Article published online: 2024-07-29

Original Article

Effects of Short-Term Creatine Monohydrate Supplementation Combined with Strength Training on the Physical Fitness Characteristics and Muscle Hypertrophy in Junior Women Wrestlers

Ghadir Zahabi[1] Amador García-Ramos[2,3] Vladimir Ilic[1] Aleksandar Nedeljkovic[1]
Valdemar Štajer[4] Nenad Žugaj[5] Damir Pekas[5]

[1] Department of Sports, Faculty of Sport and Physical Education, University of Belgrade, Belgrade, Serbia
[2] Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain
[3] Department of Sports Sciences and Physical Conditioning, Faculty of Education, Universidad Catolica de la Santísima Concepcion, Concepción, Chile
[4] Department of Sports, Faculty of Sport and Physical Education, University of Novi Sad, Novi Sad, Serbia
[5] Department of Sports, Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia

Address for correspondence Ghadir Zahabi, PhD Scholar, University of Belgrade, Faculty of Sport and Physical Education, Studentski Center Beograd, Studentski grad Dom 2, Tusin bunar 147, 11700 Belgrade, Serbia (e-mail: gh.zahabi@yahoo.com).

J Health Allied Sci[NU]

Abstract

Background Creatine is a nutritional supplement commonly used to increase strength performance and muscle mass, but its effects on female wrestlers are still unclear and equivocal. The purpose of the present study is to investigate the efficacy of short-term creatine monohydrate supplementation combined with strength training on the physical fitness characteristics and muscle hypertrophy in junior women wrestlers.

Methodology Eighteen women wrestlers (age = 18.7 ± 0.9 years, body mass index = 21.4 ± 2.5 kg/m^2) participated in this research. Participants were randomly divided into three groups: Experimental Group 1—EXP1: (training with creatine supplementation), Experimental Group 2—EXP2: (training without creatine supplementation), and Control group (without training or creatine supplementation). Strength training was performed for 6 weeks, four sessions per week, with a training intensity ranging from 65 to 75% of the maximal heart rate reserve and one-repetition maximum. EXP1 was supplemented with 10 g creatine during training days. Various physical fitness characteristics and muscle hypertrophy variables were collected at three time points (pretest, midtest, and posttest).

Results A number of variables were significantly improved in the EXP1 after 6 weeks (weight, body mass index, one-repetition maximum, agility, muscular power, and hypertrophy) but not in the EXP2 and control groups.

Conclusion Short-term creatine supplementation, in conjunction with strength training, emerges as a highly effective approach for enhancing hypertrophy and

Keywords
- nutritional supplements
- muscular power
- hypertrophy
- freestyle wrestling

DOI https://doi.org/10.1055/s-0044-1788683.
ISSN 2582-4287.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

boosting physical fitness factors in female wrestlers. Therefore, it is recommended that junior wrestlers individuals supplement with creatine during their strength training routines.

Introduction

Wrestling was an important part of the ancient Olympic Games and is still one of the more popular events of the modern Olympic Games. This combat sport is based on a weight class system, which aims to balance out the physical characteristics between wrestlers and therefore increase the percentage of performance that depends on technical and psychological skills. Currently, in the Olympics two wrestling styles are included: Greco-Roman and Freestyle.[1] Freestyle wrestling is practiced in two 3-minute periods with a 30-second rest between rounds in current international competition. Female wrestling is classified as a different category because of the gender difference, although its rules are the same as freestyle wrestling of men. A wrestling match requires tremendous physical activity, power, and strength of body musculature as well as isometric force for various wrestling techniques.[2] Wrestling has been described as an intermittent physical event, which produces great strength and muscle power demands of both the upper and lower body, with a high anaerobic energy metabolism demand.[3] Numerous researchers have also reported that, although aerobic performance may be a basic requirement for wrestlers, it cannot be considered a critical component of success in this sport.[4] Wrestlers periodically engage in a higher degree of dietary restraint than other athletes, because wrestling depends on the weight of the participating athlete. This often includes a change in dietary intake or habits. Weight regulation practices among wrestlers have been proven to have negative effects on health parameters such as nutritional status, hormonal status, and immune function.[5] Wrestlers have to be adapted to repetitive bouts of high-intensity actions to be successful. Maximal strength and power, muscular endurance, maximal aerobic power, and anaerobic capabilities are important factors for success in wrestling competitions.[6] Wrestling is a highly intensive sport, which requires a great effort from the wrestler to bear the burdens of the game. It became like other sports in which players accept food aids, including creatine, and the consumption of varying doses that are not regulated. Every wrestler uses creatine in a personal way or according to what they hear from other wrestlers.[7]

