Creatine supplementation and strength training: alterations in the resultant of dynamic maximum strength and anthropometric variables in college students submitted to 8 weeks of strength training (hypertrophy)

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ABSTRACT

Objective: To verify the alterations promoted by creatine supplementation in the anthropometric variables and the resultant of dynamic maximum strength (RDMS) in college students submitted to 8 wk of strength training. **Methodology:** The sample consisted of 18 male college students, aged between 19 to 25 years. Height (cm), body mass (kg) and tests of maximum voluntary muscular action (1MVMA) weight in the squat were determined prior to the training. The subjects were divided in two groups: A (creatine) or B (placebo). The double-blind protocol was adopted. After 8 weeks of strength training, the tests battery from the pre-training was repeated. **Results:** After 8 wk of training, it was verified that both groups had statistically significant (SS) alterations in the RDMS in all the exercises (p = 0.007 / 0.008). The analysis of the percentile improvement (PI) and the RDMS delta in the squat exercises, military press and close-grip-extensions, showed that group A had positive SS alterations higher than group B (p = 0.008 / 0.038). Lean body mass only SS increased in group A (p = 0.038). However, the percentage of body fat did not show alterations in none of the groups. The relationship between the PI of the arm and forearm circumferences (C) and the PI in the RDMS of the development exercise was SS (r = 0.481 and 0.546, respectively), as well as between the PI in the thigh C and the PI of the RDMS of the squat exercise (r = 0.619). **Conclusion:** Regardless the substance ingested, strength training was able to increase in RDMS; however, creatine supplementation was shown to be more efficient that the placebo, showing higher percentual and delta improvement in strength.

Keywords: Sports nutrition. Physical training. Ergogenic aid.

INTRODUCTION

Due to the increase of commercialization of nutritional products with the purpose to play an ergogenic effect in sports performance, many physical activities practitioners, especially body-builders, have been using them in order to promote strength and muscular mass increase. Thus, several nutritional supplements can be found in the market, from amino acids to zinc, which have been sold as effective ergogenics for physically active individuals. With a few exceptions, such as the carbohydrates supercompensation (overload), well-elaborated research does not support the ergogenic effect for the majority of the nutritional supplements when added to a healthy and suitable diet[1-3].

In the end of the 80's and beginning of the 90's, creatine supplementation (Cr) has been an important ergogenic aid in the worldwide sports scenario, as well as for practitioners of endurance exercises with the purpose to increase strength and muscular mass[4-5]. The success of British runners and jumpers in the beginning of the 90's was associated with Cr supplementation[3,6-7]. Nowadays, this practice has been used by many athletes with maximal strength, explosive strength and velocity, such as bodybuilders, fighters, cyclists, footballers, swimmers, amateur and professional athletes and fitness centers goers.

According to what has been discussed in the investigations by Pereira and Souza Junior[8-10], the term adaptation should not be used to explain structural-functional alterations concerned with physical training, once they are reversible. Therefore, we have adopted the term *alteration* to explain the alterations occurred in this study.

According to proposals by Phillips[11], also supported by Pereira and Souza Júnior[9-10,12] and Souza Junior *et al.*[13-14], the correct use of the terminology applied to the maximal load test would be 'Maximal Voluntary Muscular Action' (MVMA), which will be able to evaluate the highest strength voluntarily generated by a maximal dynamic voluntary muscular action (MDVMA) or maximal static voluntary muscular action (MSVMA). Although the terminology proposed by DeLorme and Watkins[15] is internationally accepted (1RM), the understanding of 'repetition' would be showing more than one performance and, since we are expressing the maximal muscular action in a single movement, we will be using in this investigation the terminology proposed here. However, when the number of bouts is equal or higher than two, we will be using the terminology *maximal repetition* (MR).

The aim of this study was to verify the alterations promoted in the anthropometric variables and in the maximal dynamic strength resultant (MDSR) between the creatine supplemented and placebo groups, after 8 weeks of strength training (hypertrophy).

