

# The Physiological Nature of Mental Fatigue: Current Knowledge and Future Avenues for Sport Science

“Fatigue” is described as a physiological destination, a perception or emotion, and an important mechanism to minimize physical injury, but also as an experimental concept, a symptom, a risk, a cause, and a consequence.<sup>1</sup> This abundance of definitions and concepts of fatigue is due to the widespread dissemination and overall division of this phenomenon throughout different research fields and professions. In a sport and exercise science context, which is the focus of the *International Journal of Sports Physiology and Performance* (IJSP), fatigue is an elusive concept that can be induced both cognitively and physically. The twin domains of fatigue have important implications for human performance.

Over the last decade, “mental fatigue” has gained significant attention. This construct can be defined as a psychobiological state induced during prolonged demanding cognitive activity and results in a subjective feeling of tiredness, decreased cognitive capacity, and/or altered brain activation.<sup>2</sup> Mental fatigue is a clearly established construct in daily life: It can ensue after only limited amounts of cognitive work and increases the risk of errors in, among other professions, surgeons, industry workers, and air traffic controllers.<sup>3</sup> Regarding sport performance, it affects not only cognitive aspects such as attention but also physical aspects such as endurance<sup>4</sup> and sport-specific psychomotor performance.<sup>5</sup> The exact nature of these changes in performance remains to be elucidated, since peripheral measurements such as blood lactate, heart rate, and neuromuscular function remain largely unaffected by mental fatigue. The most consistent change as a result of mental fatigue is the increase in the rating of perceived exertion.<sup>4</sup>

One hypothesized mechanism behind the occurrence and effects of mental fatigue is accumulation of adenosine in the brain. It has indirectly been shown that the concentration of cerebral adenosine rises because of mental exertion.<sup>6</sup> This increase inhibits presynaptic neurotransmitter releases and neuronal firing, essentially diminishing neural activity in task-specific brain areas. A brain area commonly connected to task-specific mental fatigue activation is the prefrontal cortex, specifically the anterior cingulate cortex. This area of the brain is responsible for many important cognitive functions, including emotional control, planning, attention, and self-regulation. The prefrontal cortex has been implicated as an important area in exercise decision making, for example, the decision to stop exercising because of an increase in effort.<sup>7</sup> Moreover, adenosine may affect motivation during specific tasks, as it can inhibit the release of dopamine and modify the affinity of dopamine receptors.<sup>6</sup> Although this is a promising hypothesis, direct evidence should be gathered to confirm it.

Studies into the effects of mental fatigue have remained mostly fundamental in design. While this is important, their practical application is often overlooked. Research into the occurrence of mental fatigue during actual competition, and the practical implications this has on performance, is still in its infancy. A very small number of studies have already quantified the evolution of mental fatigue throughout a competition, training camp, or season,<sup>8–10</sup> while others have attempted to identify the possible causes behind the

appearance of mental fatigue.<sup>11</sup> These trials confirmed that mental fatigue can rise during a multiday competition (eg, padel) and during a regular season in a team sport (eg, netball). It is important to note that athletes can differentiate mental fatigue from physical fatigue, highlighting that mental fatigue is a largely separate construct from physical fatigue.<sup>9,12</sup> Several factors have been identified that potentially play a role in the manifestation of mental fatigue, with financial and sporting pressure, in addition to expectations and social media, and travel and fixture planning, as important triggers. However, a lot more work needs to be done, and it is time for research groups examining mental fatigue in sport science to go beyond the fundamental angle and design research to understand this phenomenon within the practical realm of sport performance. For example, while some studies have already examined the role of different countermeasures to combat mental fatigue, these studies did not attempt to translate these results to the real world. Not only is it important that valid measurement tools be further developed to quantify mental fatigue in practical settings, but we also still need to understand the exact nature and causes of this phenomenon outside of a laboratory environment. Moreover, we must not forget that the performance of all humans can be impacted by mental fatigue, which means that every person employed in professions related to sport performance is at risk. It is therefore important that coaches, clinicians, players, and other relevant personnel be adequately informed on the nature of this phenomenon and how to identify and counter it. IJSP is a prime vehicle to publish and communicate these efforts to the sporting community.

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