THE IMPORTANCE OF CREATINE TIMING FOR MUSCLE SIZE AND STRENGTH

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The evidence supports that creatine supplementation, regardless of timing, is an effective strategy to improve skeletal muscle strength and cross-sectional area. Although there is currently limited supportive evidence, there is a sound theoretical basis for supplementing with creatine in close proximity to exercise rather than other times in the day (3,20).

The following are basic guidelines for creatine supplementation:

Type of creatine: Although various forms of creatine exist in the market today, creatine monohydrate is the most studied form and has consistently been shown the be the most effective, safe, and cost-effective (8).

Dosage: A 5-g dose of creatine monohydrate is well-absorbed into the bloodstream and reaches peak plasma concentration in approximately 1 – 2 hr.

Timing: The current consensus would be that creatine monohydrate should be supplemented either before, during, or after a workout as opposed to other times throughout the day. However, there does not seem to be a clear advantage to pre- versus post-exercise creatine supplementation based on the current evidence. If creatine uptake is indeed maximized by exercise-induced increases in blood flow, it may be worth supplementing with creatine within 1 – 2 hr prior to your workout (20).

Creatine with Carbohydrates: Co-ingestion of creatine with carbohydrates or carbohydrates and protein may also enhance creatine uptake into the muscle (10,11,12,19,23).

The following sections provide a more detailed discussion of the evidence on creatine timing and supplementation.

UNDERSTANDING CREATINE

Creatine is a naturally occurring compound that can be made endogenously from the amino acids glycine, arginine, and methionine. It is considered a non-proteinogenic amino acid similar to ornithine, citrulline, and homoserine, which means it is an amino acid that is not one of the 20 amino acids incorporated into proteins (17,18). Although creatine can be made by the kidneys, liver, pancreas, and brain, this only accounts for about half (1 – 2 g) of the daily creatine requirements for the average person (2). As such, the rest of the creatine content must come through diet from foods, such as beef, meat, and fish, or from dietary creatine supplementation (15).

Approximately 95% of creatine is stored in skeletal muscle, but small quantities are also found in the brain and the testes (15). Roughly 67% of the creatine in muscle is stored as phosphocreatine, with the remaining ~33% being free creatine (15). In total, skeletal muscle creatine concentrations are ~120 mmol/kg of dry muscle mass for a 70-kg person (14,15). Vegetarians may have lower baseline creatine stores and upper limits of ~160 mmol/kg of dry muscle mass can be reached by most individuals (14,15). In order to reach the higher limits of skeletal muscle creatine levels, dietary creatine supplementation is usually required as it would require eating around one pound of beef or salmon daily to achieve roughly 2.5 g of creatine. Creatine monohydrate supplementation (typically 3 – 5 g per day) may increase muscle creatine and phosphocreatine by 20 – 40% (15).

Supplementation with creatine monohydrate increases skeletal muscle creatine stores to support adenosine triphosphate (ATP) regeneration via the creatine kinase/phosphocreatine energy system. Therefore, it helps to maintain ATP availability, especially during maximal effort anaerobic exercise (e.g., sprints, weight training) (15). While this largely explains the ergogenic potential, the performance and health benefits of creatine supplementation also include improved exercise recovery, enhanced tolerance to exercise in the heat, improved rehabilitation outcomes, and brain and spinal cord neuroprotection (15,16).

DOES TIMING MATTER?

Few studies have examined the impact of creatine timing on total creatine uptake and performance outcomes. Supplementing with creatine in close proximity to exercise may enhance creatine delivery, uptake, and retention (20). Exercise promotes an increase in blood flow to the working muscle and may spark an upregulation in the muscle creatine transport systems (20). The notion that exercise potentiates the increase in intramuscular creatine is supported by studies demonstrating greater increases in intramuscular creatine in an exercised versus non-exercised leg following supplementation (13,21). It has also been shown that supplementing with a creatine-based supplement (~5.6 g creatine monohydrate per serving) before and after training sessions leads to greater gains in intramuscular creatine and glycogen content, lean body mass, and one-repetition maximum (1RM) squat and bench press strength as compared to supplementing in the morning and evening during a 10-week resistance training program (6).

