MIGUEL ZERAN, MS, CSCS

CREATINE SUPPLEMENTATION—A METHOD TO SUPPORT BRAIN HEALTH AND COGNITIVE FUNCTION IN THE TACTICAL PROFESSION

INTRODUCTION

Tactical athletes often must perform under stress, under observation, under orders, under time constraints, under load, under-nourished, and under-slept. They have done it all and will continue to do it all to complete the mission. Regularly, these individuals are exposed to situations and scenarios that require high cognitive demand. Additionally, their daily duties, training, and operations put them at risk for impacts to the head (sub-concussive; concussive; and mild, moderate, and severe traumatic brain injury [TBI]). The same level and attention to maintenance performed on their truck, gear, or guns must be applied to their own most powerful weapon, the brain. Creatine supplementation might be a great additive to their arsenal for cognitive performance enhancement and overall neuroprotection.

AN EXPLANATION AND OVERVIEW OF CURRENT CREATINE SUPPLEMENTATION

As the most heavily studied and scientifically supported ergogenic aid, the amino acid creatine takes a place of high importance in the lives and training of all tactical athletes. Endogenous, or naturally occurring, creatine is synthesized in the pancreas, liver, and kidneys from methionine, glycine, and arginine. One to two grams are synthesized daily, and around 95% of this creatine is moved out of these organs and into the muscles, with the remaining percentage distributed between the kidneys, testes, and brain (16). While most creatine is found in skeletal muscle, the brain accounts for approximately 20% of the body's energy consumption, and this high metabolic activity drives creatine needs (19).

A recent review on creatine use for physical performance enhancement included the analysis and synthesis of 180 research articles (29). This review explained that creatine's benefits are supported by research, which showed supplementation could lead to increased strength, improved work capacity, elevated force output, augmented recovery, enhanced power output, increased anaerobic threshold, and improved training adaptations (29). These benefits apply predominantly to short duration, power, and anaerobic exercise. When examining creatine from a purely ergogenic standpoint, what can be inferred is that taking creatine closer in time to exercise (i.e., immediately pre or immediately post exercise) appears to provide greater benefit than when taken hours before or hours after physical training (17). Exercise, in general, can enhance muscle creatine accrual, however, when creatine is taken supplementarily, high-dosing (20 g/day for 5 – 7 days) and chronic low dosing (3 – 5 g/day for 28 days) both produce the same muscle creatine saturation (17).

A systematic review on creatine illustrated its benefits on heart disease reduction, managing blood lipid/triglycerides/cholesterol levels, enhancing glycemic control, attenuation of certain forms of cancer, enhancing cognitive function in aging adults, providing antioxidant actions, and increasing muscle size and strength (8). The key takeaway is that these general health improvements are seen with the dosing of at least three grams of creatine supplementation a day.

WHY COGNITIVE FUNCTION MATTERS

Any endeavor that includes tactical planning, anticipation, quick-reaction, adaptation, and analytical decision-making demands a high amount of cognitive performance. Success or failure on for tactical athletes can often be determined by an individual's ability to out-think the opponent. The greatest contributor to training and battle-related accidents is cognitive impairment since cognition declines at a faster rate than physical function during continuous operations (9). Any recurring or persistent demand, such as those seen in military and first responder training, combat actions, fire ground actions, and life-saving operations, can lead to an energy crisis in the brain and the associated lapses in attention and cognitive function (7). The recurring and persistent exposure to high cognitive demand coupled with stress has been linked to decrements in impulse control, maintaining focus, and reaction time, all of which are vital to success in tactical scenarios (7). Decreased unit cohesion, as a result of morale or motivation, are other damaging results of impaired cognitive function.

The maintenance of effective cognitive performance is a necessity for tactical athletes where sub-optimal performance has serious consequences (12). Military and tactical operations often require high physical and cognitive performance levels under fatigued conditions. Research on the relationship between combat-related tasks and fatigue illustrated that when individuals reached high levels of fatigue, measured as "pursue and shoot" efforts lasting for 20 minutes at a rate of perceived exertion of >6.5, they stopped chasing the target sooner, took longer to aim, and and shot at the target with less frequency (14). These findings indicate that physiological parameters, such as fatigue, can influence perception, situational awareness, and transitions between different actions. Lastly, the majority of the mishaps that occur during combat, training, and formal instructional courses are the result of impaired cognitive performance (28).

