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Review Article

The Use of Creatine in Sport: An Educational Article

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Abstract

Many sports and strenuous exercises are associated with some degree of muscle damage, pain and fatigue that can lead to poor athletic progress, therefore the need for recovery speeding methods has been increasingly demanded. The use of performance enhancing nutritional supplements to improve athletic performance has been increasing during the previous decades. Supplementation with vitamins and minerals in excess of recommended daily allowances has been increasingly reported to have no effect on muscle mass or athletic performance, and the need to identify evidence-based sport supplements has been increasingly demanded.

The aim of this paper is to provide an overview of the use of creatine in sport research progress.

Keywords: creatine; sport; research progress

The use of supplements in sports

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Many sports and strenuous exercises are associated with some degree of muscle damage, pain and fatigue that can lead to poor athletic progress, therefore the need for recovery speeding methods has been increasingly demanded. The use of performance enhancing nutritional supplements to improve athletic performance has been increasing during the previous decades. Supplementation with vitamins and minerals in excess of recommended daily allowances has been increasingly reported to have no effect on muscle mass or athletic performance, and the need to identify evidence-based sport supplements has been increasingly demanded [1,2].

The early use of creatine

Dietary interventions have been used as early as the early 1900s by sportsmen to improve their strength. Friedrich Wilhelm Müller (Figure-1A) who was also known as Eugen Sandow was one of the earliest sportsmen who used dietary interventions during the early 1900s to improve muscle growth and strength. Earle Liederman (Figure-1B) used beef juice to promote muscle recovery [3, 4].

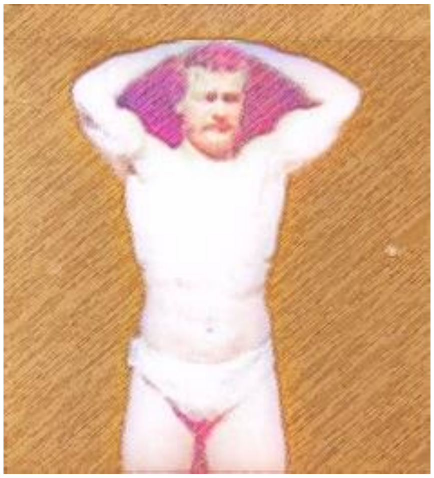

Figure-1A: Friedrich Wilhelm Müller (2 April 2, 1867-October 14, 1925) was also known as Eugen Sandow

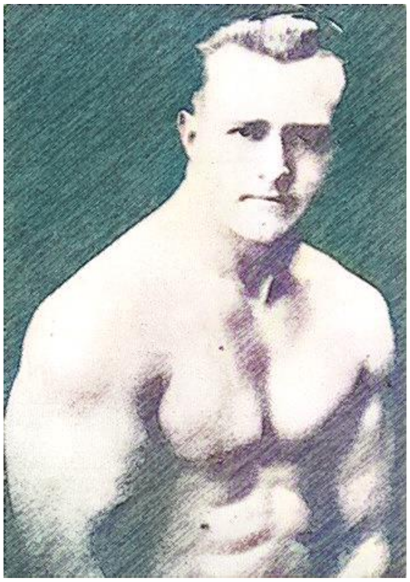

Figure-1B: Earle Edwin Liederman (1886-1970) was an American bodybuilder

Irvin P Johnson (Figure-1C) introduced egg-based protein powdered supplement for physical athletes.

Figure-1C: Irvin P Johnson was also known as Rheo H Blair, a pioneer

Thereafter, endurance and strength exercises have been increasingly recognized to be associated with increased protein/amino acid requirement which has been attributed to enhanced oxidation rates during exercises, and also the need for more substrate to repair damaged muscle tissue. The need for protein/amino acid in endurance exercises may increase by 50 to 100%. Therefore, it has been recommended that the daily intake for adult athletes is about 1.5 g (1-2 g) / kg body weigh and the amount of protein to be taken to obtain the highest benefit is about 10 to 20 g / hour.

The available evidence suggests that protein supplements can help in enhancing muscle hypertrophy more than whole foods.