Among the available research, most have investigated the effect of creatine supplementation before versus after resistance exercise on measures of body composition and strength. In the first study by Antonio and Ciccone, 19 recreational male bodybuilders were randomly assigned to supplement with 5 g of creatine monohydrate immediately pre- or post-exercise (1). No significant differences between groups were noted for body composition and 1RM bench press using a traditional statistical approach. However, based on magnitude-based inferences (a statistical approach that has been challenged), it was reported that the post-workout supplementation group was "possibly better" for improving gains in fat-free mass (2.0±1.2 versus 0.9±1.8 kg), reductions in fat mass (-1.2±1.6 versus -0.1±2.0 kg), and 1RM bench press (7.6±6.1 versus 6.6±8.2 kg). Nevertheless, this study was limited by its short four-week duration, lack of a placebo group and participant blinding, and variation in participants' exercise selection. Subsequently, two studies by Candow and colleagues lasting 12 weeks and eight months showed no effect of timing on muscle size and strength adaptations when older adults supplemented with creatine monohydrate either immediately before or after training sessions during a three-day per week resistance training program (4,5). However, in these studies, creatine monohydrate (0.1 g per kg of body mass) was only supplemented on the three days per week around training sessions. Using a novel within-subject research design, Forbes and colleagues had subjects complete an eight-week elbow flexion/knee extension resistance training program, whereby participants trained their right elbow flexors and knee extensors twice per week and their left elbow flexors and knee extensors twice per week on alternate days (9). Participants were randomized to supplement with creatine monohydrate (0.1 g per kg of body mass) immediately before and placebo immediately after training one side of the body and placebo immediately before and creatine monohydrate (0.1 g per kg of body mass) immediately after training the other side of the body (on alternate days). While both sides of the body significantly increased muscle thickness and strength, there was no difference between creatine timing strategies. Lastly, Dinan et al. also showed that creatine monohydrate timing did not influence changes in muscle size and strength (7). In this study, 34 resistance-trained male and female athletes were randomized to consume a 5-g dose of creatine monohydrate within one hour prior to or following exercise sessions during an eight-week full body resistance training program (four days per week). Both groups received their creatine monohydrate or placebo within a protein and carbohydrate beverage before and after training, and there was a third group who only received the protein and carbohydrate beverages with no creatine added. All groups had similar increases in muscle size and strength measures, and the gains were not influenced by the creatine timing strategies. Overall, there does not appear to be a clear advantage of supplementing with creatine pre- versus post-exercise during a resistance training program. More research is needed to evaluate the effects of timing (e.g., hours before, immediately before, intra-workout, immediately after, or several hours after training) compared to a placebo control group.

CO-INGESTION WITH OTHER MACRONUTRIENTS?

Supplementing creatine along with carbohydrates may enhance creatine uptake by the muscle over the short term (10,11,12,19,23). This effect is likely attributed to the carbohydrate-induced insulin response which can enhance creatine kinetics and increase creatine transport systems (22). Several studies have shown that, compared to creatine alone, co-ingestion of creatine with carbohydrates or carbohydrates and protein can significantly enhance creatine uptake (10,11,12,19,23). For example, a mixture of 50 g of protein, 47 g of carbohydrate, and 5 g of creatine monohydrate increased whole body creatine retention by ~25% as compared to creatine monohydrate alone (23). The relevance of this acutely enhanced creatine uptake during long-term creatine supplementation protocols remains unknown, as studies have not yet evaluated the timed co-ingestion strategy on muscle size and strength gains over time.

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Conflicts of Interest: *Dr. Gonzalez serves as a scientific advisor for Shifted LLC, a manufacturer of sports supplements. Dr. Escalante serves as a scientific consultant to Bang© and serves/has served as an expert witness on current and past cases related to creatine. Dr. Escalante also serves on the board of directors for Bang©.*

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