Optimal athletic performance results from a combination of factors, including training and nutrition.[8] Young female athletes have more nutritional needs than other adolescents because of physical activity and physical development, especially those athletes who exercise strenuously in order to maximize their performance.[5,9] Despite the increased interest in nutrition and the use of dietary supplements to enhance performance,[10,11] some athletes might be consuming diets that are less than optimal.[12] Some athletes purposefully restrict their dietary intake to lose weight and maintain a low body weight.[13]

One of the issues considered by athletes since a long time ago is improving sports performance. In recent years, hundreds of special nutritional supplements have been introduced for athletes. Creatine is among these supplements. Extensive studies have investigated the effects of supplements on sports performance.[14] Creatine is a nutritional supplement used to increase strength and muscle mass and helps delay fatigue in high-intensity exercises.[15] Creatine monohydrate (CrM) is one of the most common sports supplements, which is used to achieve high levels of phosphate needed to generate energy during exercise.[16] Creatine is the biggest contributor to athletes because it is not a banned substance and has a positive effect as a key source of energy. It helps athletes increase speed and ability to exert more effort during sports activities, especially in wrestlers.[17]

Nevertheless, previous clinical studies reported inconsistent data regarding the effects of creatine supplementation. A previous study conducted by Joan Eckerson[18] showed that creatine supplementation in women athletes significantly effects the exercise performance and body composition. In addition, an experimental research[14] found that creatine supplementation combined with strength training resulted in significant improvements in hypertrophy and physical performances in women. Similarly, one study reported[15] that resistance training could increase power, but for increase in strength, weight, and hypertrophy in wrestling, creatine intake is necessary. Another study conducted by García-Pallarés et al[1] investigated physical fitness factors in wrestlers. The authors suggested that the higher absolute and relative values of maximal strength, muscle power, and anaerobic metabolism, explained in part by the differences in lean mass and neural activation patterns, will give elite wrestlers a clear advantage during training. However, certain authors have reported conflicting outcomes. In a double-blind, placebo-controlled, parallel-group study by Aedma et al,[19] the researchers found that short-term creatine supplementation (5 days) has no impact on upper body muscle anaerobic power output in consecutive UBISP (upper body intermittent sprint performance) anaerobic tests in trained wrestlers.

During the 1980s, a few studies examined fitness profiles for wrestlers at different competitive levels in order to identify physiological differences that may contribute to success.[20,21] However, a limited number of studies have examined differences in physical fitness characteristics related to success in modern wrestling performance following the aforementioned rule changes and evolution in training methods during the last 20 years. These changes include an overall increase in wrestling performance at the elite level, the struggle against illegal pharmacological interventions, an increase in the total number of competitions per year, as well as the evolution of training and assessment equipment.

Furthermore, examination of physical fitness factors in female wrestlers can be very helpful for optimizing strength, power, and endurance training programs to improve wrestling performance. According to the researchers, the problem of the research lies in the absence of studies that confirm the proper ratios of taking creatine by athletes of wrestling sport, which is characterized by high loads and intensity during training. A further reason for conducting the current research is the lack of enough studies to determine the effect of creatine intake on these variables in women wrestlers.

We hypothesized that supplementation with creatine intake will have a significant improvement in physical fitness characteristics and lead to increase in muscle hypertrophy in junior female wrestlers who are engaged in strength training. This study therefore aimed to examine the effect of short-term CrM supplementation on the physical fitness characteristics (weight, body mass index [BMI], body fat percentage [BF%], fat-free mass [FFM], maximal oxygen consumption [VO_2 max], resting heart rate [RHR], one-repetition maximum [1RM], agility, muscular power) and muscle hypertrophy variables in junior women wrestlers combined with strength training.

