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Effect of oral creatine supplementation and Pre-cooling on isometric strength and isometric endurance

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Abstract

Background and Purpose: Athletes use various Ergogenic aids to enhance performance capacity or the ability to perform work during various sporting events. The purpose of the study was to investigate the effect of oral creatine supplementation and pre-cooling on neuromuscular variables such as isometric strength and endurance.

Materials and methodology

30 healthy university level players participated in the different subject design, experimental study (Mean age 21.37 ± 0.4 Yr, mean height 176.16 ± 11.06 cm and mean body weight 70.48 ± 1.96). They were randomly divided into three groups (n=10) Creatine supplementation (20gm per day for 6 days), precooling (20 minutes in water at $16 \pm 2^\circ\text{C}$ till iliac crest) and placebo group (cornstarch 20gm per day for 6 days). Following administration, subjects performed 2 isometric holds; one of 10 seconds duration and other of 60 seconds. Isometric angle specific peak force, average force and fatigue index of quadriceps in extension moment were measured.

Results

A significant increase in all the above mentioned variables ($p < 0.05$) were observed after creatine supplementation but for precooling a reduction in both average and peak force was observed. On comparison significant differences were observed for isometric endurance in the pre-cooling group as compared to the placebo group.

Conclusion

It is thus concluded that creatine supplement can act as an effective Ergogenic aid both in terms of isometric strength and endurance but pre-cooling effectively increases isometric endurance only within the investigated range.

Keywords: Creatine supplement, pre-cooling, peak force, average force, isometric endurance

Introduction

Athletes have been continuously searching for an elixir to enhance their performance. For the same purpose use of various ergogenic aids (nutritional supplements etc.) has gained popularity among athletes in recent years¹. Ergogenic aid is a technique or practice that serves to increase performance capacity, the efficiency to perform work, the ability to recover from exercise, and/or the quality of training thereby promoting greater training adaptations.²

Amongst ergogenic aids creatine is the most popular nutritional supplement used by the athletes. Creatine is found predominantly in skeletal muscle in which approximately 40% is the free creatine form, while the remaining 60% is in the phosphorylated form; creatine phosphate. It is used as a source of energy to replenish adenosine triphosphate (ATP). The rate at which ATP is hydrolyzed is dictated by the level of force production of muscle.³ This is mainly achieved first through the accumulation of Pcr itself which is available as an immediate buffer to ATP use, and secondly by the facilitation of energy translocation from mitochondria to sites of ATP utilization.⁴

The stores of CrP (creatine phosphate) can fall to a level of zero with continued high intensity exercise and have been demonstrated to be finite. Consequently, CrP may have a limiting effect upon re phosphorylation of ADP to ATP and is commonly associated with onset of muscle fatigue.⁵ Oral creatine supplementation is capable of increasing the total Cr content of skeletal muscle by 20-25%⁴. After creatine supplementation there is both an increase in creatine pool and also an increase in rate of resynthesis. Both of these factors limit the rate of force decline with repeated sets of explosive work and enhance performance⁶.

Beyond loss in strength and fatigue physical performance can be impaired by elevations in the core temperature (T_c), particularly during prolonged exercise. In an effort to reduce the elevations in T_c and possibly improve performance various cooling procedures and devices have been employed prior to exercise.

Pre-cooling has become increasingly common as an Ergogenic aid before some athletic competitions. Lowering of body temperature before exercise (pre-cooling) can be beneficial to athlete's performing in hot and humid environments as it is well established that exercise is prematurely terminated in the heat. The basis of pre-cooling strategy is to decrease body temperature before exercise, thereby increasing the margin for metabolic heat production and increasing the time to reach the critical limiting temperature when a given exercise intensity can no longer be maintained.

Generally pre-cooling has been shown to increase time to exhaustion or increase the distance run or cycled. The various methods of pre-cooling are cold air, water immersion, water perfused suits and cold packs which can be employed with different exercise protocols, and environmental conditions.