Creatine is a guanidino-compound molecule that is produced endogenously, and also acquired exogenously through diet. It is found primarily in meat products and is produced endogenously by the liver, kidneys, and pancreas. Figure-2 shows the steps of endogenous creatine production.

Exogenous (nutritional) creatine is obtained primarily from meat products. About 5 g of creatine is present in 1.1 kg of beef).

In humans, more than 95% of creatine is present in skeletal muscle, of which a third is in the free form and the remaining is in the phosphorylated form.

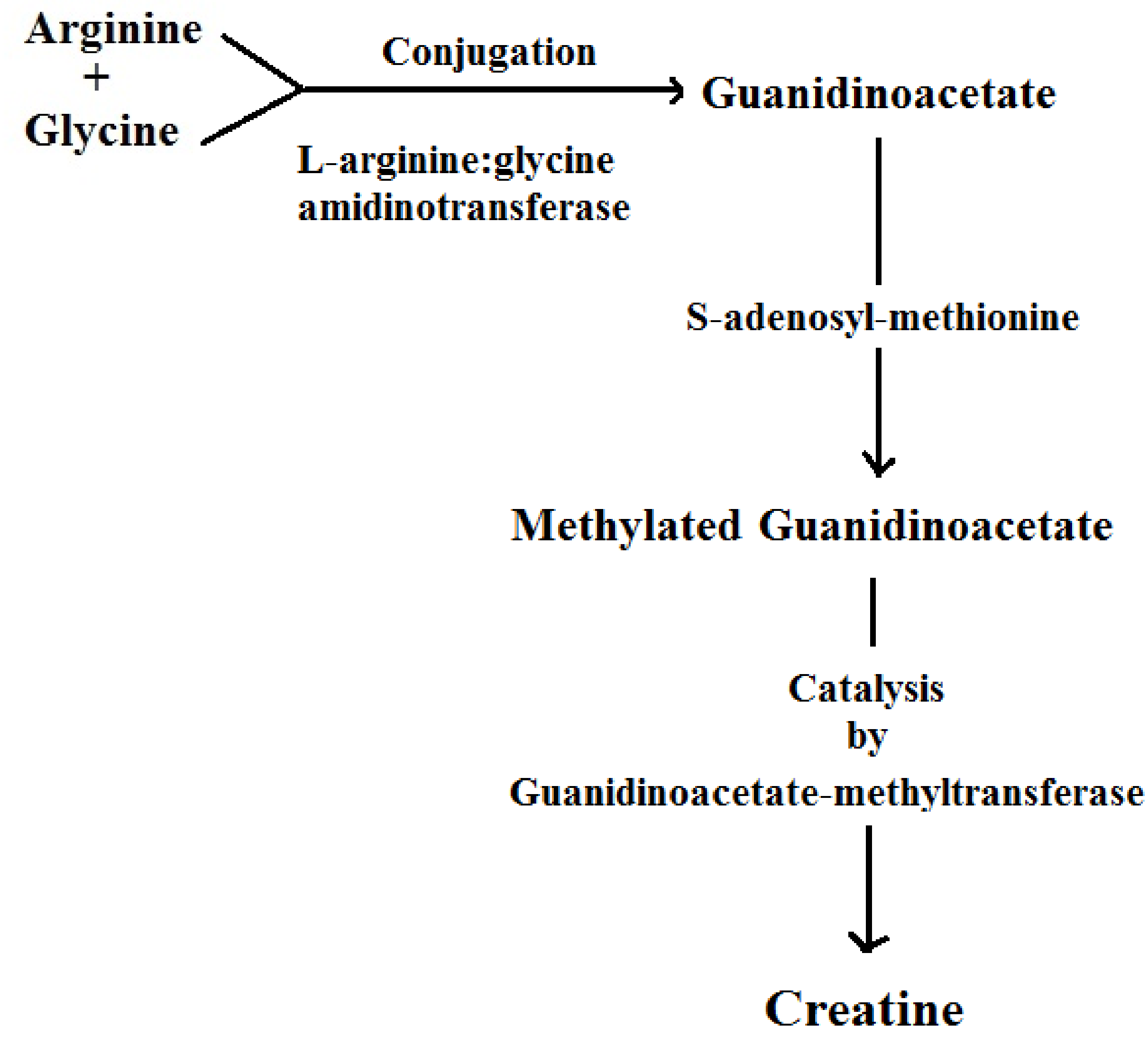

Figure-2: The steps of endogenous creatine production

Creatine works by converting into creatine phosphate, which provides an extra phosphorus molecule in the regeneration of ATP, and thus provides the body with more energy during exercises including weight training. Creatine supplement can considerably increase muscle strength and hypertrophy during resistance training.