Materials and Methods

Study Design

This quasi-experimental research study employed purposive sampling to select participants based on specific criteria. Subsequently, the participants were allocated into three groups using the systematic random grouping method, ensuring an equal distribution of female subjects across each group. A wrestling coach and a fitness trainer met with each participant and explained strength training in detail. Obtaining written consent from study participants was a crucial step, involving a comprehensive explanation of the research's objectives and methods. This process aimed to ensure participants' thorough comprehension of the study, enabling an informed decision regarding their involvement. Participants were familiarized with various aspects, including training, research characteristics, variable measurement, training protocol, pretest, midtest, and posttest procedures, as well as instructions, possibilities, and limitations related to the research's time and location. The researcher introduced the study's objectives and procedure to each participant. The participant then completed a training that demonstrated the low- and high-demand tasks. Performance feedback was provided during the training. After the participant confirmed that they felt comfortable with the task, the researchers worked with them. Various physical fitness characteristics and hypertrophy variables were collected at three time points (pretest, midtest, and posttest).

Participants and Sampling Techniques

The study employed the purposive sampling technique to select participants based on predetermined criteria. We assessed level of performance based on objective measures such as training experience, competition results, and rankings. They reached the highest level of performance in their sport, often competing at international or professional levels. Inclusion criteria specified junior female freestyle wrestlers aged under 20 years with a BMI within the range of 20 to 23 kg/m^2. Recruitment occurred in the Belgrade city area in Serbia through direct outreach and advertising. Exclusion criteria included allergies to creatine, a lack of recent physical activity, chronic illnesses, and medication use.

Initially, 21 women wrestlers were recruited based on the sampling technique and criteria. However, three individuals withdrew from the study for reasons unrelated to the research. Consequently, a cohort of 18 junior females, with a mean weight of 63.17 ± 2.65 kg, height of 1.61 ± 1.22 m, BMI of 21.37 ± 2.52 kg/m^2, and an average age of 18.66 ± 0.93 years, competing experience of 5.93 ± 2.4 years were enrolled. These participants were randomly assigned to one of three groups: Experimental Group 1—EXP1: (training with creatine supplementation), Experimental Group 2—EXP2: (training without creatine supplementation), and Control group (without training or creatine supplementation). Participant demographics and characteristics are detailed in ►**Table 1**.

Consumption of Creatine Supplement

The experimental groups received CrM (OstroVit Creatine Monohydrate 300 g natural as a powder form) 30 minutes before and immediately after training sessions administered at a dosage of 10 g while maintaining their habitual daily diet. Also, they had a loading phase only for 1 week.[22]

This supplementation occurred four times per week over a 6-week period, with the creatine dissolved in distilled water.

Table 1 Participant characteristics

Participant characteristics	EXP1	EXP2	Control
Sample size	6	6	6
Age (y)	18.8 ± 0.7	18.9 ± 0.65	18.3 ± 1.45
Height (m)	1.61 ± 1.36	1.64 ± 1.07	1.60 ± 1.25
Weight (kg)	62 ± 2.31	64 ± 3.89	63.5 ± 1.77
BMI (kg/m^2)	21.45 ± 1.33	21.8 ± 3.67	20.87 ± 2.56
1RM	121.5 ± 4.14	125.6 ± 5.29	122.4 ± 5.16
Training experience (y)	6.6 ± 1.9	5.7 ± 2.4	5.5 ± 2.9

Abbreviations: 1RM; one-repetition maximum; BMI, body mass index; EX1, Experimental Group 1; EX2, Experimental Group 2.
Note: All values are presented as mean ± standard deviation.

The morning following the pretest, the subjects began using supplements. Pure powder is used to make CrM. CrM has been micronized to 100% and produced in a plant that makes products containing milk, egg, gluten, soy, crustaceans, Sulphur dioxide, and nuts. As part of their loading phase, they used 450 g of CrM produced by Biotech USA products in every meal for 5 consecutive days. Taking 20 to 25 g of creatine daily for 5 to 7 days is the most typical way to load it. It is common for this to be divided into four 5-g doses throughout the day. The schedule would consist of 5 g in the morning, 5 g in the noon, 5 g before training, and 5 g immediately after training. During the maintenance phase, creatine intake is lower, and it lasts for 4 to 6 weeks following the loading phase. Creatine supplementation should be discontinued for 2 to 4 weeks after the maintenance phase.[23]