The purpose of the experiment was to investigate whether creatine supplementation and pre-cooling exert an ergogenic effect on maximal force production and endurance of human quadriceps muscle.⁷

Materials and Methods

Subjects: 30 healthy university level players (footballers and runners) with Mean age 21.37 ± 0.4 Yr, mean height 176.16 ± 11.06 cm and mean body weight 70.48 ± 1.96 kg were included in the study. Prior history of use of any of the ergogenic aids were also taken into consideration. The experimental protocol and potential risks of the study were explained to each subject both verbally

and in writing before and their informed consent was obtained. The study was approved by the local medical ethical committee.

Pre-experimental protocol: Subjects in all the three groups viz. Placebo, Creatine supplementation and Pre-cooling(n=10) were told to visit the testing laboratory before the start of the experimental protocol to determine base line readings of peak force(PF), average force (AVF) and fatigue index (FI) of the quadriceps femoris muscle of the dominant leg. Subject performed maximum voluntary isometric contraction with 10 second and 60 second hold with a rest period of 2 minute in between the two contractions, on HUR isotonic/isometric dynamometer (University of Technology in Helsinki, Finland) along with above mentioned strength testing protocol additionally in the creatine supplementation group a venous sample was drawn to analyze plasma urea and creatinine and body composition analysis was done. While in the pre-cooling group skin temperature was noted prior to the intervention.

Instructions to subjects: The subjects were asked to refrain from any dietary modulations, heavy meals or any strenuous activity during the entire length of the study. Pre-structured standardized diet was given to the subjects in the creatine supplementation group to ensure avoiding any variability in the plasma creatinine level of the body.

Experimental protocol

The study utilized a pre test post test, different subject experimental design with all the three groups completed in a random order on separate days with a constant time of the day for each individual.

Group I-Creatine Supplementation

Subjects were given oral creatine supplementation in form of creatine monohydrate for duration of 6 days. A dose of 20 gm was given every day and the subject consumed creatine in 4 doses of 5 gm each. The subject was advised to consume creatine after meals. After the supplementation protocol on 7th day the blood sample and the test for Body composition were repeated.

Group II-Pre-Cooling

Subjects were exposed to pre-cooling of lower torso muscles. The subject was made to sit in a water tank with water level reaching upto the iliac crest. The water temperature was maintained at $16\pm 2^{\circ}\text{C}$ with crushed ice and the subject was made to sit for a duration of 20 minutes on a stool placed in the water tank.

Before and after pre-cooling the skin and rectal temperature were measured. The skin temperature was measured at thigh and calf and the mean was taken after the pre-cooling procedure the subjects were allowed to pat dry with towel and change clothes.

Group III-Placebo

Subjects were given placebo supplementation which consisted of 20 gm of corn starch per day in 4 divided doses of 5 gm each. The subjects were instructed to mix the powder in juice or beverage and to be consumed after meals. Post supplementation a blood sample was taken and body impedance analysis was done.

On the day of testing the subjects were asked to consume a light meal prior to the test. Following a 5-7 minute warm-up for the quadriceps, the PF, AVG and FI were measured at optimal standardized angle of the knee joint (60° of knee flexion; 0°= full knee extension), the angle at which the quadriceps muscle applies maximum force. The isometric test protocol was applied as per standardized procedure mentioned by HUR research line software user manual (Version 1.3)

Analysis: Isometric strength measurement: The torque (Nm) was measured at 10 sec isometric hold at 60° knee flexion for quadriceps in all the 5 groups. It was normalized to force (N) by dividing the torque (Nm) by lever arm length (m). Thereafter Peak Force (pf) and Average Force (avf) for 10 sec were calculated (avf of 4 quarters; 1 quarter=2.5 sec). Isometric endurance measurement: After 2 min rest with no activity, fatigue index (fi) was calculated as a measure of isometric endurance with the same seat position and knee angle as above. Isometric hold of 60 sec was performed, to calculate isometric endurance. Torque in 1st sec (T1) and torque at 60th sec (T60) were observed. Torque T1 and T60 was normalized to force F1 and F60 respectively.