Creatine was isolated for the first time from muscle in meat by a French chemist, Michel Eugène Chevreul (Figure-3A) in 1832 and he called it creatine after the Greek word "Kreas" which means flesh.

Figure-3A: Michel Eugène Chevreul (August 31, 1786-9 April 9, 1889), a French chemist

Thereafter, the German scientist Justus von Liebig (Figure-3B) suggested that creatine is important in producing muscular action in vertebrates. He developed a creatine product "Fleisch Extrakt" to help the body to work more, and for decades it remained the only creatine supplement known.

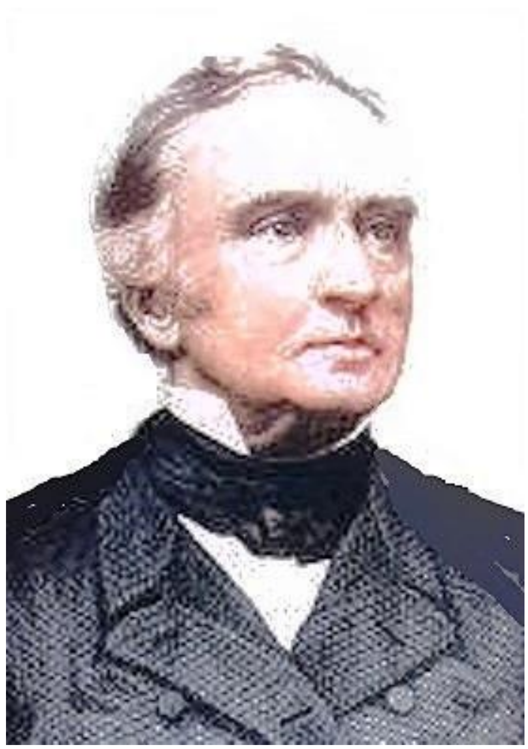

Figure-3B: Justus von Liebig (May 12, 1803-April 20, 1873), a German scientist who had important contributions to biological chemistry

In 1912, the work of Harvard University researchers Otto Folin (Figure-3C) and Willey Glover Denis (Figure-3D) suggested that creatine intake can considerably increase creatine content of muscles [4].

Figure-3C: Otto Knut Olof Folin (April 4, 1867 -October 25, 1934), a Swedish American chemist who is best known for his studies of protein metabolism

Figure-3D: Willey Glover Denis (February 26, 1879-January 9, 1929), an American biochemist and physiologist best known for her studies of protein metabolism

In 1926, Alfred Chanutin reported that the oral intake of 10g of creatine daily for one week was week was associated with an increase in creatine storage in the muscles suggesting an anabolic effect [4, 5].

In 1975, Crim et al and colleagues reported that creatine intake increased nitrogen retention in the muscles, and therefore it can result in faster muscle recovery and increased performance.

Ingwall et al (1975) suggested that creatine is a product of muscular contraction that can stimulate myofibrillar protein synthesis. They reported an experiment which showed that creatine can selectively stimulate the synthesis of contractile proteins in skeletal and cardiac muscle in vitro and thus can contribute to muscle hypertrophy [6].

The use of creatine in sport

Harris and colleagues (1992) from Sweden emphasized that a single 5g dose of creatine monohydrate corresponds to the creatine content of 1.1 kg of fresh, uncooked steak. They reported that the intake of 5g of creatine monohydrate, four or six times daily for 2 or more days was associated with a considerable increase in creatine content of the quadriceps femoris muscle. Creatine uptake into muscle was maximal during the first two days of intake. During August 1992, the Times (7 August 1992) reported that Linford Christie (Figure-4A) and Sally Gunnell (Figure-4B) who won gold medals were using creatine monohydrate before the 1992 Summer Olympic Games in Barcelona, Spain.