THE PREVALENCE OF TBI IN THE TACTICAL WORLD

According to recent research, most firefighters have sustained at least one career head injury that led to mild TBI (mTBI) (24).

The Department of Defense's numbers as of 2021 state that more than 383,000 service members have been diagnosed with a TBI (23). "Career breachers" in law enforcement and the military who were exposed to repeated and numerous low-level blasts exhibited changes in the brain that included inflammation and brain injury (23). An Federal Bureau of Investigation (FBI) study found that there were 505 non-fatal and 482 fatal head, neck, and throat injuries in the United States police force from 1998 – 2013 (4). The issue was so prevalent that in 2020, the Second Session of the 116th Congress House of Representatives passed a bill (H.R. 6008 – "TBI and PTSD Law Enforcement Training Act") to increase the training, awareness, and resources available to first responders regarding interacting with persons who have a TBI and the surveillance and reporting of first responders who sustain concussions or experienced TBIs.

Jobs in the tactical profession at risk for mTBI or worse include breacher, combatives guru, parachutist, hand crew, corrections specialist, Specal Operations Forces (SOF) officer, Special Weapons and Tactics (SWAT) officer, admin clerk, desk jockey, training chief, or supervisor. Throughout their career, there is a high likelihood that they already have, or will have, sustained sub-concussive and concussive impacts alike from fists, floors, falling debris, crashes, or blast waves. TBI literature links brain injury to post-concussive symptoms, greater risk and incidence of PTSD, depression, and the coping mechanisms around "self-medication" (21,26). Growing amounts of research suggest that the persistent damage to and atrophy of white and gray brain matter that results from a solitary TBI not only increases the probability that an individual will develop motor neuron disease, Alzheimer's disease, or Parkinson's disease, but also advances the neurodegeneration associated with the aging process (13).

WOMEN MAY BE AT GREATER RISK

Emerging literature is highlighting the sex-specific differences in head trauma mechanisms, severity, hormone response, and chronic complications between women and men. Several investigators and leading research institutes such as the National Institutes of Health, the Center for Neuroscience and Regenerative Medicine, and the Defense and Veterans Brain Injury Center, are calling for education, rehabilitation, return to play/duty, and immediate post-injury protocols to be sex-specific due to the very real differences observed in female concussions (27). Work in this field has been done with several models and has investigated college-aged sports players and the mechanisms (e.g., neck strength, hormone levels, menstrual cycle, brain and axon sizes, susceptibility to damage) that contribute to the differences in concussion outcomes; however, this subject is still undergoing active research and review to better understand mitigation and recuperation measures that focus specifically on women. As both a function of dietary intake and relative muscle mass, females have 70 – 80% fewer endogenous creatine stores than their male counterparts (21). This low creatine status is one potential contributor to the sex-specific differences seen in female and male concussion and TBI signs and symptoms. Thus, females may have a greater risk of concussion incidence and severity than males. Current research illustrated that women have worse post-concussion syndrome than males post-injury and have a higher post-TBI mortality rate (3.4% compared to 1.6% in males) (11). However, it should be noted that there are a host of female/male differences in dopamine, microglia, and steroid reactions post-TBI; creatine status may be one small part of a much larger equation.