Fatigue Index designed by Milner and Brown et al. (1986) was calculated using the equation; Fatigue index (fi) = $(F1 - F60 / F1) * 100$ (%) No visual or verbal feedback was given during the test session to the subject so that no external stimuli were instituted except for the subject's own maximal effort and hold.

Data Analysis

Data was presented as mean ± SD. The data was analyzed for statistical significance by using the statistical package for social sciences (SPSS 14.0) software. The dependent variables peak force, average force and fatigue index were analyzed using one way analysis of variance (ANOVA) for statistical analysis of effect of different Ergogenic aids. Since significant differences were found ($p < 0.05$) Multiple comparison Scheffe's (Post Hoc Test) was applied to test for differences between the groups The mean; standard deviation and standard error were calculated to describe the data.

Results and Analysis

For isometric strength: peak force and average force were examined using a 10 second isometric hold.

1) Peak force: on inter group comparison for mean peak force (N) of quadriceps before and after the interventions, it was found that creatine supplementation group gained strength significantly at ($p \leq 0.05$) but there was a significant reduction in the strength of placebo group and pre-cooling group at ($p \leq 0.05$) respectively.

Table-1: Comparison of quadriceps peak force before and after intervention in all 3 groups.

Group	Quadriceps Peak Force (N)	
	Before Intervention	After Intervention
	Mean	Mean
Creatine Supplementation	466.38±97.39	490.25±80.88*
Pre-cooling	518.96±134.46	461.42±147.96**

Placebo	480.58±69.78	429.03±78.15*
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* indicates significance $p < 0.05$

** indicates significance $p < 0.01$

Fig. 1: Distribution of mean values of quadriceps peak force (N) before and after intervention in all 3 groups.

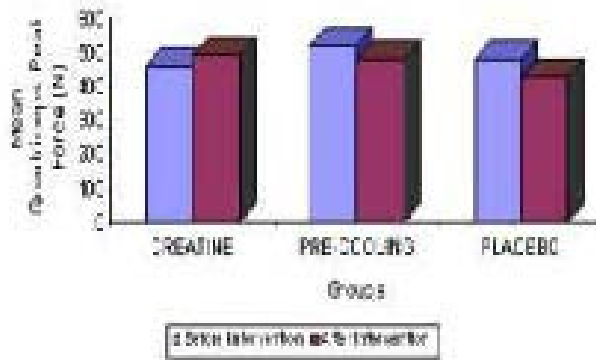


Table-2: Comparison of quadriceps average force before and after intervention in all 3 groups.

Group	Quadriceps Peak Force (N)	
	Before Intervention	After Intervention
	Mean	Mean
Creatine Supplementation	416.75±87.38	444.10±82.48**
Pre-cooling	458.79±128.22	415.05±138.74**
Placebo	431.03±66.88	386.13±76.01**

* indicates significance $p < 0.05$

** indicates significance $p < 0.01$

Fig. 2: Distribution of mean values of quadriceps average force (N) before and after training in all 3 groups.

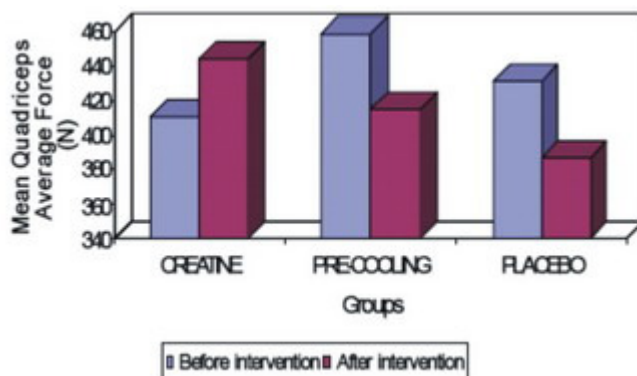


Table-3: Comparison of quadriceps fatigue index (%) before and after intervention in all 3 groups.

