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

Article *in* International journal of sports physiology and performance · June 2017

DOI: 10.1123/ijspp.2017-0080

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Pacing and self-regulation: Important skills for talent development in endurance sports

Submission type: invited commentary

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Preferred running head: Pacing and self-regulation in youth athletes

Abstract word count: 242
Text only word count: 1999
Number of Figures: 1 figure
Number of Tables: 0 tables

Available at: http://journals.humankinetics.com/doi/abs/10.1123/ijspp.2017-0080

Abstract

Pacing has been characterized as a multi-faceted 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 as well as psychological characteristics associated with adequate pacing and performance are known to develop with age. Consequently, the multi-faceted skill of pacing might be under construction throughout adolescence as well. Therefore, we 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, we aim to bring together literature on pacing as well as literature on talent development and self-regulation of learning. Subsequently, by applying the cyclical process of self-regulation to pacing, we 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, 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, sport

Pacing in endurance sports

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[2,3,4]. For example in speed skating, a technically/biomechanically favorable crouched posture (i.e., 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 multi-faceted skill of pacing can be considered a marker for talent. In youth athletes, data on development of pacing strategies are scarce. So far, only one 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 towards the pacing strategies observed in world-class senior elite athletes, i.e., they were able to maintain their velocity high towards 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 as well as 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 on sub-elite swimmers showed that swimmers aged 12-14 as well as 15-18 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 characteristics as well as 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 thirty[14], peak performance in middle distance endurance events is reached at younger ages[15]. Maturing athletes 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 towards 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 four to six 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-minutes 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 13-18 years, pacing strategies between younger and older athletes differed. In particular the elite junior speed skaters improved their pacing strategies over time towards a profile observed in elite speed skaters whereas the non-elite 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 multi-faceted 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 towards 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 ten 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, i.e., 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 afterwards[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.

****Figure 1 *****

Each consecutive race performance is mediated by the mechanism of self-regulation. Conform 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 three phases that have been proposed in pacing literature from a meta-cognitive perspective (i.e., 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 (1996)[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 (e.g., 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 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 behaviour 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. FMRI 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 etcetera.

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 (i.e., 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 as well as 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[48,49,50] 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 pro-active, 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 pro-active, deliberate viewpoint, it could be proposed that athletes can benefit from anticipating the actions of their opponents by preparing for a range of likely 'scenario's 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.

Author contributions:

FH and MEG have both contributed to conception and design of the work. Both authors drafted the work, and revised it critically for important intellectual content.

All authors have approved the final version of the manuscript, agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved, and all persons designated as authors qualify for authorship, and all those who qualify for authorship are listed.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding:
Authors have not received any funding.

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Figure captions:

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.

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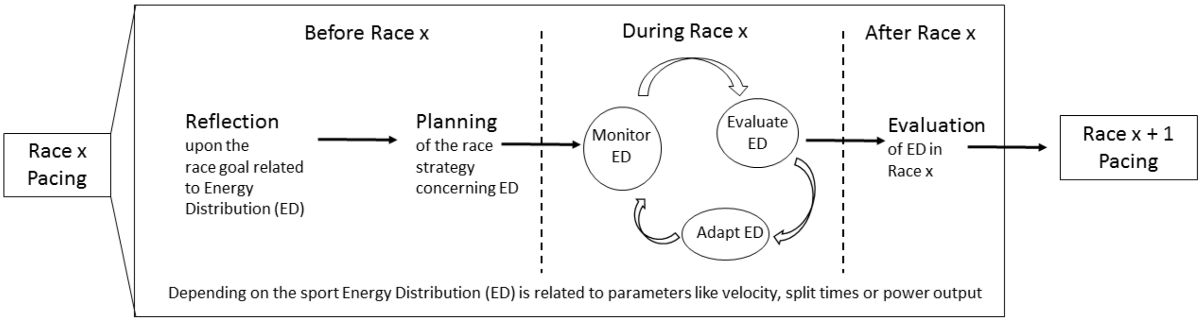

Race x
Pacing
Before Race x
During Race x
After Race x
Reflection
upon the
race goal related
to Energy
Distribution (ED)
Planning
of the race
strategy
concerning ED
Monitor
ED
Evaluate
ED
Adapt ED
Evaluation
of ED in
Race x
Race x + 1
Pacing
Depending on the sport Energy Distribution (ED) is related to parameters like velocity, split times or power output