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Athletics and executive functioning: How athletic participation and sport type correlate with cognitive performance

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ABSTRACT

Objectives: This study aims to further the knowledge regarding the documented link between physical exercise and cognitive function. Specifically, we examined the relationship between the type and level of sports in which college students participate and their executive functioning (EF).
Design: We utilized a 3-way quasi-experimental design, and grouped participants by athletic status (athlete or non-athlete), sport type (self-paced, externally paced, or non-athlete; see Singer, 2000), and level (high-skilled or recreational).
Methods: We evaluated EF by administering a battery of validated tests of decision making, problem solving, and inhibition.
Results: We found that athletes scored higher on some of the EF measures than non-athletes. Furthermore, we observed that scores varied by sport type according to which subset of EF each test measured. Self-paced athletes scored highest on an inhibition task, and externally paced athletes scored highest on a problem-solving task.
Conclusions: Our results suggest that athletes outperform non-athletes on tests of such EF domains as inhibition and problem solving, and that different types of athletic experience may correlate with higher levels of particular EF domains.

Many researchers have sought to explore the ways the body and mind influence one another. Recent studies (e.g., Keating, Castelli, & Ayers, 2013) have established a link between exercise and cognitive proficiency. After sessions of acute physical exercise, people tend to score higher on cognitive tests than when they have not exercised (Etnier & Chang, 2009). Of more significance to our study, elite athletes appear to perform with higher proficiency on tasks testing executive functioning (EF), a subcategory of cognitive functioning (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). Situations that require EF include activities that involve effortful problem solving, inhibition, planning, or vigilance (Diamond, 2006). Executive functions are highly utilized both in goal-oriented action under distraction and in novel response production when habitual dominant responses are apparent (Unsworth et al., 2009). Researchers break EF into more specific mental capacities such as problem solving, planning, inhibition, and decision making, in order to operationally measure it (Diamond, 2006; Spreen & Strauss, 1998). Researchers have been assessing both the relationship between exercise and EF, and the relationship between sport training and cognition, and many researchers are working to unite these two related lines of research (Pesce, 2012). To our knowledge, no previous researchers have tested hypotheses regarding the relationship between EF and specific types of sports; we aim to examine this relationship in our study. We seek to illuminate the relationship between sports and cognitive performance, which may have implications for athletic programs and physical education. If certain sports correlate with higher cognitive ability more than others, then physical educators, coaches, and policy-makers may seek to emphasize certain activities in athletics and throughout development.

The documented differences in EF performance between elite athletes and non-athletes (e.g., Vestberg et al., 2012) may be attributed to cognitive skill transfer (CST), the process by which training in a cognitive task may improve performance on related untrained cognitive tasks. Various models for how CST works have been proposed, and, although they differ, most theorists agree that every task consists of many skills and/or pieces of knowledge, and

Abbreviations: EF, executive functioning; CST, cognitive skill transfer; DM, decision making; DMA, decision-making accuracy; DMS, decision-making speed; PS, problem solving; MPS, mental processing apeed; SP, self-paced; EP, externally paced.

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that tasks that share more skills and knowledge will have the strongest transfer effects in both the short and longterm (Taatgen, 2013). Researchers disagree on how "far" these skills can transfer; that is, the degree of difference between two given tasks for which transfer effects may be present. For example, chess players appear to have improved working memory capacity with regard to arrangements of chess pieces, but their overall working memory is normal (Chase & Simon, 1973). This finding supports the "narrow transfer" hypothesis: the idea that individuals with expertise in a particular field may have superior cognitive processes within that field, but not necessarily outside of it (Furley & Memmert, 2011). Contradictorily, video game training appears to cause improvements in scores on laboratory reaction time tests (Green, Pouget, & Bavelier, 2010). This finding supports the "broad transfer" hypothesis: the theory that extensive practice of context-specific skills improves individual components of cognition, and that these improvements are present regardless of context (Furley & Memmert, 2011).

With regard specifically to sports, a parallel debate is ongoing. Voss, Kramer, Basak, Prakash, and Roberts (2010) made a distinction between two paradigms for analyzing improved cognition in athletes. Researchers using the "expert performance" approach have investigated the idea that athletes have improved cognition within their sport (e.g., Mann, Williams, Ward, & Janelle, 2007; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996). On the other hand, proponents of the "cognitive component skills" approach assert that athletes improve in specific cognitive skills, which are present in non-sport contexts and can be measured in the laboratory (Voss et al., 2010). Although much research has supported this idea with respect to skills like attention (Anzeneder & Bosel, 1998; Pesce, Cereatti, Casella, Baldari, & Capranica, 2007), many studies have found no benefits for athletes on related cognitive skills (e.g., Lum, Enns, & Pratt, 2002). Research on the transfer of EF skills from athletics is sparse (Voss et al., 2010); we propose that differences in EF may be present between athletes and non-athletes, and that CST may play a role in this.