METHODOLOGY

Subjects

Eighteen male university students, aged 19-25 years were volunteers in this study. The inclusion criteria were: (a) to have practical experience of at least 1 (one) year in overload exercises; (b) not to smoke and/or drink alcohol; (c) not to make use of androgenic anabolic steroids or similar substances and (d) not to present pathological history. The study was approved by the Ethics Committee of the College of Medical Sciences of UNICAMP (Project: # 260/2005 – CAAE: 0078.0.146.000-05), according to the norms of the

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4. UNICAMP-FEF – Universidade Estadual de Campinas – Faculdade de Educação Física.

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Resolution 196/96 from the National Health Board on research involving humans.

After having signed a written consent form, the aims and procedures of the study, as well as the involved risks were explained. After the tests battery, the subjects were randomly placed in one of the two groups of the study: creatine group (A; n = 09) and placebo group (B; n = 09).

Evaluation protocol of the maximal dynamic muscular strength resultant

The 1MDVMA tests for exercises of the upper and lower extremities were performed at different days, so that the volunteers could have a longer recovery interval between tests.

1MDVMA test for the bench press exercise

For the 1MDVMA test performed in the bench press exercise (flat and incline), the volunteers had a previous warm-up and could perform three tries (when not determined in a single try) to determine the 1MDVMA. It was considered 1MDVMA when the volunteer was able to repeat a complete movement, having the elbow flexion until the bar touched the chest and immediately after, extending elbow until returning to initial position, using its maximal dynamic voluntary strength, with no external aid (only for safety) of the proposed exercise. In case the volunteer was able to repeat the same movement more than once, the test was stopped and after 5 minutes of rest, it was resumed with load increase to the exercise.

1MDVMA test for the squatting exercise

The 1MDVMA determination in the squatting exercise was measured with simultaneous knee flexing, with the barbell rested on shoulders until reaching a 90° angle. For volunteers' safety, a bench was placed behind each of them, so that they could bend knees until the proposed angle and immediately return to initial position, as soon as the gluteus touched the bench. It was considered 1MDVMA when the volunteer, using his maximal volunteer strength, was able to bend knees until touching the gluteus on the bench and return to initial position without external help (just for safety).

1MDVMA test for knee flexion and extension exercises

The remaining exercises for lower extremities, knee flexion and extension, were performed with specific machines (extensor chair and flexor table), always with three tries for determination of the 1MDVMA and always with 5-minute rest between tries, in case the test had not been determined in a single try.

1MDVMA test for shoulder exercises

In the exercises selected for the shoulders (development and lateral arms lift), the volunteers were instructed to perform 1MDVMA without body balancing ('stolen' repetition), totally starting from inertia. The 1MDVMA test for development was performed as following: a) the volunteer was helped to remove the barbell from the ground with the aid of the evaluators; b) the barbell was placed on the posterior part of the deltoids; and c) the volunteers should lift the proposed load in a single time, making total elbow extension without external help. In the determination of 1MDVMA for the lateral arms lift exercise, the subject started the movement with the dumbbells touching the thigh, in total inertia, making abduction of upper extremities up to the shoulders height. In case there was need for another try, the procedure would be performed according to what was previously described.

1MDVMA test for arm exercises (biceps and triceps)

The exercises called 'barbell curl' and 'dumbbell curl' elbow flexion with forearms lift in prone position, lifting the barbell towards the trunk and elbow alternated flexion with forearm lift in prone position with wrist rotation for the exterior, lifting the dumbbell towards the shoulder, respectively, were also performed with the movement starting from initial position, with total lack of movement. In order to determine 1MDVMA in the selected exercises for the triceps, pulley triceps extension and closed bench press, respectively, the volunteers performed the following procedures: a) pulley triceps: the volunteers faced the machine and were told to perform 1MDVMA extending the elbow, holding the barbell with the two hands and returning to initial position without external help; b) closed bench press: the volunteers started the exercise laid on the bench, holding the barbell with a slight space between hands (distance between thumbs), removing the barbell from the rest with the evaluators' aid and performed 1MDVMA, flexing the elbow until the barbell touched the chest and later extending the elbow until initial position without external help (only for safety).