Training Protocol

Subjects engaged in a strength program on Mondays, Wednesdays, Fridays, and Saturdays. All are meticulously supervised by the researcher as a wrestling coach and a minimum of two experienced personal trainers. Variable measurements were conducted for all groups before the study initiation, at the 3-week mark, and at the conclusion of the 6-week period. The study protocol comprised four sessions per week, each lasting 60 to 70 minutes, maintaining an intensity of 65 to 75% of maximal reserve heart rate and 1RM. The strength training protocol, commenced in the first week at 65% heart rate reserve (HRR) and 1RM for 60 minutes, progressively increasing to 70 minutes with 75% maximum HRR and 1RM by the study's conclusion. This progression involved the addition of 5 minutes to the duration and a 5% intensity increase every 2 weeks (►**Table 2**).

Experimental Measurements

Bioelectrical impedance analysis was employed to estimate physical fitness characteristics, involving the passage of a weak electric current through the body, with voltage measurements used to calculate body impedance (resistance). The Tanita TBF-300 Body Composition Analyzer was utilized to measure variables such as weight, BMI, BF%, and FFM.[24] Body height and weight measurements were obtained using a calibrated height–weight digital balance beam scale, with recordings in meters and kilograms, respectively.[25]

VO_2 max was determined through a continuous treadmill test for exhaustion on a motorized treadmill, employing the modified Bruce protocol. The treadmill speed was adjusted during the warm-up phase to achieve a heart rate of approximately 70% of the predicted maximal heart rate. Subsequently, treadmill speed remained constant, and the treadmill grade increased by 2% every 2 minutes until volitional fatigue.[26]

RHR was assessed in beats per minute using the Polar RS400 Heart Rate Monitor following a 10-minute rest period in the supine position, adhering to standard protocols.[27]

To estimate strength 1RM, subjects underwent an 8-to-10-minute warm-up, and the test was conducted under the supervision of a researcher. The 1RM for chest press and leg press was recorded and estimated using the formula proposed by Brzeski.[22,28]

The Illinois Agility Test (IAT) was administered using a version standardized from previous literature.[29–32] The length of the IAT was originally set at 30 ft, which was increased slightly to 10 m for ease of test administration. The IAT course was marked by cones, with four center cones spaced 3.3 m apart and four corner cones positioned 2.5 m from the center cones (►**Fig. 1**). The participant began the test lying prone on the floor behind the starting line with his arms at his side and his head turned to the side or facing forward. On the "go" command, the participant ascended to his feet and ran or moved quickly forward to the first tape mark. Participants were required to touch or cross the tape mark with their feet. The participant turned around and moved back to the first center cone, where he weaved up and back through the four center cones. The participant then ran or moved possibly to the second tape mark on the far line. Again, participants were required to touch or cross the end-line tape marks with their feet. Lastly, the participant turned around and ran or moved as quickly as possible across the finish line. The time to complete each trial was recorded in seconds. Disqualification was determined if the participant failed to run the course as instructed, failed to reach the end lines, failed to complete the course, or moved any cones.[32]

Table 2 Resistance training

Training sessions	Training movements			
Chest and biceps (first session)	Barbell bench press, incline barbell bench press, machine fly, dumbbell bicep curls, cable curls			
Back muscles and triceps (second session)	Lat pull-down, seated pulley row, T-bar row, triceps push-down, dip			
Shoulder (third session)	Standing dumbbell fly, dumbbell raise complex, clean and press, dumbbell shoulder, lift dumbbell			
Leg, abdominal (fourth session)	45-degree leg press, machine leg extension, machine leg flexion, ball crunch, side bend			
Week	Set	Repeat	1RM	Rest
First, second	3	12–14	65%	30 s–1 min
Third, fourth	3	12–14	70%	30 s–1 min
Fifth, sixth	3	12–14	75%	30 s–1 min