Figure-4A: Linford Cicero Christie (born 0n the 2nd of April 1960), a Jamaican- British sprinter who is the only British man to have won gold medals in the 100 meters at all four major competitions open to British athletes

Figure-4B: Sally Jane Janet Gunnell (born on the 29th of July 1966), a British former athlete who won the 1992 Olympic gold medal in the 400 meters hurdles.

Linford Christie, a 32 year-old sprinter used creatine monohydrate as a sport supplement to compete with the younger athletes. He won the title of the World's Fastest Man [4, 7].

In 1994, Paul Greenhaff (Figure-5A) from Nottingham and his research group reported that the oral intake of 20 g creatine daily for 5 days was associated with considerable increase in muscle creatine.

Figure-5A: Paul Greenhaff from Nottingham

Birch and colleagues (1994) from the United Kingdom reported a placebo controlled study which showed that creatine intake in a dose of 5 g four times for 5 days markedly increased peak power output in the first exercise session ($p < 0.05$) and increased mean power output and total work output in exercise in the first and second exercise sessions .

Balsom et (1995) from Sweden reported that supplementation of males performing sessions of high-intensity exercise, on a cycle ergometer with 20 g creatine daily for six days was associated with increased total muscle creatine [creatine + phosphocreatine)] at rest, increased body mass by a 1.1 (0.5) kg ($P < 0.05$), lower muscle lactate, and with improved ability to maintain power output [8].

Hultman et al (1996) from Nottingham, United Kingdom suggested using an initial loading dose of 20 g for 6 days to load skeletal muscle. Thereafter, the increased muscle content can be maintained using 2 g daily dose, and in the long term 3 g creatine daily can be used. Hultman et al reported the use of creatine supplement in different doses and durations in 31 males. 20 g creatine daily for six days was associated with increased total muscle creatine increased by 20%. The increased level was maintained with a dose of 2 g daily for an other 30 days. Without the 2 g/day maintenance, total creatine level slowly declined, and returned to pre-supplementation level 30 days after stopping supplementation. The use of a dose of 3g creatine daily for 28 days was also associated with increased total muscle creatine increased by 20%.

In 1997, Jeff S Volek (Figure-5B) from the United States and his research group reported a placebo controlled study which included 14 males performing a bench press exercise (5 sets to failure using each participant's pre-study 10-repetition maximum) and a jump squat exercise (5 sets of 10 repetitions using 30% of each participant's 1-repetition maximum squat).

Figure-5B: Jeff S Volek from the United States

The participants received either a creatine 25 g creatine monohydrate daily or a placebo.

The use of creatine was associated with a considerable increase in body mass of 1.4 kg, and also with a considerable improvement in peak power output during all five sets of jump squats and a considerable improvement in repetitions during all five sets of bench presses. Therefore, the study suggested the use of creatine 25g daily can improve muscular performance during repeated sets of bench press and jump squat exercise [9].

In 1997, Schneider et al from Australia reported a placebo controlled study which included 9 untrained males and conducted in a sequential manner. The study showed that creatine supplementation (5 g creatine X 5 doses) was associated with a considerable increase in the work performed during 15-seconds sessions of maximal cycling compared to placebo. Schneider et al attributed the effect of creatine to increasing the rate of ATP resynthesis from phosphocreatine during exercise.

In 2000, Motier Daniel Becque from the USA and his colleagues reported a placebo controlled study which included 23 males who had at least one year of weight training experience, and had no important differences in mean pretest one repetition maximum in arm flexor strength. All subjects trained twice weekly with training loads started at 6-repetition maximum and progressed to 2-repetition maximum. Ten subjects received creatine and thirteen subjects received a flavored, sucrose drink as a placebo. Creatine monohydrate was given in a dose of 5 g in a flavored, sucrose drink four times daily for 5 days, thereafter, the dose reduced to 2 g four times daily. Creatine supplementation increased arm flexor muscular strength, upper arm muscle area, and fat-free mass than increased one repetition maximum more than placebo [10].

