

Creatine HCl and Creatine Monohydrate Improve Strength but Only Creatine HCl Induced Changes on Body Composition in Recreational Weightlifters

Elias de França¹, Bruno Avelar¹, Caroline Yoshioka¹, Jeferson Oliveira Santana¹, Diana Madureira¹, Leandro Yanase Rocha¹, Cesar Augustus Zocoler¹, Fabrício Eduardo Rossi², Fabio Santos Lira², Bruno Rodrigues³, Érico Chagas Caperuto^{1,4*}

¹University São Judas Tadeu, São Paulo, Brazil

²Exercise and Immunometabolism Research Group, Department of Physical Education, Universidade Estadual Paulista (UNESP), Presidente Prudente, Brazil

³Faculty of Physical Education, University of Campinas (FEF/Unicamp), Campinas, Brazil

⁴University Presbiteriana Mackenzie, São Paulo, Brazil

Email: ericocaperuto@gmail.com

Received 9 December 2015; accepted 25 December 2015; published 28 December 2015

Copyright © 2015 by authors and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Background: Creatine supplementation is a subject that is very well studied. New forms of creatine are suggesting improvements in this supplement performance. Creatine HCl is supposed to have better solubility and absorption than creatine. The aim of this study was to compare the effects of two different doses of creatine HCl with creatine monohydrate on the strength and body composition in recreational weightlifters and to verify the relationship between strength and body composition. **Methods:** 40 subjects were divided in four groups: Creatine Monohydrate (CMG) 5 g/daily; Creatine HCl-1 (HCl-1) 5 g/daily, Creatine HCl-2 (HCl-2) 1.5 g/daily and Control group (CG) = 5 g of resistant starch/daily. All groups performed a resistance training program during 4 weeks. Body composition and strength were evaluated pre and post intervention. **Results:** The 1 RM at the Leg press was increased significantly in all groups (CMG: pre = 264.4 ± 83.8 × post = 298.1 ± 90.9 ; HCl-1: pre = 295.0 ± 88.3 × post = 338.3 ± 86.8 and HCl-2: pre = 274.3 ± 57.1 × post = 305.7 ± 59.4 ; $p < 0.05$), Bench press 1 RM was increased significantly only in HCl-2 (pre = 72.4 ± 25.7 × post = 76.0 ± 25.0 ; $p = 0.003$), however, there was no statistically significant difference between groups. Fatmass was significantly decreased in HCl-1 (pre = 14.5 ± 8.0 × post = 13.3 ± 8.3 ; $p = 0.034$) and

*Corresponding author.

HCl-2 (pre = 13.8 ± 5.8 × post = 12.7 ± 5.6 ; $p = 0.005$) but fat-free mass was increased only in HCl-1 (pre = 52.2 ± 8.9 × post = 53.8 ± 8.9 ; $p = 0.031$), with no differences between groups again. We observed strong correlations between upper limb strength and fat mass ($r = -0.93$, $p < 0.05$), and between lower limb strength and FFM ($r = 0.93$, $p < 0.05$) only in HCl-1 group. Conclusions: We concluded that creatine HCl and creatine Monohydrate improve performance but only creatine HCl induces changes on body composition in recreational weightlifters with differences between creatine HCl doses.

Keywords

Creatine Hydrochloride, Creatine, Resistance Training, Fat Free Mass, Fat Mass

1. Background

Creatine monohydrate (CrM) is one of the most studied sport supplements of the last decade. The American College of Sports Medicine [1], and a recent meta-analysis conducted by Lanhers *et al.* [2], showed results from articles published with CrM and the different effects about strength, muscle mass, and improvement on performance in repeated short bouts of intense exercise. However, although CrM seems to be a consensus in terms of efficacy to certain performance aspects and safety, some adverse effects of that supplementation have been reported.