Researchers have employed various methods in the pursuit of improving EF (e.g., Diamond & Lee, 2011; Kesler et al., 2013). In a study of disabled athletes (Di Russo et al., 2010), the researchers suggested that overall EF was lower in physically disabled populations, and that playing certain sports such as basketball, in which the athlete interacts with his/her environment on a constantly changing basis, may reduce this deficit by promoting response flexibility. On the other hand, sports like swimming, where athletes are not thinking creatively or reacting to time-pressured stimuli, did not seem to benefit participants in this manner (Di Russo et al., 2010). These results indicate that different types of sports may differentially facilitate EF improvements. Contrastingly, in a meta-analysis of fitness training and cognitive function (Colcombe & Kramer, 2003), the authors suggested that particularly aerobic fitness training is likely to have positive effects on EF. In our study, we aim to address not only the effects of mere aerobic exercise on cognition, but also the sport-specific mental skills that may be related to differences in particular aspects of EF.

In a literature review of sports psychology (Singer, 2000), focused on improving performance, the researcher asserted that sports could be classified into two categories: self-paced (SP) and externally paced (EP). Sports like bowling, golf, and running, as well as aspects of sports like baseball pitches and tennis serves, were classified as SP because they allow time for the athletes to prepare themselves for critical actions and perform at a pace they control. Sports like soccer, basketball, and volleyball require adaptability and quick decision making in response to external cues, and are labeled as EP. Two sub-categories of EP sports are interceptive sports, such as racquet sports, and strategic sports, or sports which involve multiple teammates and opponents and tactical formations (Mann et al., 2007). The EP vs. SP sport distinctions were based partly upon Singer's (1988) experiment, geared towards understanding how to improve performance in self-paced athletics. Later, Singer (2000) developed a strategy to improve performance in EP sports, highlighting attention and decision making. EP athletes, especially those playing at a high level, may have faster and more accurate decision-making processes (Singer et al., 1996; Zoudji, Thon, & Debû, 2010). We theorized that the categorical distinction between self- and externally paced athletes would correspond to differential performances on EF tasks testing skills like inhibition and decision making.

Furthering the notion of athletics correlating with higher levels of cognitive performance, Vestberg et al. (2012) evaluated the relationship between EF and athletic ability in a healthy population of elite athletes (Swedish professional soccer players) and non-athletes. They compared the participants' scores on tasks measuring creativity, inhibition, and cognitive flexibility, finding significant variation between two levels of athletes and a control group of non-athletes (Vestberg et al., 2012). These results indicate a positive correlation between EF and athletic ability. Based on this finding, we drew a distinction in our study between high-skilled and recreational athletes; we expected that athletes with more expertise would score higher on EF tests. In the Swedish study, the researchers later tracked the athletes through two seasons and analyzed their goal and assist statistics (the most objective measure of soccer success). They found that players who had scored higher on the EF tasks scored and assisted more goals than those who had not performed as well on the tasks (Vestberg et al., 2012). Therefore, high EF may predict athletic success in EP sports like soccer.

Below, we elaborate on the facets of executive functioning that we expected to correlate most strongly with each of the classifications of athletics. These constructs include decision making (DM), problem solving (PS), and inhibition. Decision making is "the cognitive process of choosing between two or more alternatives, ranging from the relatively clear cut … to the complex" (VandenBos, 2006, p. 259). It utilizes the executive functions of shifting, planning, and categorization (Brand et al., 2005). Adaptive decision making has been closely linked with higher-level EF in military leaders (Hannah, Balthazard, Waldman, Jennings, & Thatcher, 2013). Because EF has such a strong association with DM, we predicted that the higher EF seen in athletes (Vestberg et al., 2012) would correlate with improvements in their DM abilities.

Problem solving is "the process by which individuals attempt to overcome difficulties, achieve plans that move them from a starting situation to a desired goal, or reach conclusions through the use of higher mental functions, such as reasoning and creative thinking" (VandenBos, 2006, p. 735). The relationship between EF and PS is well documented (e.g., Harris, 2001; Kotsopoulos & Lee, 2012). PS highly utilizes shifting and updating, two widely accepted foundational executive functions (Diamond, 2013; Kotsopoulos & Lee, 2012). Improvements in EF appear to correlate with improved PS abilities in healthy college students (Wen, Butler, & Koutstaal, 2012). Because of this direct link to EF we predicted that, as with DM, the documented EF proficiency seen in EP athletes (Vestberg et al., 2012) would correlate with higher PS abilities.

Inhibition is "the suppression of covert responses in order to prevent incorrect responses" (VandenBos, 2006, p. 481). Inhibition is a stand-alone executive function according to a number of theorists (e.g., Diamond, 2006; Kotsopoulos & Lee, 2012). Multiple types and definitions of inhibition exist (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000); in this study we focus on the suppression of dominant or prepotent responses. Inhibition correlates moderately with other executive functions like shifting and updating, but the functions are separable and differentially contribute to performance on complex executive tasks (Miyake et al., 2000). Inhibition can be bettered through practice; in a