1MDVMA test for torso muscles

In order to determine the 1MDVMA value in the exercise for the torso muscles performed in the frontal pulldown, the volunteers seated facing the machine, holding the barbell on the extremities with extended elbows, and at the evaluator's command, performed elbows flexion, approaching the barbell towards the torso until touching it, using his maximal dynamic voluntary strength without external interference. In the determination of 1MDVMA in the low row exercise, the volunteer seated on the ground, knees slightly flexed and feet resting on the specific foot rest from the machine, extended elbows and holding the triangle. At the evaluator's command, the volunteer flexed the elbow, together with the shoulder extension, until touching the triangle on the torso, using his maximal dynamic voluntary strength.

1MDVMA tests for the abdomen

In the abdominal exercise (crunch), the 1MDVMA test was performed with volunteers facing the *pulley*, seated on their ankles, holding the triangle with fleeted elbows and flexing the spine until the elbows would touch the knees. In case other tries were needed, the procedures were equal to the ones previously described for all exercises.

The 1MDVMA load determination was performed in the pre and post-training.

Strength training protocol

The training protocol was applied during 8 weeks. During the two first weeks (Phase A) the training had the aim to provide neuromuscular adjustments in the students; in the six subsequent weeks (Phase B) the training aimed to increase the MSR and muscular mass (hypertrophy).

The training was performed in 6 weekly sessions, from Monday to Saturday. Free weights and machines were used and the training was supervised by a group of students especially prepared for the task. Phase A consisted of exercises performed at 50% of 1MDVMA, with 120-second pause between them (table 1 and table 2). Phase B consisted of exercises at 80% of 1MDVMA, performing 4 bouts with 8 to 10 repetitions with 120-second pause between exercises from one muscular group to another (table 3, table 4, table 5). The pauses were decreasing during the subsequent training weeks, according to the protocol proposed by Souza Junior[13-14,16], illustrated in table 6.

Supplementation protocol

The protocol proposed by Souza Junior[16], from the study by Volek *et al.*[17] was applied. During the 3rd week of training (Phase B) the subjects from group A ingested 30 g of monohydrated creatine (CrH_2O) a day, divided in five equal doses of 5 g at 3 to 4-hour intervals. From week 4 to 8, 5 g of monohydrated creatine a day were administered, which corresponded to the maintenance phase. Group B received the same supplementation profile, where the placebo used was maltodextrine.

TABLE 1
Phase A, training A performed on Mondays, Wednesdays and Fridays during weeks 1 and 2

Exercise	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
Bench press	50	12	3	120
Incline bench press	50	12	3	120
Frontal Pulldowns	50	12	3	120
Extensor chair	50	12	3	120
Squatting	50	12	3	120
Flexor table	50	12	3	120

MDVMA: maximal dynamic voluntary muscular action.

TABLE 2
Phase A, training B performed on Tuesdays, Thursdays and Saturdays during weeks 1 and 2

Exercise	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
Frontal development	50	12	3	120
Lateral lifting	50	12	3	120
Barbell curl	50	12	3	120
Dumbbell curl	50	12	3	120
Pulley triceps extension	50	12	3	120
Barbell triceps extension	50	12	3	120
Abdominals with overload	50	20	5	120

MDVMA: maximal dynamic voluntary muscular action.

TABLE 3
Phase B, training A performed on Mondays and Thursdays during weeks 3 to 8

Exercise	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
Bench press	80	8-10	4	Pauses were
Incline bench press	80	8-10	4	decreasing according
Frontal Pulldown	80	8-10	4	to description
Low row	80	8-10	4	on table 6.

MDVMA: maximal dynamic voluntary muscular action.

TABLE 4
Phase B, training B performed on Tuesdays and Fridays during weeks 3 and 8

Exercise	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
Frontal development	80	8-10	4	Pauses were
Lateral lift	80	8-10	4	decreasing
Barbell curl	80	8-10	4	according to
Dumbbell curl	80	8-10	4	description
Pulley triceps extension	80	8-10	4	on table 6.
Barbell triceps extension	80	8-10	4	

MDVMA: maximal dynamic voluntary muscular action.