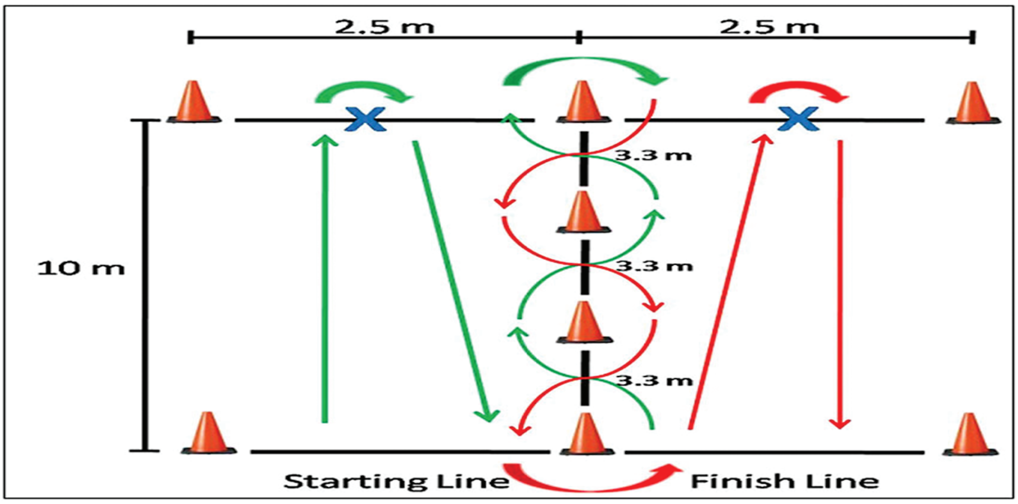

Fig. 1 Illinois Agility Test.

A test of muscular power is often used in fitness testing. The Sargent jump test (vertical jump test) consists of measuring the difference between a person's maximum vertical reach before jumping and at the highest point during a jump. Immediately before testing, all participants performed a 10-minute general warm-up, which included 2 minutes of low-intensity aerobic exercise, dynamic stretching exercises, and one set of six submaximal jumps. After the warm-up, participants performed five maximal countermovement jumps. A one-minute rest interval was given between each countermovement jump attempt. Participants kept the arms akimbo from the start until the completion of the landing phase of the jumps. The countermovement jump test was executed on a force plate (Quattro Jump, Kistler Instrument AG, Winterthur, Switzerland) sampling at 500 Hz.[33]

According to the most simple and straightforward way of reasoning, hypertrophy should be accompanied by a proportional increase of active contractile force. If hypertrophy implies buildup of more myofibrils and more myosin motors and if each myosin generates the same force, force should increase in close proportion to increase of muscle mass during a maximal activation.[34] Hypertrophy refers to the increase in the size of a tissue or organ due to the enlargement of its individual cells. In the context of exercise and physiology, hypertrophy is often used to describe the increase in muscle size. Muscular hypertrophy can result from various forms of resistance training or strength training. Changes in the muscle hypertrophy measured by an ultrasound in cm. The multivariable analyses were conducted and split into upper body (arms and chest) and lower body (thigh, calf).[35] Common areas to measure for muscle hypertrophy include: taking the measurement with the arm relaxed by the side, measuring of the circumference at the midpoint between the shoulder and elbow. For accuracy, you can use the acromion process (bony point on the shoulder) and the olecranon process (elbow point) to find the midpoint. Measure around the fullest part of the chest, typically across the nipples. Ensure the tape is level and straight across the back. Measure at the midpoint between the hip and the knee. For consistency, measure both thighs,and use the average or track each thigh separately. Measure at the thickest part of the calf muscle, typically about halfway between the knee and the ankle. We measured at three time points from the right side of the body when the subjects were at rest and/or fully recovered from exercise. Take these measurements consistently at the same time of day and under the same conditions preferably in the morning before any exercise. The muscle volume of the subjects was measured and recorded in the chest, arm, thigh, and calf areas using a flexible tape meter by McBride et al method.[14] Measuring muscle hypertrophy with a flexible measuring tape involves taking circumference measurements of various body parts. This method is simple, noninvasive, and cost-effective.

Statistical Analysis

All data were set as mean ± standard deviation (SD). The Kolmogorov–Smirnov test was used to examine if variables were normally distributed. For the data analysis, A two-way analysis of variance (ANOVA) with time as within-subject factor and group as between-subject factor with the post hoc analysis of variance (least significant difference test) was used, at a significance level set on $p \leq 0.05$. All data were processed using SPSS software (IBM SPSS Statistics 22).[36]