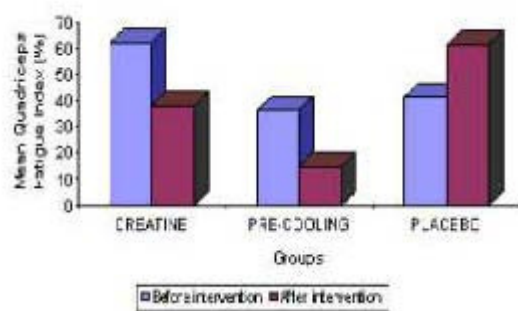
Group	Quadriceps Fatigue Index (%)#	
	Before Intervention	After Intervention
	Mean	Mean
Creatine Supplementation	62.13±62.23	38.06±41.21
Pre-cooling	36.32±3.39	14.58±14.17
Placebo	41.23±36.81	61.67±41.17**

* indicates significance $p < 0.05$

** indicates significance $p < 0.01$

Decrease in Fatigue Index (%) indicates increase of isometric endurance and vice versa.

Fig. 3: Distribution of mean values of quadriceps fatigue index (%) before and after training in all 3 groups.



2) Average force: On inter group comparison of mean average force (N) of quadriceps before and after Intervention, it was found that the creatine group gained average force significantly at ($p < 0.05$) on the contrary pre-cooling and placebo group significantly lost strength at ($p < 0.05$) respectively.

Isometric endurance: On inter group comparison of mean fatigue index (%) of quadriceps before and after intervention (taken as a measure of isometric endurance measured using a 60 second isometric hold) it was found that Creatine supplementation and pre-cooling group gained isometric endurance significantly at ($p \leq 0.05$) whereas placebo group showed a significant reduction in isometric endurance at ($p \leq 0.05$) respectively.

Decrease in Fatigue Index (%) indicates increase in isometric endurance and vice versa.

Discussion

Isometric Strength

The result of the study showed that the trend for isometric curve was on increase with 8.1% in average force and 6.09% in peak force of quadriceps, in oral creatine supplementation group.

These parameters were taken as a measure of isometric strength.

The energy required to perform brief explosive-type exercise is almost exclusively provided by the high energy phosphate stores in skeletal muscle. Creatine supplementation produces elevated muscle creatine phosphate (CrP) content which increases the capacity for ATP re-phosphorylation ($\text{Cr} + \text{ADP} \rightarrow \text{creatine} + \text{ATP} + \text{H}^+$) thereby increasing the potential to maintain high power output during repeated short bouts of supra maximal exercise, during which energy is primarily derived from the ATP-creatine phosphate system. This results in an increased peak power output following supplementation.

Luc et al⁸ reported similar findings for isometric strength in a study twenty subjects who underwent five days of creatine supplementation (20gm per day) indicating an increase in the average power. Further, Maganaris et al⁹ reported that the increase in Maximal Voluntary Contraction force (MVC) after creatine supplementation might be a result of neural or peripheral changes. This is consistent with the study conducted by Harris et al⁴ also supported the notion that creatine supplementation might improve energy substrate availability during the later stages of sustained bout of high intensity exercises

Further, Hultman et al³ reported that an increase in peak torque production after creatine supplementation may be a consequence of muscle buffering capacity being increased as a result of rise in muscle Pcr stores.

The results for the above mentioned parameter in the present study are in agreement with the results of Greenhaff et al¹⁰ and Urbanski et al¹¹ stating similar results on peak torque after creatine supplementation and reporting that creatine supplementation can increase maximal strength and time to fatigue during isometric exercise.

The implication of the study that creatine supplementation in sports persons can be an effective ergogenic aid to improve strength is in accordance with the findings of Lin et al¹ suggesting the use of creatine supplementation in conjunction with a good conditioning program can significantly increase more muscular strength and power than the good conditioning program alone.