TABLE 5
Phase B, training C performed on Wednesdays and Saturdays during weeks 3 to 8

Exercise	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
Extensor chair	80	8-10	4	Pauses were
Squatting	80	8-10	4	decreasing according
Flexor table	80	8-10	4	to description
Abdominals with overload	50	20	4	on table 6.

MDVMA: maximal dynamic voluntary muscular action.

TABLE 6
Decreasing pauses outline during phase B of training

Week	Load (%1MDVMA)	Repetitions	Bouts	Pause (s)
3	80	8-10	4	105
4	80	8-10	4	90
5	80	8-10	4	75
6	80	8-10	4	60
7	80	8-10	4	45
8	80	8-10	4	30

MDVMA: maximal dynamic voluntary muscular action.

CrH_2O was kindly provided by the Pro Tech Nutritional Systems of Brazil, while the placebo substance was bought at a store from the nutritional supplements market. The substances were stored and labeled in 0.5 g capsules by Pedrosa & Delsin – Pharmacy LTDA. Neither the subjects nor the researchers would know which substance was being ingested until the end of the study.

Anthropometric measurement protocol

The anthropometric measurement was determined through weight, height, measurement of eight skinfolds and eight circumferences. The adopted procedures and materials are as follows:

Weight

For weight measurement, a Filizola mechanical with 0.1 kilogram scale was used. After the scale calibration, the subject would wear the minimum clothes as possible and stand in the center of the scale. The reading was performed when the scale lever reached balance. Weight was registered in kilograms (kg), with precision of 100 grams[18].

Height

For height determination, Sanny mobile stadiometers with scale in 0.1 centimeter (cm) were used. According to Petroski[18], height comprises the distance between the vertex (highest point of the head) and the feet soles, with head being according to the Frankfurt plan. The subject would be barefeet or wearing socks and stand keeping heels, pelvic waist, scapular waist and occipital region touching the stadiometers; after the subject performed a maximal inspiration followed by apnea, height was registered in centimeters, with 0.1 cm precision.

Skinfolds

For skinfolds measurement, a Lange adipometer with 1 millimeter scale (mm) and steady pressure in 10 grams per square millimeter (g/mm^2) was used. The procedures described by Heyward and Stolarczyk[19] for determination of the eight skinfolds adopted were: subscapular skinfold, tricipital skinfold, medium axillary skinfold, torso skinfold, suprailiac skinfold, abdominal skinfold, thigh skinfold and medial calf skinfold, being them measured on the right side of the body and repeated three times in each point in rotational order.

Circumferences

For the circumferences determination, a Sanny metallic measuring tape with scale in 0.1 cm was used. The procedures presented by Heyward and Stolarczyk were followed[19].

Body fat percentage estimation

For estimation of the body density, the sum of seven skinfolds was used, namely: subscapular, tricipital, torso, medium axillary, suprailiac, abdominal and thigh. This sum was applied in the equation developed by Jackson and Pollock (1978) apud Petroski[18].

After determination of the body density, the equation by Siri (1961) apud Petroski[18], was used for determination of the body fat percentage.

Statistical analysis

The Shapiro-Wilk statistical proof was applied, as well as the inspection of the quantis charts (qq-plot) in order to determine whether the dependent variables (BM, BMI, MDSR) followed or could be rounded up by the normal distribution. Once these variables could not be rounded up by the normal distribution, non-parametric statistics were chosen to be applied for description and inference of the observations.

Quartis 1, 2 and 3 were calculated as indicators of the central position measurement (quartil 2 or median) and the dispersion (quartis 1 and 3, as well as interquartil interval).

The non-parametric hypothesis analysis defined by Brunner and Langer was applied[20] in order to verify the significance of the difference between groups A and B, between pre and post-training, as well as the interaction between these factors. The statistical significance was accepted in $\alpha \leq 0.05$.