In 2002, Mikel Izquierdo from the Spain and his research group reported a placebo controlled study which included 19 trained male handball players. Nine players received either creatine (20 g daily for 5 days) and ten received placebo. Creatine supplementation was associated with a considerable increase in body mass and improvements in lower-body maximal strength, maximal repetitive upper- and lower-body high-power exercise sessions, and also increased total repetitions performed to fatigue. Creatine supplementation was also associated with improved repeated sprint performance and reduced the deterioration in jumping ability after power-output exercise sessions.

In 2003, Luc J C van Loon from the Netherlands and his research group reported the use of creatine in a dose of 20 g daily for five days in 10 individuals, followed by 20 g daily for six weeks. The effects of creatine were compared with effects of placebo in an other ten individuals. Creatine loading was associated with increased muscle free creatine, creatine phosphate and total creatine content ($P < 0.05$). The maintenance dose of 2 g daily was associated with lowering of increased creatine phosphate and the total creatine content with maintaining free creatine level. Both short and long-term creatine intakes were associated with improvement in performance of repeated supra-maximal sprints on a cycle ergometer. The elevated body mass after creatine loading was maintained for six weeks of continued supplementation of creatine and led to an increased fat-free mass.

Michael E. Powers from Florida and his research group reported a placebo controlled study which included 16 males and 16 females involved in resistance training whom were randomized to receive either creatine or sucrose as a placebo.

Creatine was given in a dose of 25 g daily for one week (loading stage) followed by 5 g daily for 3 weeks (maintenance stage), The intake of creatine was associated with a considerable increase in muscle creatine, body mass, and total body water. Individuals in the placebo group experienced a small but significant increase in total body water only.

In 2003, Caroline Rae from Australia and her research group reported a placebo-controlled study which included 45 young adult, vegetarian participants. The study showed that creatine intake in a dose of 5 g daily for six weeks was associated with a considerable positive effect on both working memory (backward digit span) and intelligence (Raven's Advanced Progressive Matrices) ($p < 0.0001$). Therefore, Caroline Rae and her research group suggested that creatine supplementation can improve intelligence test scores and working memory performance in subjects [11].

In 2004, Jeff S Volek from the United States and his research group reported a placebo-controlled study which included 17 males performing resistance exercise 5 days a week for 4 weeks. Nine participants received creatine monohydrate 0.3 g/kg daily, while eight participants received placebo. Creatine supplementation prevented the decrease in maximal bench press and squat and explosive power in the bench press during the initial weeks of training, while the decrease occurred the participants who received placebo. Creatine supplementation also enhanced body mass, explosive power in the bench press, and lean body mass in the legs. Therefore, the study showed that the intake of creatine helped in maintaining muscular performance in high-volume resistance training.

In 2009, the American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians in Canada published a joint statement on performance enhancing agents which didn't consider creatine to have a harmful effect on renal function.

In 2011, Eric S Rawson from the United States and his research group reported a randomized double-blind placebo-controlled study which included 20 males and females.

The study showed that a low dose of creatine (2.3 g daily) for 6 weeks was associated with a considerable increase of plasma creatine concentration and improved resistance to fatigue during repeated sessions of high-intensity contractions.

Bruno Gualano from the Brazil and his research group reported double-blind, placebo-controlled which included type 2 diabetic patients performing exercise training. The study showed that patients who received creatine had higher muscle phosphorylcreatine content when compared to patients who received placebo, and they didn't experience changes in creatinine clearance, serum and urinary urea, electrolytes, proteinuria. Bruno Gualano and his research group suggested that creatine supplementation does not affect kidney function in type 2 diabetic patients [7, 8].

Vítor de Salles Painelli from the Brazil and his research group reported a placebo-controlled study which included 32 strength-trained males performing a graded exercise test (A 5-km run on a treadmill [aerobic exercise], continuously or intermittently followed by either a leg- or bench-press) who received either creatine 20 g daily for a week followed by 5 g daily or received a placebo.

Creatine supplementation was associated with considerable increase in bench-press sets following aerobic exercises when compared to placebo.

In 2017, Richard B Kreider and his research group emphasized that the available research evidence supports the value of creatine in improving performance in high intensity exercises. They also emphasized that the available research evidence suggests that short and long-term creatine supplementation of up to 30 g daily for 5 years is safe and well-tolerated.