The main reports were on weight gain and water retention [1] [3] [4] with some studies reporting gastrointestinal stress [1] [3] [5] and one of these studies reporting a strong correlation between diarrhea and the CrM doses ingested [6]. These adverse effects of CrM are probably related to the mechanism of action of the substance and the dose used to ensure the efficacy of the supplement. CrM is usually supplied in a large dose, a loading protocol, in order to completely fill muscle storages, being absorbed in the intestine. This protocol usually generates an excess of creatine in the system that is partially responsible for the side effects associated with CrM supplementation.

In order to minimize these negative effects, Creatine Hydrochloride (CrHCl) was introduced in the market by Dash *et al.* [7], which is a molecule that is supposed to be 41 times more soluble in water than creatine monohydrate [8]. Moreover, it appears that its permeability in the intestinal tract is also greater than CrM [9]. According to Gufford *et al.* [8] the amount of water to dilute 5 to 10 g of CrM is around 400 to 600 ml while CrHCl would, for the same amount, need 21 ml of water. The authors then propose that greater solubility and permeability could decrease the amount of creatine needed to fill the muscle. That would mean more absorption, less creatine excretion, and less gastrointestinal discomfort. Furthermore, its effect on the strength and body composition may be different and the doses can affect the results in athletes.

Thus, the aim of this study was to compare the effects of two different doses of CrHCl (1.5 g and 5 g) with CrM on the strength and body composition in recreational weightlifters and to verify the relationship between upper and lower limb strength and body composition in the different groups. We hypothesized that, CrHCl improves performance similarly to CrM, but promotes different results in body composition.

2. Methods

2.1. Experimental Approach to the Problem

This controlled study was carried out from May to October of 2014 at the University São Judas Tadeu, São Paulo, SP, Brazil. Evaluations were performed at baseline and after the training program and involved the following: screening for inclusion in the study, anthropometric measurements, body composition and performance tests. Evaluations were performed one week before the beginning of the intervention and in the first week after the intervention.

The CrM Group (CMG) = 5 g of creatine monohydrate/day; Creatine HCl-1 (HCl-1) = 5 g of creatine HCl/day, Creatine HCl-2 (HCl-2) = 1.5 g of creatine HCl/day, and the Control group (CG) = 5 g of resistant starch/day. All groups performed 4 weeks of strength training and they were asked to maintain 4 weeks without participating in any regular physical exercise before the start of the training program.

2.2. Subjects

All experimental procedures were approved by the University São Judas Tadeu ethical research committee (CAAE: 21463313.9.0000.0089).

The participants contacted the researchers by phone and an appointment was made in order to carry out a more detailed interview. All measurements were taken at the University Laboratory. The inclusion criteria were: 1) Subjects had at least 1 year of weight lifting experience; 2) no using supplements of creatine for at least 2 months; 3) signing the consent form. The exclusion criteria were: 1) Subjects that didn't do 25% of the training sessions; 2) No ingestion of the supplements in the way prescribed or changed the diet; 3) Subjects that didn't do the last evaluation or had any health problems that made it impossible to keep the study.

40 healthy individuals, both genders between 20 and 40 years were selected. They were randomly divided in four groups. Each group was composed of approximately 60% to 70% men and 30% to 40% women and 10 participants were excluded of analyzes because didn't attended the criteria of exclusion.

2.3. Procedures

2.3.1. Anthropometric Measurements and Body Composition

Body weight was measured using an electronic scale (Tanita HD-357 Digital Weight Scale, USA), with a precision of 0.1 kg. The participants were barefoot and wearing light clothing so as not to interfere with the measurement.

The body composition was evaluated by skinfold thicknesses and were measured at the Chest, triceps, subscapular, suprailiac, abdominal, midaxillary and thigh skinfolds on the right side of the body with a Lange caliper (Beta technology, USA) and three sets of measurements were taken to the nearest millimeter at each site; the median of the three values was used [10]. The percentage of fat (%BF) was calculated according to Jackson and Pollock [11] and fat mass (FM) and fat-free mass (FFM) in Kilograms were calculated. Subjects were assessed before and after the experimental protocol by the same evaluator.