Results

Physical fitness characteristics of the subjects for pretest, midtest, and posttest based on the mean and SD is shown in (►**Table 3**). Creatine has a significant effect on the development of physical fitness factors in junior women wrestlers during strength training. The ANOVA in the groups in three stages showed that 6-week CrM supplementation combined with strength training showed significant effect on the EXP1 in comparison to the EXP2 and control group. Research findings have shown that creatine in EXP1 improved weight, BMI, VO_2 max, 1RM, agility, and muscular power more than the EXP2 and the control group at only posttest in junior

Table 3 Physical fitness characteristics and muscle hypertrophy of study participants

Variable	Group	Pretest	Midtest	Posttest
Weight (kg)	EXP1	62 ± 2.31	64 ± 4.23	66 ± 3.44[a,b]
	EXP2	64 ± 3.89	65 ± 2.89	65 ± 4.03
	Control	63.5 ± 1.77	63.4 ± 2.52	63.6 ± 3.77
BMI (kg/m^2)	EXP1	21.45 ± 1.33	21.87 ± 3.11	22.22 ± 3.08[a,b]
	EXP2	21.8 ± 3.67	21.7 ± 2.84	20.75 ± 1.55
	Control	20.87 ± 2.56	20.05 ± 2.63	20.11 ± 1.39
BF%	EXP1	18.81 ± 2.51	18.02 ± 2.34	19.89 ± 2.48
	EXP2	17.11 ± 2.10	18.85 ± 2.11	17.31 ± 2.02
	Control	19.97 ± 3.98	18.09 ± 3.95	18.06 ± 3.90
FFM (kg)	EXP1	50.31 ± 7.10	50.04 ± 7.08	51.93 ± 7.09
	EXP2	51.95 ± 7.73	52.77 ± 7.28	51.41 ± 7.36
	Control	52.32 ± 6.28	52.38 ± 6.03	52.37 ± 6.04
VO_2 max (mL/kg/min)	EXP1	32.24 ± 3.54	33.88 ± 2.45	36.21 ± 3.65[a,b]
	EXP2	32.84 ± 2.86	32.33 ± 4.12	32.46 ± 2.79
	Control	32.01 ± 3.66	32.78 ± 2.40	32.37 ± 4.95
RHR (bpm)	EXP1	74.60 ± 4.15	75.20 ± 4.46	74.70 ± 4.37
	EXP2	75.95 ± 4.74	75.60 ± 4.47	75.30 ± 3.91
	Control	75.10 ± 4.29	75.00 ± 4.29	76.90 ± 4.12
1RM (kg)	EXP1	121.5 ± 4.14	125 ± 2.67	131.55 ± 4.14[a,b]
	EXP2	125.6 ± 5.29	127.05 ± 4.33	128.46 ± 3.1
	Control	122.4 ± 5.16	123 ± 3.29	122.87 ± 0.22
Agility (IAT)	EXP1	17.9 ± 2.35	17.7 ± 3.44	17.1 ± 2.59[a,b]
	EXP2	17.8 ± 4.23	17.7 ± 3.55	17.6 ± 4.12
	Control	17.8 ± 2.56	17.8 ± 4.94	17.7 ± 2.88
Muscular power (SJT)	EXP1	45.25 ± 6.2	46.02 ± 5.03	50.77 ± 3.97[a,b]
	EXP2	44.59 ± 5.33	44.25 ± 3.59	45.29 ± 6.47
	Control	43.5 ± 4.66	44 ± 6.11	42.8 ± 5.69

Abbreviations: 1RM, one-repetitions maximum; BMI, body mass index; BF %, body fat percentage; EXP1, Experimental Group 1; EXP2, Experimental Group 2; FFM, fat-free mass; IAT, Illinois Agility Test; RHR, resting heart rate; SJT, Sargent jump test; VO_2 max, maximal oxygen consumption.
Note: All values are presented as mean ± standard deviation.
[a]Significant differences compared with pretest.
[b]Significant difference compared with the control group.

women wrestlers. These variables were not significant for the EXP2 and the control group ($p \leq 0.05$).

Muscle hypertrophy (volume of muscle) of the subjects for pretest, midtest, and posttest based on the mean and SD is shown in ►**Fig. 2**. Creatine has a significant effect on the muscle hypertrophy variable in junior women wrestlers combined with strength training. The ANOVA in the groups in three stages showed that 6-week CrM supplementation combined with strength training showed significant effect on the EXP1 in comparison to the EXP2 and the control group. Research findings have shown that creatine in EXP1 improved hypertrophy at only posttest in junior women wrestlers. These variables were not significant for the EXP2 and the control group ($p \leq 0.05$).