WHAT THE RESEARCH SAYS REGARDING CREATINE AND THE BRAIN

Numerous clinical studies (controlled trials) and literature reviews (meta-analyses) support creatine monohydrate for use in performance enhancement, cognitive function, and mild or moderate TBI protection/rehabilitation (1,2,3,4,5,6,8,15,16,17,18,19,22,29). Emerging research explained that the current body of literature strongly supports creatine supplementation to improve cognitive function and processing during instances of acute stressors (e.g., sleep deprivation, exercise, high cognitive load/mental demand) or chronic maladies (e.g., depression, mTBI, Alzheimer's disease) (19). Additionally, the authors stated that after mTBI, brain creatine is reduced; a chronic supplementation strategy may serve to improve recovery from and decrease the severity of such an injury by mitigating the damage-associated energy crises (19). Earlier research supports this, claiming that in addition to mTBI prophylaxis, elevated creatine concentrations may rapidly provide energy when ATP turnover is increased, leading to enhanced brain function in exhausting exercise, sleep deprivation, and acute hypoxia (5). A systematic review revealed evidence that in healthy individuals, intelligence and reasoning, alongside short-term memory, may be improved by creatine supplementation; however, these results were absent in young adults (2). The authors suggested that individual differences in stress and epigenetic aging process-related changes likely affect creatine supplementation's effectiveness (2).

The importance of creatine's pre-injury mitigation in those populations who are at risk for sub-concussive impacts to the head and mTBI, namely military service members and athletes, has also been illustrated in research. According to this review, preemptive chronic creatine supplementation (20 g/day for 5 – 7 days with five grams per day thereafter or 3 – 5 g/day for 28 days and continuing with the dose thereafter) before a brain injury may provide neuroprotective effects greater than those obtained from post-injury supplementation (1). The review examined animal models where creatine supplementation reduced cortical damage by 36 – 50% after experimental TBI and child and adolescent (ages 1 – 18 years) models where creatine supplementation after moderate to severe TBI reduced headaches, fatigue, dizziness, and post-traumatic amnesia while improving understanding, cognitive function, and language articulation (1). The reasons for this pertain to creatine's ability to enhance brain mitochondrial

function and decrease oxidative stress and cortical damage (1). This was shown by additional work, which stated that human data illustrated creatine's beneficial effects on TBI outcomes in children and adolescents, where individuals who were given supplemental creatine (0.4 g/kg of bodyweight) exhibited better self-care, cognition, communication, and behavior/personality traits six months post-injury compared to those who did not supplement with creatine (18). Those authors explained that the improvements are mediated by creatine's role in stabilizing adenosine triphosphate (ATP) levels in the cell, as one of the main drivers of injury is the post-impact cellular energy crisis in the brain (18). This energy crisis can last for weeks, even if the impact was sub-concussive. Additionally, the authors cited the International Society of Sports Nutrition's (ISSN) recommendation that any athlete who participates in a sport that presents a risk of spinal cord injury or TBI should be supplemented with creatine to reduce injury severity for these two complications (18).

Other research showed that three grams per day of creatine supplementation produced a small (15 – 40 millisecond improvements in the creatine group over no improvement in the control group) but beneficial effect on the cognitive capabilities of female Muay Thai fighters following exhaustive exercise (15). These improvements occurred in visual reaction time, visual go/no go reaction time, and the Erikson flanker test (15). This has implications for female warfighters and uniformed female first responders who train or fight hard in the execution of their daily duties or the pursuit of preparedness. Furthermore, increases in creatine intake, as seen with supplementation, have evidence of efficacy for supporting mood improvement and mitigating depression in females, as well as attenuating menstrual cycle-induced alterations in cognition and sleep (22).

Additional investigation expressed that creatine supplementation can produce cognitive benefits in young and elderly individuals alongside the reduction of mental fatigue from high cognitive loads (6). Also, the application of creatine in neurodegenerative diseases has led to its use in enhancing the quality of life and decreasing depression in patients with posttraumatic stress disorder (PTSD) (1,5,8). While this remains a sensitive topic, far too many military personnel (11 – 20%) and first responders (30%) suffer from PTSD (20,25). The U.S. Department of Veteran's Affairs stated that numerous individuals who sustain a TBI also develop PTSD (26). Relevant evidence explained that military populations are 4.18 times more likely to be diagnosed with PSTD after a TBI (10). The signs and symptoms greatly overlap, and creatine may serve as a dual-function intervention.

WHAT CAN BE DONE ABOUT IT?

Make an educated decision regarding tactical athlete risk for sub-concussive and concussive impacts to the head. Inquire about the range of available options for neuroprotection. Determine whether the lifestyle, job requirements, and functionality of tactical athletes warrant cognitive enhancement and neuroprotection from impacts and potentially, aging.