2.3.2. Maximum Repetition Procedures

The test of one maximum repetition (1MR) was performed in the Leg press and Bench press. The 1MR test consisted of a warm-up with 15 repetitions of 50% of estimated 1 MR, followed by 8 repetition with 70% of estimated 1MR. The load was increased gradually during the test until the participants were no longer able to perform the entire movement, and five attempts were considered to meet the corresponding 1MR load and an interval of 5 minutes between attempts was given for recovery [12].

2.3.3. Supplementation Protocol

Before the beginning of supplementation program, all groups had their diet homogenized by the research team Nutritionist. Individuals were supposed to be at least 2 months without taking any creatine supplement. Whey protein and other amino acid supplements were also managed to fit in the protein amount of the diet. All experimental groups did a specific training protocol, supplemented for 28 days and were divided like this: Control group (CG) ingested capsules with resistant starch. CrM group (CMG), ingested 5 g of CrM. CrHCl1 (HCl-1) ingested 5 g of CrHCl. CrHCl 2 (HCl-2) ingested 1.5 g of CrHCl. (Creatine monohydrate, Crea caps, Universal Nutrition; Creatine HCl-HydroCrea, GT USA; Resistant Starch, Orion Pharmacy).

CrM dosages were based on the study published by Hultman *et al.* [13] that shows that 5 g of CrM during 28 days, is enough to promote the ergogenic effects of the supplement. CrHCl dose of 1.5 g is the dose proposed by the manufacturer as enough to promote the same effects of 5 g of CrM.

Supplements were distributed in a double-blind manner and the supplements were supplied to the subjects in individualized bottles with no identification of its content.

2.3.4. Strength Training Procedures

The subjects performed strength training, four times per week, during 4-weeks. The training program consisted of four routines (A, B, C and D). On the 1st to 3rd week, the subjects performed A and B training and on the 2nd and 4th week, performed C and D training. The program were composed of four exercises of chest and back muscles, three to shoulder muscles, four to legs muscles, three to biceps and triceps, and two abdominal exercises. Subjects performed four sets of 10 to 12 reps (80% to 90% of 1 MR) of each exercise and the sets were

executed until momentary exhaustion.

2.3.5. Statistical Analysis

The Levene test was used to analyze homogeneity of the data set and parametric statistics were carried out. To identify the similarity of the groups at baseline and after the intervention, one-way ANOVA with Tukey Post-hoc was used. The “mean differences” (post exercise value minus baseline value) was calculated and finally, Pearson correlation was used to analyze the relationship between the mean differences in upper limb strength and lower limb strength with body composition. All analysis was performed using the statistical software SPSS version 17.0 (SPSS, IBM) and the significance was $p < 0.05$.

3. Results

Table 1 presents the general characteristics of the groups at baseline in mean values and standard deviation of body weight, body composition, and upper and lower limb strength. It can be seen that there were no statistical differences for all variables investigated.

Table 2 presents the changes in the values of weight, body composition and strength variables after 4-week of training and supplementation in the CG, HCl-1, HC-2 and CMG group.

The 1 RM at the Leg press was increased significantly in all groups after the intervention ($p < 0.05$), but at the Bench press 1 RM was increased significantly only in HCl-2 ($p = 0.003$), however, there was no statistically significant difference between groups.

When body composition was analyzed, FM was significantly decreased in HCl-1 ($p = 0.034$) and HCl-2 ($p = 0.005$) but FFM was increased only in HCl-1 ($p = 0.031$), however, there was no statistically significant difference between groups again.

Table 3 presents the values of Pearson correlation between upper and lower limb strength (1 RM) and body composition in recreational weightlifters and different groups of creatine supplementation.

We observed strong negative correlations between upper limb strength and FM ($r = -0.93$, $p < 0.05$), and strong positive correlations between upper limb strength and FFM ($r = 0.93$, $p < 0.05$) only in HCl-1 group. There was no correlation in the other groups analyzed.