The results for isometric strength however, are in contradiction to the findings of Bembien et al¹² concluding that oral supplementation with creatine monohydrate in untrained males does not positively influence isometric strength but may enhance intermittent isometric muscular endurance.

Further, Cooke et al¹³ did not find a positive influence of creatine supplementation on power output or fatigue during continuous high intensity bicycle exercise in untrained men.

Studies investigating the effects of creatine supplementation on short term, high intensity exercises have reported equivocal results, with approximately equal numbers reporting significant and non-significant results.

Regarding pre-cooling in the present study results demonstrate a significant loss of strength with a decrease of 9.53% average force and 11.08% peak force in the pre-cooling group. Also a similar trend was observed in the control group with a 10.40% decrease in average force and 10.72% in peak force of quadriceps which were taken as a measure of isometric strength.

Asmusen et al¹⁴ and sergeant et al¹⁵ reported that decreased strength in the Pre-cooling group may be due to the reason that cooling the muscle results in changes that may impair short term muscular performance. However recent studies suggest that the impairments in muscle function last less than twenty minutes consistent with the studies of Further a rapid decrease in skin temperature with

initiation of cooling significantly decreases peak torque, suggesting a significant contribution of local skin temperature on isokinetic strength, these results have been supported by the study of [Cheung et al¹⁶] reporting an impairment in isokinetic force production independent of core temperature in a study of twenty young healthy males who performed two maximal voluntary knee extensions.

Isometric endurance

The results of the present study showed an increase in the trend for isometric endurance with a 60.9% decrease in fatigue index of quadriceps for the Pre-cooling group, as fatigue index decreases endurance increases. This denotes an increase in the isometric endurance. Significant increase in muscular endurance in the precooling group may be due to the reason that with exercise there is a decreased in the blood supply to the skin as a result of cold induced vasoconstriction. This probably is a reason for the delay in the onset of fatigue. These findings are consistent with those of Smith et al¹⁷ evaluating the effect of skin pre-cooling, at 10°C on fatigue and reported a delay in the onset of fatigue. As pre-cooling lowers core and skin temperature this reduces the need for blood at skin. Also pre-cooling increases central blood volume and enhance blood delivery to the working muscles. An increase in central blood volume may be potentially beneficial to maximal exercise performance, as it results in enhanced oxygen delivery resulting in a greater contribution of aerobic system to energy supply for any given power output [Marsh et al¹⁸]. For the creatine supplementation group there was a 38.74% decrease in the fatigue index, which was taken as a measure of isometric endurance.

A significant increase in fatigue index by 49.5% and thus a reduction in muscular endurance was seen in Control group.

A significant result in the creatine supplementation group could be attributed to an increased post creatine supplementation Maximum Voluntary Contraction [Magnaris et al⁹]. A higher level of pre-exercise energy substrate availability [Harris et al⁴] and an increased buffering capacity [Greenhaff et al¹⁰] could also contribute to the increased endurance capacity. An increase in the endurance capacity could also be partially attributed to an improvement in ADP homeostasis in the muscle after creatine supplementation. Such an effect could improve performance in two ways, first by maintaining the ATP/ADP ratio in the micro environment of the contractile proteins and therefore the energy charge of the muscle cell at optimum level. Secondly, an increase in resting ADP may result in earlier mitochondrial respiration in the muscle [Green et al¹⁹] which in turn would increase the contribution of ATP regeneration in the muscle cell from aerobic metabolism.

Conclusion

Summarizing the findings of this study to investigate and compare the effects of oral creatine supplementation and pre-cooling on isometric strength and endurance of quadriceps femoris muscle and also on aerobic power, it is concluded that a regime of 6 days of oral creatine supplementation (5gm x 4 doses per day) increases the isometric strength and endurance and also aerobic power.

Pre-cooling at 16±2°C results in an immediate loss in strength but isometric endurance and aerobic power is improved.