Discussion

This research explored the impact of short-term CrM supplementation in combination with strength training on physical fitness characteristics and muscle hypertrophy among young women wrestlers. The primary outcome of this investigation revealed that a 6-week regimen of creatine supplementation paired with strength training led to substantial improvements in both physical fitness factors and muscle hypertrophy. In contrast, in the experimental group that consumed creatine supplements without engaging in physical exercise, no significant alterations were observed across the measured variables. These results highlight the critical role of physical exercise in eliciting beneficial

Fig. 2 Muscle hypertrophy of study participants. All values are presented as mean ± standard deviation. *Significant differences compared with pretest; ¥significant difference compared with the control group. EXP1, Experimental Group 1; EXP2, Experimental Group 2.

changes in physical fitness factors and muscle hypertrophy, reinforcing the synergy between dietary supplementation and physical training.

The results showed that short-term CrM combined with exercise training led to a significant increase in weight and BMI in EXP1. Creatine is known to enhance muscle mass and strength, and when combined with exercise, it can lead to increased muscle protein synthesis and potentially result in weight gain, particularly in the form of muscle mass. Changes in weight (in this study) seem to be due to water retention.[37] Moreover, the impact of creatine on water retention can also influence short-term weight changes. Researchers often use various measures, such as BF% and muscle mass, to get a more comprehensive understanding of the effects of interventions on body composition.[38] In agreement with this, Almeida et al showed that CrM supplementation promoted an increase in the performance and body weight.[39] Similarly, increased body mass may be indirectly related to and explained by greater muscle accretion from creatine supplementation and resistance training.[40]

Our analysis showed that short-term creatine along with concurrent training significantly increased VO_2 max in EXP1 after 6 weeks. Since oxidation of fat requires more oxygen compared with carbohydrates, the cardiovascular system should receive more oxygen for muscles. In this regard, L-carnitine increases oxygen consumption and lipid oxidation by stimulating the pyruvate dehydrogenase complex and the entry of pyruvate into the beta-oxidation pathway.[41] The results of the present study are in agreement with many studies demonstrating an increase in VO_2 max from training.[42]

It was hypothesized that short-term creatine supplementation would result in a significant increase in 1RM after 6 weeks of strength training in EXP1 compared with EXP2 and the control group. It probably was myofibrillar protein synthesis and recruitment of fast twitch motor units that our study was also in agreement with other authors.[43] Although studies using physically active and highly trained females as participants are lacking, both short- and long-term creatine supplementation has been shown to result in significant improvements in muscular strength and power. One of the first comprehensive studies to investigate the effects of creatine on strength performance in females was conducted by Vandenberghe et al.[44] Aguiar et al indicated that creatine supplementation combined with resistant training improves the ability to perform submaximal strength functional tasks and promotes a greater increase in maximal strength (1RM) in women that was compatible with our result.[45]

Our analysis showed that short-term CrM supplementation along with strength training significantly increased agility in EXP1 after only posttest. Developing agility can enhance a wrestler's ability to change direction quickly, evade opponents, and improve overall on-mat maneuverability. For young women wrestlers, agility training should be tailored to their specific needs, considering factors such as age, skill level, and individual characteristics.[46] These findings were also shown in a study by Bogdanis et al who demonstrated that creatine supplementation improved the mean Agility test despite an increase in body weight.[47]