4. Discussion

The results of the present study demonstrated that CrHCl (without an ethyl ester group) and CrM improved the upper and lower limb strength after 4 weeks of resistance training but only CrHCl induced changes on the body composition in recreational weightlifters. Furthermore, there seems to be a difference between CrHCl doses when the body composition was analyzed.

The notion that a bigger amount of water is needed to dissolve CrM when compared to CrHCl [8], implicates in an excess of water available, that might be related to water retention in the individuals that supplement with CrM, as described in the literature [14] [15] with a consequent increase in body weight [16]. This can be considered one of the main advantages of CrHCl compared to CrM, which is to promote the same ergogenic effects, without the weight gain.

Only the groups supplemented with CrHCl showed significant changes in %BF and FFM. Although CrM can

Table 1. The general characteristics of the groups at baseline in mean values and standard deviation of body weight, body composition, and upper and lower limb strength.

Variables	Placebo (n = 6)	HCL 1.5 g (n = 7)	HCL 5.0 g (n = 6)	Monohidrate (n = 8)	p-value
Weight (Kg)	69.67 ± 11.5	71.14 ± 15.4	67.33 ± 15.1	71.13 ± 13.1	0.954
Fat mass (Kg)	15.167 ± 7.8	13.857 ± 5.8	14.500 ± 8.0	16.375 ± 4.8	0.895
Fat mass (%)	21.67 ± 9.3	19.57 ± 7.8	20.67 ± 7.2	22.88 ± 3.7	0.832
Fat-free mass (Kg)	53.667 ± 9.0	56.429 ± 13.2	52.167 ± 8.9	53.750 ± 9.5	0.900
Leg Press (Kg)	260.00 ± 118.6	274.29 ± 57.1	295.00 ± 88.3	264.38 ± 83.8	0.899
Bench Press (Kg)	61.33 ± 26.1	72.43 ± 25.7	85.67 ± 40.7	71.88 ± 29.9	0.605

Table 2. The changes in the values of weight, body composition and strength variables after 4 weeks of training and supplementation in the CG, HCl-1, HC-2 and CMG group.

	Placebo (n = 6)		HCL 1.5 g (n = 7)		HCL 5.0 g (n = 6)		Monohidrate (n = 8)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Weight (Kg)	69.7 ± 11.5	69.8 ± 11.5	71.1 ± 15.4	71.1 ± 16.3	67.3 ± 15.1	67.67 ± 14.4	71.1 ± 13.1	71.9 ± 12.5
Fat mass (Kg)	15.2 ± 7.8	14.3 ± 8.0	13.8 ± 5.8	12.7 ± 5.6*	14.5 ± 8.0	13.3 ± 8.3*	16.4 ± 4.8	15.6 ± 3.7
Fat mass (%)	21.7 ± 9.3	20.5 ± 10	19.6 ± 7.8	18.0 ± 7.7*	20.7 ± 7.2	18.7 ± 8.2	22.9 ± 3.7	21.7 ± 2.9
Fat-free mass (Kg)	53.7 ± 9.0	54.8 ± 9.5	56.4 ± 13.2	57.4 ± 13.9	52.2 ± 8.9	53.8 ± 8.9*	53.7 ± 9.5	55.4 ± 9.9
Leg Press (Kg)	260 ± 118.6	293.3 ± 111.1*	274.3 ± 57.1	305.7 ± 59.4*	295.0 ± 88.3	338.3 ± 86.8**	264.4 ± 83.8	298.1 ± 90.9*
Bench Press (Kg)	61.3 ± 26.1	64.5 ± 27	72.4 ± 25.7	76.0 ± 25.0*	85.7 ± 40.7	90.5 ± 37.0	71.9 ± 29.9	78.7 ± 33.4

* $p < 0.05$; ** $p < 0.001$.

Table 3. The values of Pearson correlation between upper and lower limb strength (1RM) and body composition in recreational weightlifters and different groups of creatine supplementation.