RESULTS

Morphological alterations

In table 7 the anthropometric characteristics of the volunteers in each of the groups are described. According to what was described in this table, no statistically significant differences have been verified between groups A and B in any of the training moments for all anthropometric variables (BM, S8SF, BFP and FFM). However, when analyzing the training and used supplement effects, it was possible to observe that the group which made use of CrH_2O presented statistically significant increase for BM and FFM, without significant alterations in the body fat profile. On the other hand, for the placebo group the alterations observed in these variables may be concerned with causal variations and not with training effects.

TABLE 7
Anthropometric characteristics of the subjects from groups A and B

Variable	Placebo Group		Creatine Group	
	Pre	Post	Pre	Post
Age (years)	23 (1)	23 (2)	25 (5)	26 (4)
Height (cm)	176.1 (8.7)	176.5 (9.0)	178.7 (9.5)	178.5 (10.0)
Weight (kg)	74.6 (9.6)	75.0 (9.8)	71.5 (4.1)	76.0 (7.7)*
S8SF (mm)	91.5 (14.0)	78.0 (12.5)	96.0 (45.5)	108.5 (35.0)
BFP (%)	10.5 (3.2)	9.1 (2.9)	13.0 (6.9)	13.4 (5.6)
FFM (kg)	65.3 (5.6)	67.8 (5.5)	63.5 (7.7)	67.3 (5.6)*

S8SF: sum of eight skinfolds; BFP: body fat percentage; FFM: fat-free massData are presented in median (interquartile breadth). * Shows statistically significant difference; *P* = 0.0040; concerning the pre-training value.

Besides the effect observed in the BM and FFM, concerning training for the creatine group, significant interaction between supplement and training was obtained for these variables, according to what was described in figure 1 and figure 2. When the supplement effect on the absolute and percentage BM alteration was analyzed, it was observed that the creatine group had alteration significantly higher than that obtained by the placebo group. The FFM percentage alteration was significantly higher in the creatine group comparing to the placebo group. For the BFP and S8SF statistically differences were not observed between groups, neither for absolute nor percentage alteration.

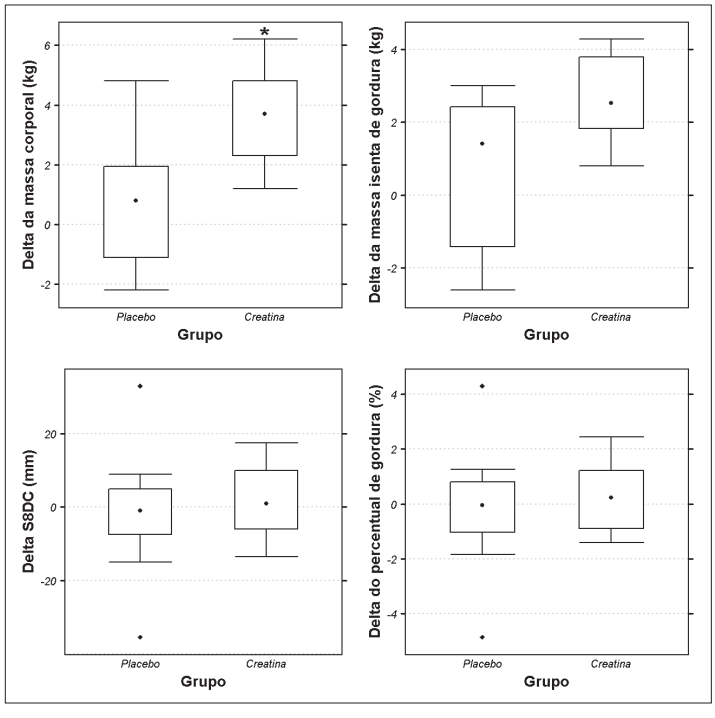

Figure 1 *– Description of the absolute alteration in the anthropometric variables in both groups. * shows statistically significant difference;* P = *0.0083; concerning the placebo group.*