In 2018, Chia-Chi Wang from Taiwan and his research group reported a placebo controlled study which included 30 athletes who received either creatine 20 g creatine daily for 6 days followed by 2 g daily, or carboxymethyl cellulose as a placebo. After six days, participants started performing tests of one repetition maximum (1-RM) strength of half squat and complex training sessions followed by performing a complex training consisting of six sets of 5-RM half squats and plyometric jumps 3 times weekly for one month. Participants who received creatine achieved considerably higher 1-RM strength than participants who received placebo ($P < 0.05$). Creatine supplementation was associated with much lower creatine kinase activity than in the placebo group ($P < 0.05$). Therefore, the study suggested that creatine intake during complex training enhanced maximal muscular strength and decrease muscle damage during training [4,9].

In 2019, Kaviani and colleagues from Canada reported a placebo controlled study which included 18 males performing resistance training three times a week. They received either creatine 0.07g/kg daily or a placebo for two months. Creatine supplementation was associated with much greater strength than placebo ($P<0.05$) after two weeks for three of the six exercises (bench press, leg press, and shoulder press). After two months, creatine supplementation was associated with much greater strength than placebo ($P<0.05$) for four of the six exercises including bench press, leg press, shoulder press, and triceps extension, but not biceps curl or lat-pulldown. However, creatine supplementation did not have a protective effect against muscle damage as muscle damage markers were higher than in the placebo group (P<0.05), and that was attributed to a higher training intensity resulting from creatine supplementation.

Also in 2019, Alexandre de Souza E Silva from Brazil and his research group conducted a systematic review and a meta-analysis which included 290 non-duplicated studies. The meta-analysis suggested that creatine intake was not associated with important change in serum creatinine, plasma urea levels or evidence of renal damage. Although, some earlier researchers including Hultman et al (1996) and Powers et al (2003) attributed the increase in muscle mass occurring in association with creatine supplementation to water retention, this notion has not been supported by recent studies.

In 2020, Alex S Ribeiro from Brazil and his research group reported a placebo controlled study which included 27 males performing two resistance training routines four times weekly.14 subjects received creatinine and 13 received placebo for 8 weeks.

The study showed that the increased muscle mass caused by creatine and resistance training occurs was not associated with alteration of the ratio of intracellular water to skeletal muscle mass [10, 11].

The use of creatine in medicine

In 2014, Rachel N Smith from the United States and her research group suggested that creatine has a therapeutic potential in the treatment of a variety of medical conditions including congestive heart failure, gyrate atrophy, elevated cholesterol and insulin insensitivity. They also suggested that the beneficial effects of creatine including antioxidant effects, decreasing mental fatigue, and neuro-protective effects make potentially useful in the treatment of disorders like depression and bipolar disorder. They also suggested that creatine useful in the treatment of a variety of other medical conditions including conditions Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis.

In 2021, Hamilton Roschel from Brazil and his research group suggested that there is convincing research evidence suggesting that creatine has a therapeutic potential because of its beneficial effects to brain health and brain functions including cognitive processing, and recovery after trauma. They emphasized a potential for creatine in improving cognitive processing in disorders associated with brain creatine deficiency such as mild traumatic brain injury, depression, aging, and Alzheimer's disease [4.10].

Al-Mosawi AJ (2019) reported that the use of creatine monohydrate 5 grams daily in the treatment of Semmola-Meryon-Duchenne syndrome can preserve muscle strength in the short term [12].

Conclusion

The use of creatine monohydrate s a sport supplement has been considered to be safe. Creatine supplementation can help in increasing strength and fat free mass. Creatine can be of benefit in resistance exercises, and also in high-intensity sprints and endurance exercises. Creatine supplementation work by increasing muscle creatine storage and promoting faster regeneration of adenosine triphosphate between high intensity exercises, and thus contributes to improving performance. The generally recommended dose of creatine supplementation is 0.1 g/kg of body weight. Creatine has been increasingly considered as the most effective supplement in improving exercise tolerance, muscle strength and also lean body mass.

Acknowledgement

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