the sense of the physiological condition of the body. *Curr Opin Neurobiol*. 2003;13(4):500–505. PubMed doi:10.1016/S0959-4388(03)00090-4
42. Ferdinand NK, Opitz F. Different aspects of performance feedback engage different brain areas: disentangling valence and expectancy in feedback processing. *Sci Rep*. 2014;4:5986 doi:10.1038/srep05986. PubMed
43. 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. PubMed
44. Skorski S, Faude O, Abbiss CR, Caviezel S, Wengert N, Meyer T. Influence of pacing manipulation on performance of juniors in simulated 400-m swim competition. *Int J Sports Physiol Perform*. 2014;9(5):817–824. PubMed doi:10.1123/ijspp.2013-0469
45. Noorbergen OS, Konings MJ, Elferink-Gemser MT, Micklewright D, Hettinga FJ. Pacing and tactical positioning in 500 and 1000m short-track speed skating. *Int J Sports Physiol Perform*. 2016;11(6):742–748. PubMed doi:10.1123/ijspp.2015-0384
46. Konings MJ, Noorbergen OS, Parry D, Hettinga FJ. Pacing behaviour and tactical positioning in 1500 m short-track speed skating. *Int J Sports Physiol Perform*. 2016;11(1):122–129. PubMed doi:10.1123/ijspp.2015-0137
47. Edwards AM, Guy J, Hettinga FJ. Oxford and Cambridge Boat Race: performance, pacing and tactics between 1890 and 2014. *Sports Med*. 2016;46(10):1553–1562. PubMed doi:10.1007/s40279-016-0524-y
48. Konings MJ, Schoenmakers PP, Walker A, Hettinga FJ. The behavior of an opponent alters pacing decisions in 4-km cycling time trials. *Physiol Behav*. 2016;158:1–5. PubMed doi:10.1016/j.physbeh.2016.02.023
49. 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;43:770–774. PubMed doi:10.1136/bjsm.2008.056416
50. Williams EL, Jones HS, Sparks SA, Marchant DC, Midgley AW, McNaughton LR. Competitor presence reduces internal attentional focus and improves 16.1km cycling time trial performance. *J Sci Med Sport*. 2015;18:486–491. PubMed doi:10.1016/j.jsams.2014.07.003
51. Renfree A, Mytton GJ, Skorski S, St Clair Gibson A. Tactical considerations in the middle distance running events at the 2012 Olympic Games. *Int J Sports Physiol Perform*. 2014;9(2):362–364. PubMed doi:10.1123/ijspp.2013-0020
52. Hettinga FJ, Konings MJ, Pepping G-J. The science of racing against opponents: affordance competition and the regulation of exercise intensity in head-to-head competition. *Front Physiol*. 2017;8:118. PubMed doi:10.3389/fphys.2017.00118
53. Micklewright D, Kegerreis S, Raglin J, Hettinga F. The conscious-subconscious pacing quagmire: Will it help elucidate the mechanisms of self-paced exercise? *Sports Med*. 2017;47(7):1231–1239. PubMed