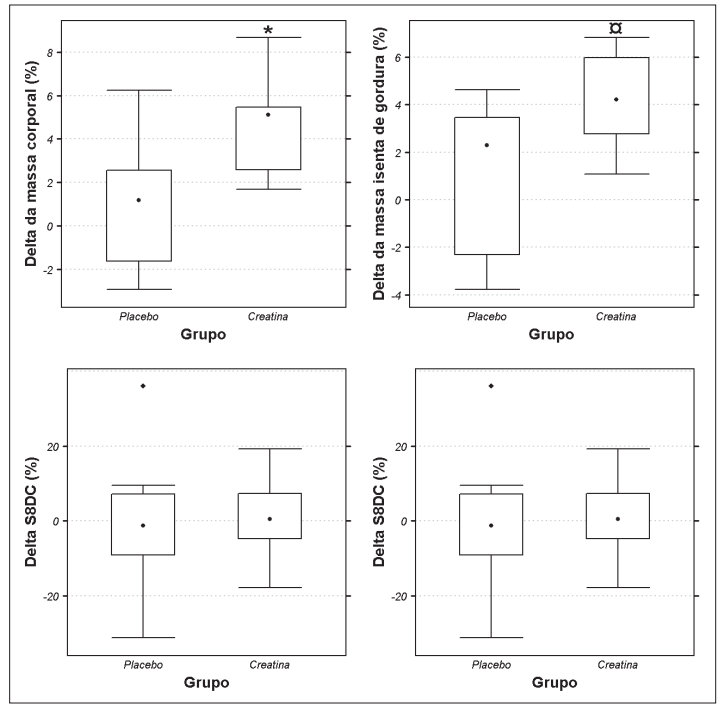

Figure 2 *– Description of the percentage alteration in the anthropometric variables in both groups. * shows statistically significant difference;* P = *0.0106; concerning the placebo group. ¤ shows statistically significant difference;* P = *0.0500; concerning the placebo group.*

Alteration in the maximal dynamic strength resultant

The MDSR analysis showed that both groups improved significantly the maximal dynamic strength profile in all exercises (bench press, closed bench press, barbell curl, development and squatting). Moreover, significant differences between creatine and placebo groups have not been observed neither in the pre nor the post-training, according to table 8.

TABLE 8
Description of the RFMD for the different exercises in both groups

Variable	Placebo Group		Creatine Group	
	Pre	Post	Pre	Post
Bench Press	92.0 (20.0)	112.0 (24.0)*	82.0 (20.0)	112.0 (30.0)*
Closed bench press	60.0 (14.0)	82.0 (18.0)*	52.0 (10.0)	94.0 (30.0)*
Barbell curl	44.0 (11.0)	58.0 (10.0)*	42.0 (7.0)	60.0 (4.0)*
Development	52.0 (8.0)	68.0 (3.0)*	47.0 (14.0)	70.0 (8.0)*
Squatting	122.0 (30.0)	150.0 (40.0)*	102.0 (10.0)	152.0 (16.0)*

Data are presented in median (interquatile breadth). * shows statistically significant difference; *P* = 0.0040; concerning the pre-training value.

Although significant differences between the groups have not been obtained when the absolute values of the MDSR in the different exercises are analyzed, the response of the absolute and relative alteration in the closed bench press, development and squatting exercises showed that the creatine group presented alterations significantly higher than those obtained in the placebo group. However, in straight seat bench press and the dumbbell

curl exercises, there was not evidence that the observed differences between both groups could be due to the supplement used (figure 3 and figure 4).