Independent variables	Placebo (n = 6)	HCL 1.5 g (n = 7)	HCL 5.0 g (n = 6)	Monohidrate (n = 8)
	Relationship with ULS (Pearson Correlation [r])			
Weight (Kg)	-0.34	-0.06	0.15	0.18
FM (Kg)	0.64	-0.14	-0.93*	-0.08
FFM (Kg)	-0.20	0.21	0.93*	0.27
Relationship with LLS (Pearson Correlation [r])				
Weight (Kg)	0.00	-0.43	-0.06	0.55
FM (Kg)	0.00	0.43	-0.64	0.28
FFM (Kg)	0.57	-0.39	0.64	-0.15

* $p < 0.05$. FM = fat mass; FFM = fat free mass; ULS = upper limb strength; LLS = lower limb strength.

be considered a consensus in the literature regarding muscle mass increase and performance improvement [2] [16]-[18], the 5 g a day protocol is a protocol that promotes its gains after 1 month of supplementation [2]. At the same time, CrM supplementation metabolic pathway is already well studied and the side effects to body composition (water retention with weigh gain) are described [1] [3] [4] [14] [15]. Our results suggest that the difference between these molecules might be the main responsible for the observed changes in the subject's body composition.

All groups have improved Leg press 1 MR test although no difference was shown between the groups. For the Bench press 1MR test, the only group that showed significant improvements was HCl-2, although no difference was shown between the groups again. These changes reflect the effects of training and supplementation. When we consider the results of body composition and along with these results, we can suggest that CrHCl improves performance the same way that creatine monohydrate with better results for body composition.

All this raises an important thought about the different dosages and effects of the different creatine supplements. It seems that the smaller dosage of CrHCl (1.5 g) tested in this study is as good as 5 g of Cr in promoting strength gains. However, when we look to the body composition results, different dosages of creatine HCl did not gave different results, although these results were different from CrM. So that led us to different lines of thinking.

Because the CrM supplementation promotes increase in total body hydration status [14] [15], there might be an overestimation of fat-free mass values after its supplementation protocol [19].

We speculate that different body hydration (promoted by creatines) might be primarily responsible for the observed changes in body composition of individuals in our study and the significant correlations between changes in %BF/FFM and strength in HCl-1 group.

Several methods, such as the method used in this study (Skinfold) and hydrostatic weighing, DXA, plethysmography or even total body potassium count consider the body hydration as a constant (*i.e.*, it considers that the body water is 73% for any individual), however, body hydration fluctuates considerably in the normal population (18%) [20]. That is even more important when a creatine supplement is being used. So, we suggest future studies with both CrM and CrHCl supplementation that assess body composition, considering in their formulas, changes in body hydration status promoted by both creatines.

Classically increased body mass (due FFM increase) is related to the short term CrM supplementation protocol (*i.e.* 20 g day⁻¹, for 5 - 7 days) [19], but it is not clear in the long term Protocol (*i.e.* 5 g day⁻¹ for 30 days or more) [16] [21]. This is important because athletic performance can be affected negatively by sudden changes in body weight (such as gain of 3% or loss of 2% in body mass) [22]. When we consider body composition, CrM had no effects, meanwhile CrHCl allowed some positive changes to happen. It would therefore be interesting to study the short-term protocol and verify if CrHCl, would promote acute changes in fat-free mass and body mass (due to water retention). Furthermore, it is valid in future studies to observe if this increase in FFM (in 5 g CrHCl group long-term supplementation) could be associated with an increased protein homeostasis in the muscle tissue (effect already demonstrated with CrM supplementation) [23].

Despite these results being of great relevance, it is necessary to mention that the intervention time of this study could have been insufficient to promote greater decreases of %BF and increases in FFM and lower limb strength. Other studies conducted over a longer period of time (similar to Larson-Meyer *et al.* [21] study protocol) and using other variables, such as metabolic ones would contribute to field.