Long-term dosing of five grams of creatine per day is deemed safe (1). To date, there are no clear guidelines or clinical recommendations for how long the prophylactic effects of creatine supplementation persist if an individual halts supplementation altogether or skips a day, week, or month due to operational commitments or a choice to cycle on/off creatine. However, one study explained that the benefits seen with creatine supplementation disappeared completely four weeks after halting supplementation (8). There is no clear timing strategy for daily supplementation when it comes to providing neuroprotective and cognitive benefits; however, it takes roughly 60 minutes for creatine to be absorbed sufficiently to reach the bloodstream (3).

The key takeaway is that protecting oneself from the lasting effects of TBIs or mitigating the damage already done is a critical component to continued operational capacity, cognitive function, and most importantly, the good health, sanity, and safety of the brave men and women in uniform who protect our country at home and abroad. Creatine supplementation may be an easy, relatively inexpensive, and effective means of accomplishing this.

REFERENCES

1. Ainsley Dean, PJ, Arikan, G, Opitz, B, and Sterr, A. Potential for use of creatine supplementation following mild traumatic brain injury. *Concussion* 2(2): CNC34, 2017.

2. Avgerinos, KI, Spyrou, N, Bougioukas, KI, and Kapogiannis, D. Effects of creatine supplementation on cognitive function of healthy individuals: A systematic review of randomized controlled trials. *Experimental Gerontology* 108: 166-173, 2018.

3. Cook, CJ, Crewther, BT, Kilduff, LP, Drawer, S, and Gaviglio, CM. Skill execution and sleep deprivation: Effects of acute caffeine or creatine supplementation - A randomized placebo-controlled trial. *Journal of the International Society of Sports Nutrition* 8(1): 2, 2011.

4. Crifasi, CK, Pollack, KM, and Webster, DW. Assaults against U.S. law enforcement officers in the line-of-duty: Situational context and predictors of lethality. *Injury Epidemiology* 3(29): 2016.

5. Dolan, E, Gualano, B, and Rawson, ES. Beyond muscle: The effects of creatine supplementation on brain creatine, cognitive processing, and traumatic brain injury. *European Journal of Sport Science* 19(1): 1-14, 2019.

6. Gualano, B, Roschel, H, Lancha, AH, Brightbill, CE, and Rawson, ES. In sickness and in health: The widespread application of creatine supplementation. *Amino Acids* 43(2): 519-529, 2012.

7. Jensen, AE, Bernards, JR, Jameson, JT, Johnson, DC, and Kelly, KR. The benefit of mental skills training on performance and stress response in military personnel. *Frontiers in Psychology* 10: 2964, 2020.

8. Kreider, RB, and Stout, JR. Creatine in health and disease. *Nutrients* 13(2): 447, 2021.

9. Lieberman, HR, Bathalon, GP, Falco, CM, Kramer, FM, Morgan, CA, 3rd, and Niro, P. Severe decrements in cognition function and mood induced by sleep loss, heat, dehydration, and undernutrition during simulated combat. *Biological Psychiatry* 57(4): 422-429, 2005.

10. Loignon, A, Ouellet, M, and Belleville, G. A systematic review and meta-analysis on PTSD following TBI among military/veteran and civilian populations. *Journal of Head Trauma Rehabilitation* 35(1): E21-E35, 2020.

11. Ma, C, Wu, X, Shen, X, Yang, Y, Chen, Z, Sun, X, and Wang, Z. Sex differences in traumatic brain injury: A multi-dimensional exploration in genes, hormones, cells, individuals, and society. *Chinese Neurosurgical Journal* 5(24): 2019.

12. Martin, K, Périard, J, Rattray, B, and Pyne, DB. Physiological factors which influence cognitive performance in military personnel. *Human Factors* 62(1): 93-123, 2020.

13. McKee, AC, and Robinson, ME. Military-related traumatic brain injury and neurodegeneration. *Alzheimer's and Dementia* 10: S242-S253, 2014.

14. Nibbeling, N, Oudejans, RRD, Cañal-Bruland, R, van der Wurff, P, and Daanen, HAM. Pursue or shoot? Effects of exercise-induced fatigue on the transition from running to rifle shooting in a pursuit task. *Ergonomics* 56(12): 1877-1888, 2013.