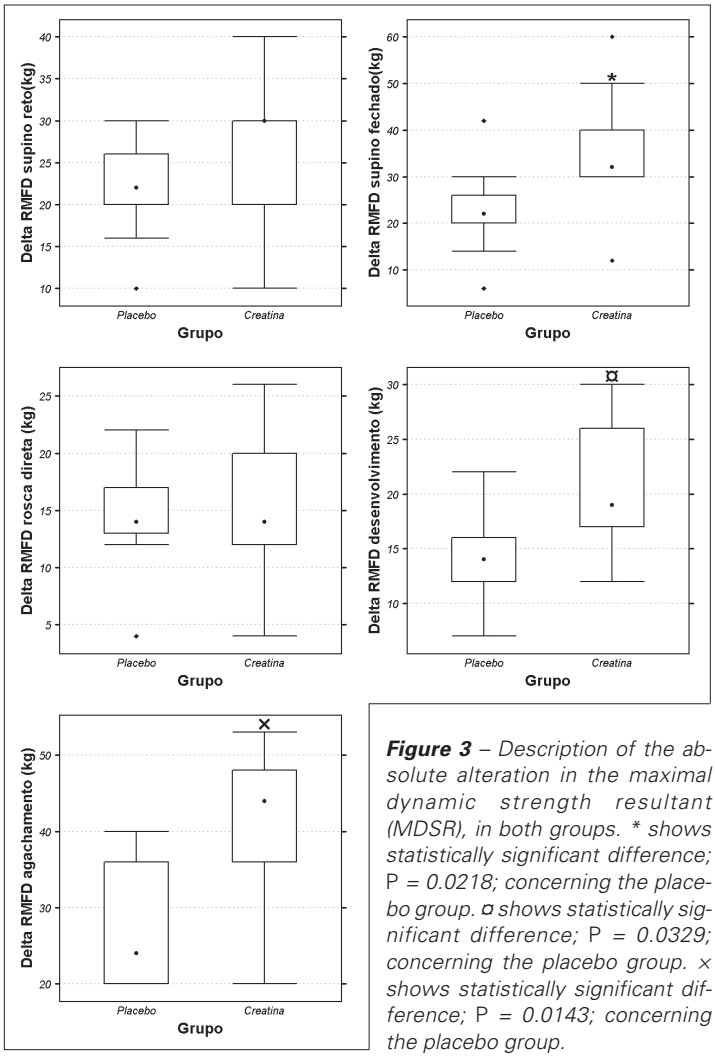

Figure 3 *– Description of the absolute alteration in the maximal dynamic strength resultant (MDSR), in both groups. * shows statistically significant difference;* P *= 0.0218; concerning the placebo group. ¤ shows statistically significant difference;* P *= 0.0329; concerning the placebo group. × shows statistically significant difference;* P *= 0.0143; concerning the placebo group.*