5. Conclusion

We can conclude that CrHCl and CrM improve performance but only CrHCl induces changes on the body composition in recreational weightlifters. We also noted that there was a stronger correlation between strength and body composition only when 5 g of CrHCl was used and there seems to be a difference between CrHCl doses when the body composition was analyzed. These results are important especially for those coaches or athletes with weight limitation, such as fighters or gymnastic athletes that need performance improvement.

Acknowledgements

We would like to thank GT Nutrition USA for providing the supplements used in the study and Orion Pharmacy for providing resistant starch and arranging them in a double blind fashion.

Declaration of Interests

The authors declare that they have no competing interests.

Authors' Contribution

All authors participated equally in all steps of the study, but EF, BA, JOS, DM, LYR helped mainly in the data collection phase, CY helped to organize and control the participant's diets and CASZ, FER, FSL, BR and ECC were responsible for the organization and discussion of the data. All authors agree with the information and data presented in this study.

References

- [1] Terjung, R.L., Clarkson, P., Eichner, E.R., Greenhaff, P.L., Heel, P.J., Israel, R.G., Kraemer, W.J., Meyer, R., Ariet, L.L., Tarnopolsky, M.A., Wagenmakers, A.J. and Williams, M.H. (2000) American College of Sports Medicine Roundtable: The Physiological and Health Effects of Oral Creatine Supplementation. *Medicine & Science in Sports & Exercise*, **32**, 706-717.
- [2] Lanhers, C., Pereira, B., Naughton, G., Trousselard, M., Lesage, F.X. and Dutheil, F. (2015) Creatine Supplementation and Lower Limb Strength Performance: A Systematic Review and Meta-Analyses. *Sports Medicine*, **45**, 1285-1294. <http://dx.doi.org/10.1007/s40279-015-0337-4>
- [3] Groeneveld, G.J., Beijer, C., Veldink, J.H., Kalmijn, S., Wokke, J.H. and Vandenberg, L.H. (2005) Few Adverse Effects of Long-Term Creatine Supplementation in a Placebo-Controlled Trial. *International Journal of Sports Medicine*, **26**, 307-313.