15. Pires, LAM, Forbes, SC, Candow, DG, and Machado, M. Creatine supplementation on cognitive performance following exercise in female Muay Thai athletes. *Neurosports* 1(1): 2020.

16. Rawson, ES, and Venezia, AC. Use of creatine in the elderly and evidence for effects on cognitive function in young and old. *Amino Acids* 40(5): 1349-1362, 2011.

17. Ribeiro, F, Longobardi, I, Perim, P, Duarte, B, Ferreira, P, Gualano, B, Roschel, H, and Saunders, B. Timing of creatine supplementation around exercise: A real concern? *Nutrients* 13(8): 2844, 2021.

18. Riesberg, LA, Weed, SA, McDonald, TL, Eckerson, JM, and Drescher, KM. Beyond muscles: The untapped potential of creatine. *International Immunopharmacology* 37: 31-42, 2016.

19. Roschel, H, Gualano, B, Ostojic, SM, and Rawson, ES. (2021). Creatine supplementation and brain health. *Nutrients* 13(2): 586, 2021.

20. Substance Abuse and Mental Health Services Administration. 2018. Disaster technical assistance center supplemental research bulletin. First responders: Behavioral health concerns, emergency response, and trauma. Retrieved from https://www.samhsa.gov/sites/default/files/dtac/supplementalresearchbulletin-firstresponders-may2018.pdf.

21. Smith, NIJ, Gilmour, S, Prescott-Mayling, L, Hogarth, L, Corrigan, JD, Williams, WH. A pilot study of brain injury in police officers: A source of mental health problems? *Journal of Psychiatric and Mental Health Nursing* 28: 43-55, 2021.

22. Smith-Ryan, AE, Cabre, HE, Eckerson, JM, and Candow, DG. Creatine supplementation in women's health: A lifespan perspective. *Nutrients* 13(3): 877, 2021.

23. Stone, JR, Avants, BB, Tustison, NJ, Wassermann, EM, Gill, J, Polejaeva, E, et al. Functional and structural neuroimaging correlates of repetitive low-level blast exposure in career breachers. *Journal of Neurotrauma* 37(23): 2468-2481, 2020.

24. Torres, VA, Strack, JE, Dolan, S, Kruse, MI, Pennington, ML, Synett, SJ, Kimbrel, N, and Gulliver, SB. Identifying frequency of mild traumatic brain injury in firefighters. *Workplace Health and Safety* 68(10): 468-475, 2020.

25. U.S. Department of Veteran's Affairs. 2022. National Center for PTSD. Retrieved from https://www.ptsd.va.gov/understand/common/common_veterans.asp.

26. U.S. Department of Veteran's Affairs. 2022. Traumatic brain injury and PTSD. Retrieved from https://www.ptsd.va.gov/understand/related/tbi_ptsd.asp.

27. Valera, EM, Joseph, AC, Snedaker, K, Breiding, MJ, Robertson, CL, Colantonio, A, et al. Understanding traumatic brain injury in females: A state-of-the-art summary and future directions. *Journal of Head Trauma Rehabilitation* 36(1): E1-E17, 2021.

28. Vrijkotte, S, Roelands, B, Meeusen, R, and Pattyn, N. Sustained military operations and cognitive performance. *Aerospace Medicine and Human Performance* 87(8): 718-727, 2016.

29. Wax, B, Kerksick, CM, Jagim, AR, Mayo, JJ, Lyons, BC, and Kreider, RB. Creatine for exercise and sports performance, with recovery considerations for healthy populations. *Nutrients* 13(6): 1915, 2021.

ABOUT THE AUTHOR

Miguel Zeran spent 21 years in the United States Marine Corps serving as a Reconnaissance Marine. Along the way, he picked up a Bachelor's degree in Health and Wellness and a Master's degree in Kinesiology. His end-user-focused understanding of human performance allows him to translate what he learned and experienced during service and schooling into viable, relevant, and meaningful interventions for tactical athletes from all walks of life. He currently works for Momentous as their Head of Tactical Athlete Science and Research.