In our results, short-term CrM supplementation significantly increased muscle hypertrophy, in EXP1 after 6 weeks, but this effect was not identified for other groups. Junior wrestlers' training focused on developing lean body mass capable of generating the power necessary to carry the athlete as rapidly as possible. Adaptations to training are specific to the mode, intensity, and duration of the exercise. These adaptations stem primarily from the exercise stimulus on the muscle fibers but may influenced by nutritional factors. Nutrition most certainly will influence muscle hypertrophy, and this aspect of nutrition is usually the focus for wrestlers. Besides specific wrestling training, weight training with the goal to develop muscle mass is the primary form of training throughout the year.[15] Burke et al demonstrated that creatine supplementation combined with resistance training promotes a small increase in the direct measures of skeletal muscle hypertrophy.[35] Creatine is a well-researched and popular dietary supplement that has been shown to have positive effects on muscle hypertrophy, especially when combined with resistance training. Muscle hypertrophy refers to the increase in the size of muscle cells, resulting in overall muscle growth. Creatine is involved in the production of adenosine triphosphate (ATP), which is the primary energy source for muscle contractions. By supplementing with creatine, individuals may enhance their ability to perform high-intensity exercise, allowing for more significant muscle stress and potential hypertrophy during resistance training.[48] One of the well-established effects of creatine supplementation is an increase in muscle mass. Creatine helps muscles retain water, leading to an increase in cell volume. This can contribute to a gain in lean body mass, as water content within muscle cells rises.[49] Creatine supplementation can increase muscle mass. This is beneficial for wrestlers who need to improve their strength without significantly increasing their weight class.[50] Creatine allows athletes to train at higher intensities and volumes, leading to better overall training adaptations and improvements in performance.[15]

However, our results failed to report any significant change in BF%, FFM, and RHR between the groups. In agreement with our study, Kutz and Gunter studied CrM supplementation on the BF%. They found that there was no significant difference in BF% for the creatine group after the supplementation period and no significant difference was found for the placebo group.[37] These findings refute the common belief held by many exercising individuals that creatine supplementation increases fat mass over time. Mechanistically, the result in BF% from creatine may be related to its involvement in adipose tissue metabolism and whole-body energy expenditure. CrM supplementation significantly increased total body mass and body water content, but it did not have significant effects on BF% for caloric intake. The weight gained using creatine supplementation is partly due to water retention and not a gain in FFM. BF% did not significantly decrease; therefore, the weight gained was not FFM.[51] Some studies investigating creatine supplementation on performance have reported noneffect in FFM. Additionally, the magnitude of changing in FFM may depend on factors such as training status, diet, and the specific protocol used for creatine supplementation.[52] Earnest et al observed a nonsignificant increase in FFM and no change in body fat in their subjects who ingested creatine.[53] These findings suggest that intramyofibrillar water retention may account for most of the increases in FFM.[54]

Research on the effects of creatine supplementation on RHR is limited, and the available evidence is not entirely consistent. Creatine is primarily known for its effects on muscle energy metabolism rather than cardiovascular parameters. Responses to creatine can vary among individuals. While some people may experience a reduction in RHR, others may not show any significant changes. It is essential to note that creatine is commonly associated with improvements in high-intensity exercise performance, muscle strength, and power rather than cardiovascular parameters. As with any supplement, individual responses can be influenced by various factors, including genetics, overall health, and lifestyle.[55]

For athletes who wish to gain weight or overall mass, creatine may be an option. Because the evidence in this study shows that water retention is a source of weight gain and not strictly FFM, it is incorrect to assume that creatine supplementation alone will increase athletic performance. Resistive strength training, aerobic conditioning, and practicing sport-specific skills have a much greater influence on improving overall performance and increasing FFM than creatine supplementation. Athletes should increase their hydration rates during supplementation that may help curb any symptoms of dehydration or cramping that may occur with supplementation. Creatine supplementation can provide several benefits for wrestlers, including increased muscle mass and strength, enhanced anaerobic performance, improved training adaptations, cognitive benefits, and better recovery. When used properly, it can be a valuable addition to a wrestler's nutrition and training regimen.

Mechanistically, creatine supplementation increases the skeletal muscles' total creatine (free creatine and phosphocreatine), allowing for a greater capacity to rapidly resynthesize ATP and consequently enhance high-intensity exercise.[35]

To our knowledge, this is the first reported case that simultaneously analyzes factors of creatine, physical fitness factors, and hypertrophy for junior women wrestlers combined with strength training. The study may be specific to junior women wrestlers, making it challenging to generalize the findings to other populations, such as male athletes or individuals in different sports. The main limitation of this research was hormonal fluctuations and pubertal status in junior women wrestlers can introduce additional variability. These factors may influence muscle development and responses to supplementation differently across individuals.

Conclusion

Creatine supplementation, in conjunction with strength training, emerges as a highly effective approach for enhancing hypertrophy and boosting physical fitness factors as a promising strategy for improving these variables in junior female wrestlers. Therefore, it is recommended that junior wrestlers individuals supplement with creatine during their strength training routines.

Conflict of Interest
None declared.

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