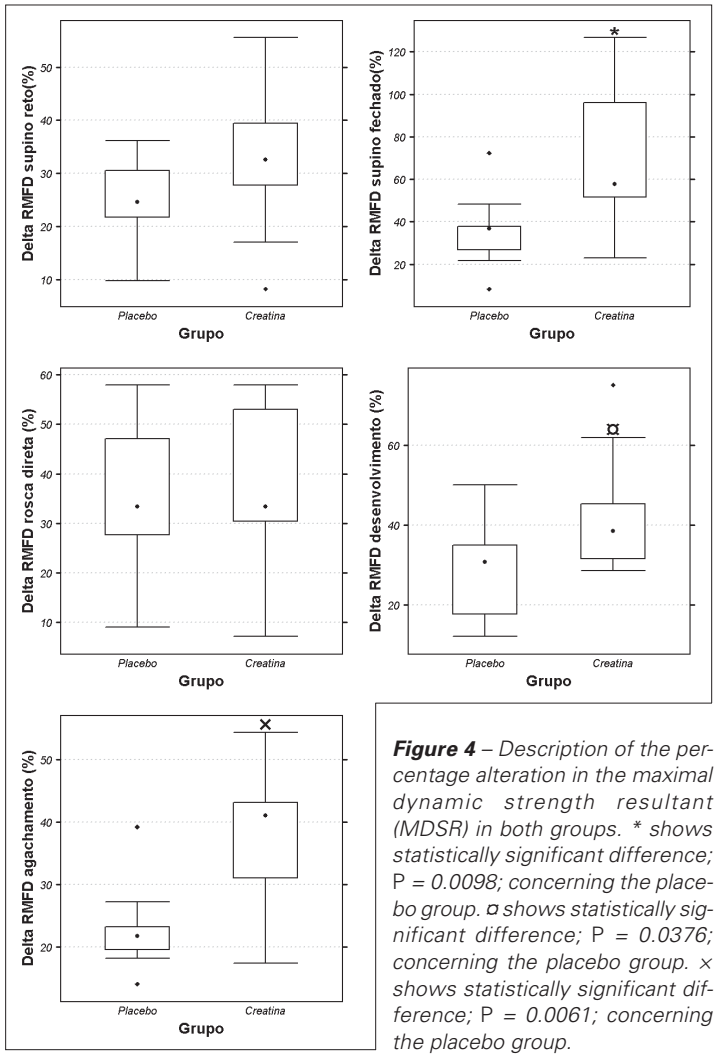

Figure 4 *– Description of the percentage alteration in the maximal dynamic strength resultant (MDSR) in both groups. * shows statistically significant difference;* P *= 0.0098; concerning the placebo group. ¤ shows statistically significant difference;* P *= 0.0376; concerning the placebo group. × shows statistically significant difference;* P *= 0.0061; concerning the placebo group.*

DISCUSSION

The alterations both in groups A (creatine) and B (placebo) are due to modifications of the biological processes which occur in the body when it is submitted to strength training. Based mainly in the principles of overload and specialization, the physical training has been frequently organized so that it allows that the body energy supplies, as well as the processes responsible for their production are maximized[8]. According to Viru[21-22], this phenomenon is known as supercompensation. The imposing of work loads using the protocol of 80% of 1MDVMA, as demonstrated in this investigation, allowed to observe that regardless the nutritional supplementation used as ergogenic resource, these positive alterations occur more significantly. Nevertheless, the results of this study corroborate with others[16,23-28], where positive alterations were found in the anthropometric variables (BMI, BM) and in the increase of the MDSR, confirming the theory that the CrH_2O supplementation can promote positive physiological and biochemical alterations in the organism, causing morphological benefits and consequently promoting improvement in physical and sportive performance. Recent evidence demonstrated by Haussinger and Lang[29] and Haussinger *et al.*[30] show that the increase of the cellular volume is modulated by amino acids and hormones which regulate the activities of the transporter ions and the ionic channels present in the plasmatic membrane, affecting the potential of the membrane or regulating the substrates that are transported by dependence of Na^+. Specifically, the anabolic effect of the hormone insulin and the anticatabolic effect of the amino acid glutamine may alter the cellular volume. This idea is supported by the fact that the anabolic effects are able to be quantitatively minimized by cells hydrated in hypoosmotic medium. According to Kreider[24]; Ziegenfuss *et al.*[31]; Vandenberghe *et al.*[32]; Haussinger *et al.*[30]; Bessman and Savabi[33] this alteration may be interpreted as one of the factors responsible for the increase of proteins synthesis (anabolism) or by the reduction of the protein degradation (catabolism), or when these mechanisms are observed associated with creatine supplementation. Corroborating this theory, Ingwall[34] has reported that the creatine addition to incubated skeletal muscular cells increases the in vitro myosin synthesis.

The literature is scarce on studies comparing strength gains and hypertrophy in the elbow flexor muscles (biceps). The results presented by Becque *et al.*[35], when evaluating the elbow flexors with the 1MDVMA test evidenced positive alterations in both groups (p = 001), with the creatine group presenting significantly positive alteration higher than the placebo group (16.77% against 6.25%, respectively). Vandenbergue *et al.*[32] compared the torque of elbow flexors in healthy bur sedentary women, in 5 bouts of 30 maximal voluntary repetitions with 2-minute interval between bouts. However, significant differences were not found between the creatine and placebo groups (n = 19). Corroborating the specificity principle, the positive alterations caused by strength training with muscular hypertrophy joined with CrH_2O supplementation as purpose do not seem to demonstrate positive alterations, when the training uses local muscular resistance protocols (LMR).

CONCLUSION

Based on the results presented in this study it is concluded that the training protocol proposed can promote positive alterations in the MDSR regardless the use of any ergogenic agent. Nevertheless, when joined with creatine supplementation, the positive alterations in the MDSR, as well as in weight, were more significant comparing with the placebo group.

It is suggested that in future studies the used protocol with decreasing pauses is compared with other protocols with different methodological design, and that the effects of creatine supplementation are verified together with carbohydrates supplementation, making use of other technologies, such as Magnetic Resonance. Additionally, the supplementation effects should be evaluated at cellular level.

All the authors declared there is not any potential conflict of interests regarding this article.

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