- [4] Benzi, G. (2000) Is There a Rationale for the Use of Creatine Either as Nutritional Supplementation or Drug Administration in Humans Participating in a ort? *Pharmacological Research*, **41**, 255-264. <http://dx.doi.org/10.1006/phrs.1999.0618>
- [5] Graham, A.S. and Hatton, R.C. (1999) Creatine: A Review of Efficacy and Safety. *Journal of the American Pharmaceutical Association (Wash)*, **39**, 803-810, quiz 875-877.
- [6] Ostojic, S.M. and Ahmetovic, Z. (2008) Gastrointestinal Distress after Creatine Supplementation in Athletes: Are Side Effects Dose Dependent? *Research in Sports Medicine*, **16**, 15-22. <http://dx.doi.org/10.1080/15438620701693280>
- [7] Dash, A.K., Miller, D.W., Huai-Yan, H., Carnazzo, J. and Stout, J.R. (2001) Evaluation of Creatine Transport Using Caco-2 Monolayers as an *in Vitro* Model for Intestinal Absorption. *Journal of Pharmaceutical Sciences*, **90**, 1593-1598. <http://dx.doi.org/10.1002/jps.1109>
- [8] Gufford, B.T., Sriraghavan, K., Miller, N.J., Miller, D.W., Gu, X., Vennerstrom, J.L. and Robinson, D. (2010) Physicochemical Characterization of Creatine N-Methylguanidinium Salts. *Journal of Dietary Supplements*, **7**, 240-252. <http://dx.doi.org/10.3109/19390211.2010.491507>
- [9] Gufford, B.T., Ezell, E.L., Robinson, D.H., Miller, D.W., Miller, N.J., Gu, X. and Vennerstrom, J.L. (2013) Dependent Stability of Creatine Ethyl Ester: Relevance to Oral Absorption. *Journal of Dietary Supplements*, **10**, 241-251. <http://dx.doi.org/10.3109/19390211.2013.822453>
- [10] Lohman, T.G. (1986) Applicability of Body Composition Techniques and Constants for Children and Youths. *Exercise & Sport Sciences Reviews*, **14**, 325-357. <http://dx.doi.org/10.1249/00003677-198600140-00014>
- [11] Jackson, A.S. and Pollock, M.L. (1978) Generalized Equations for Predicting Body Density of Men. *British Journal of Nutrition*, **91**, 161-168. <http://dx.doi.org/10.1079/bjn19780152>
- [12] Brown, L.E. and Weir, J.P. (2003) Recomendação de procedimentos da Sociedade Americana de Fisiologia do Exercício (ASEP) I: Avaliação precisa da força e potência muscular. *Revista Brasileira de Ciência e Movimento*, Brasília, **11**, 95-110.
- [13] Hultman, E., Söderlund, K., Timmons, J.A., Cederblad, G. and Greenhaff, P.L. (1996) Muscle Creatine Loading in Men. *Journal of Applied Physiology*, **81**, 232-237.
- [14] Francaux, M. and Poortmans, J.R. (1999) Effects of Training and Creatine Supplement on Muscle Strength and Body Mass. *European Journal of Applied Physiology and Occupational Physiology*, **80**, 165-168. <http://dx.doi.org/10.1007/s004210050575>
- [15] Powers, M.E., Arnold, B.L., Weltman, A.L., Perrin, D.H., Mistry, D., Kahler, D.M., Kraemer, W. and Volek, J. (2003) Creatine Supplementation Increases Total Body Water Without Altering Fluid Distribution. *Journal of Athletic Training*, **38**, 44-50.
- [16] Branch, J.D. (2003) Effect of Creatine Supplementation on Body Composition and Performance: A Meta-Analysis. *International Journal of Sport Nutrition and Exercise Metabolism*, **13**, 198-226.
- [17] Bembem MG, Lamont HS. Creatine supplementation and exercise performance: recent findings. *orts Med.* 2005; 35(2), 107-125.
- [18] Devries, M.C. and Phillips, S.M. (2014) Creatine Supplementation during Resistance Training in Older Adults—A Meta-Analysis. *Medicine & Science in Sports & Exercise*, **46**, 1194-1203. <http://dx.doi.org/10.1249/MSS.0000000000000220>
- [19] Kilduff, L.P., Lewis, S., Kingsley, M.I., Owen, N.J. and Dietzig, R.E. (2007) Reliability and Detecting Change Following Short-Term Creatine Supplementation: Comparison of Two-Component Body Composition Methods. *The Journal of Strength & Conditioning Research*, **21**, 378-384. <http://dx.doi.org/10.1519/00124278-200705000-00015>
- [20] Moon, J. (2013) Body Composition in Athletes and Sports Nutrition: An Examination of the Bioimpedance Analysis Technique. *European Journal of Clinical Nutrition*, **67**, S54-S59. <http://dx.doi.org/10.1038/ejcn.2012.165>
- [21] Larson-Meyer, D.E., Hunter, G.R., Trowbridge, C.A., Turk, J.C., Ernest, J.M., Torman, S.L. and Harbin, P.A. (2000) The Effect of Creatine Supplementation on Muscle Strength and Body Composition during Off-Season Training in Female Soccer Players. *The Journal of Strength & Conditioning Research*, **14**, 434-442.
- [22] Sundgot-Borgen, J. and Garthe, I. (2011) Elite Athletes in Aesthetic and Olympic Weight-Class Sports and the Challenge of Body Weight and Body Compositions. *Journal of Sports Sciences*, **29**, S101-S114.
- [23] Tang, F.C., Chan, C.C. and Kuo, P.L. (2013) Contribution of Creatine to Protein Homeostasis in Athletes after Endurance and Sprint Running. *European Journal of Nutrition*, **53**, 61-71.