Results of the present study support the following conclusion:

- The regime of oral creatine supplementation, used in this study produced isometric strength gain whereas the protocol used for pre-cooling resulted in loss of strength post cooling.
- Both the protocols resulted in an improved isometric endurance but pre-cooling significantly improved isometric endurance as compared to creatine supplementation.
- Both the ergogenic aids resulted in an improved aerobic power but as compared to pre-cooling creatine supplementation significantly enhanced the aerobic power

References

1. Lin JY, The effects of creatine supplementation on body composition, muscular strength and power. Department of health and physical education, Northern State University. 1999
2. Richard BK, Effects of creatine supplementation on performance and training adaptations. *Molecular and cellular biochemistry*. 244: 89-94, 2003.
3. Hultman E, Bergstrom M, Breakdown and resynthesis of phosphorylcreatine and adenosine triphosphate in connection with muscular work in men. *Scand J Clin Lab Invest*. 19(suppl 94) 56-66, 1967.
4. Harris RC, Soderlund K, Elivation of creative in resting and exercised muscle of normal subjects by creatine supplementation, *Clinical Science* 83: 367-374,1992.
5. Westerblad HJA, Lee J. cellular mechanisms of fatigue in skeletal muscles. *Am J physiol*. 261 (cell physiol. 30): (195-209), 1991.
6. Gilliam JD, Hohzorn C, Effects of oral creatine supplementation on isokinetic torque production. *Medicine and science in sports and exercise*. 32(5):993-96, 2000.
7. Marino PE, Methods, advantages and limitations of body cooling for exercise performance. *Br J Sports Med*. 36:89-94, 2002.
8. Luc JC, Loon V, Effects of creatine loading and prolonged creatine supplementation on body composition, fuel selection, sprint and endurance performance in humans. *Clinical Science*. 104:153-162, 2003.
9. Magnaris CN, Maughan RJ, Creatine supplementation enhances maximal voluntary isometric force and endurance capacity in resistance trained men. *Acta Physiologica Scandinavica*. 163(3):279, 1998.
10. Greenhaff PL, Casey A, Influence of oral creatine supplementation on muscle torque during repeated bouts of maximal voluntary exercise in man. *Clin Sci(Lond)*. 84(5): 565-71, 1993.
11. Urbanski RL, Vincent WJ, Creatine supplementation differently affects maximal isometric strength and time to fatigue in large and small muscle groups. *Int J Sport Nutr*. 9(2): 136-145, 1999.
12. Bembem MG, Tuttle TD, Effects of creatine supplementation on isometric force time curve characteristics. *Medicine and science in sports and exercise*. 33 (11):1876- 81, 2001.
13. Cooke WH, Grandjean PW, effects of oral creatine supplementation on power output and fatigue during bicycle ergometry. *J Appl Physiol*. 78(2):670, 1995.
14. Asmusen E, Boje O. Body temperature and capacity of work. *Acta physiol Scand*. 10: 1-22. 1945.
15. Sergeant AJ. Effect of muscle temperature on leg extension force and shortterm muscle power output in humans. *Eur J Appl Physiol*. 56: 693-698, 1987.
16. Cheung SS, Robinson AM, The influence of upper body pre-cooling on repeated sprint performance in moderate ambient temperatures. *Journal of Sports Sciences*. 22: 605-612, 2004.
17. Smith JA, Yates K, Precooling improves cycling performance in hot/humid conditions. *Medicine and science in sports and exercise*. 29(5) supplement abstract 1501. 1997.
18. Marsh D, Sleivert G, Effect of pre-cooling on high intensity cycling performance. *Br J Sports Med*. 33: 393- 397, 1999.

19. Green AL, Hultman E, carbohydrate ingestion augments skeletal muscle creatine accumulation during creatine supplementation in humans. Am J Physiol. 271 (Endocrinol Metab. 34); E821-826, 1996.

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