Journal of Nutrition and Food Security
Shahid Sadoughi University of Medical Sciences
School of Public Health
Department of Nutrition

eISSN: 2476-7425 pISSN: 2476-7417 JNFS 2024; 9(4): 788-801 Website: jnfs.ssu.ac.ir

# The Effects of Beta-Alanine Supplementation on Body Composition Indices: A Systematic Review and Meta-Analysis of Controlled Clinical Trials

**Masoud Khorshidi; PhD[1,2], Sanaz Jamshidi; PhD[2], Javad Heshmati; PhD[3], Zohreh Sajadi Hezaveh; MSc[4], Beheshteh Olang; MSc[1,5], Omid Moradi Moghaddam; PhD[6], Zahra Shahveghar; PhD[7,8], Zohreh Ghoreishi; MSc[8], Alireza Ostadrahimi; PhD[7] & Meysam Zarezadeh; PhD*[9]**

*[1] Pediatric Gastroenterology, Hepatology and Nutrition Research Center, Research Institute for Children's Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [2] Department of Nutrition, School of Public Health, Iran University of Medical Sciences, Tehran, Iran; [3]Department of Nutritional Science, School of Nutritional Science and Food Technology, Kermanshah University of Medical Sciences, Kermanshah, Iran; [4] Department of Health Sciences, Faculty of Medicine and Health, University of Sydney, Sydney, Australia; [5] Department of Community Medicine, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran; [6] Critical Care Medicine Department, Iran University of Medical Sciences, Tehran, Iran; [7] Department of Clinical Nutrition, School of Nutrition and Food Sciences, Tabriz University of Medical Sciences, Tabriz, Iran; [8] Nutrition Research Center, Tabriz University of Medical Sciences, Tabriz, Iran; [9] Student Research Committee, Tabriz University of Medical Sciences, Tabriz, Iran.*

***ARTICLE INFO***

***SYSTEMATIC REVIEW and META-ANALYSIS***

***Article history:***
Received:14 Feb 2023
Revised: 5 Apr 2023
Accepted:21 Apr 2023

***Corresponding author:***
zarezadehm@tbzmed.ac.ir
Tabriz University of Medical Sciences, Tabriz, Iran, Attar-Neishaburi St, Golgasht Alley, Azadi Blvd. Tabriz, Iran

***Postal code:*** 51368
***Tel:*** +98 9143319531

***Keywords*:**
*Beta alanine; Weight; Obesity; Body composition; Meta-analysis*

***ABSTRACT***

**Background**: Beta-alanine is an important oral supplement for improving athletes' performance, followed by probable effects on body composition. Current meta-analysis was performed to investigate the role of beta-alanine supplementation on body weight, fat mass, free fat mass, and body fat percentage in adults. **Methods:** Web of Science, PubMed, Scopus, Cochrane library databases, and EMBASE were searched between January 1990 and May 2021. Randomized controlled trials (RCTs) comparing beta-alanine supplementation with a placebo assessing anthropometric indices were included. Meta-analysis was performed using the random-effects model. Publication bias was evaluated using standard methods, and subgroup analysis and meta-regression were carried out. **Results:** A total of 875 articles were identified through database searching, of which 12 RCTs with 15 datasets were included in the study. This study showed that beta-alanine supplementation did not have any significant effect on body weight [SMD, 0.08; 95% CI (−0.17, 0.33); *P*=0.517], fat percentage [SMD, 0.09; 95% CI (−0.18, 0.37); *P*=0.504], fat mass [SMD, 0.10; 95% CI (−0.29, 0.50); *P*=0.612], and fat free mass [SMD, 0.16; 95% CI (−0.18, 0.49); *P*=0.517]. **Conclusions:** Results showed that beta-alanine supplementation does not change body composition significantly.

## Introduction

Nutrition is a substantial and effective component which improves athletic performance by optimizing training and recovering (Spriet, 2019). Athletes face challenges regarding

***This paper should be cited as:*** Khorshidi M, Jamshidi S, Heshmati J, Sajadi Hezaveh Z, Olang B, Moradi Moghaddam O, et al. ***The Effects of Beta-Alanine Supplementation on Body Composition Indices: A Systematic Review and Meta-Analysis of Controlled Clinical Trials.*** *Journal of Nutrition and Food Security (JNFS)*, 2024; 9(4): 788-801.



[ DOI: 10.18502/jnfs.v9i4.16907 ]

their body shape and weight-related issues while they are focused on losing fat mass or gaining lean mass, as well as maintaining or improving their performance for a competition (Manore, 2015). Notably, various available nutritional supplements are claimed to be beneficial for improving the athlete's performance (Spriet, 2019). Among them, oral supplementation with amino acid and beta-alanine evidently plays a positive role in the athletic performance (Baguet *et al.*, 2010, Gross *et al.*, 2014).

Beta-alanine supplementation has been shown to increase intracellular levels of carnosine, attenuate muscular fatigue, and improve physical performance, lean body mass, and body composition (Quesnele *et al.*, 2014, Smith *et al.*, 2019). This amino acid participates in carnosine structure (β-alanyl-L-histidine) which is an important cytoplasmic dipeptide in large quantities in skeletal muscle with few reported adverse effects (Quesnele *et al.*, 2014, Sale *et al.*, 2010). Physical improvements following beta-alanine supplementation results from an increase in systemic levels of carnosine, pH homeostasis, higher fatigue threshold, and stronger myofibril contraction, which is due to the enhancement of sarcomere calcium sensitivity (Furst *et al.*, 2018, Quesnele *et al.*, 2014). For above reasons, the effects of beta-alanine on body composition and performance improvement has recently attracted a lot of attention (Baye *et al.*, 2017).

Antioxidant, anti-glycation, anti-inflammatory, anti-ischemic, and chelating properties of beta-alanine may underline some proposed mechanisms of its efficacy for obtaining the desired body composition in athletes (Baye *et al.*, 2017). Additionally, several investigations have reported that carnosine, as a main source of beta alanine, is effective in reducing harmful complications of excessive body weight and is able to sequester Hydroxynonenal (HNE), which is a lipid peroxidation product involved in cardiometabolic diseases as well as obesity-related disorders, such as dyslipidemia, lipotoxicity, and insulin resistance (Anderson *et al.*, 2018, Zhang *et al.*, 2013). Moreover, it seems that carnosine prevents damaging effects of reactive carbonyl species (RCS) and regulates sterol regulatory element-binding transcription factor1 (SREBP-1) activity, which in turn can affect body weight (Baye *et al.*, 2017, Boldyrev *et al.*, 2013, Regazzoni *et al.*, 2016, Zhou *et al.*, 2020). On the other hand, L-carnosine showed beneficial effect on reducing total body weight, abdominal obesity, waist circumference, and retroperitoneal fat. It's also suggested that L-carnosine may play a role in amelioration of proinflammatory adipokine production in adipose tissue (Al-Sawalha *et al.*, 2019). Currently, several randomized controlled trials (RCTs) have been published with regards to the effect of beta-alanine on body composition; however, the results are controversial. As Sale et al. indicated, administration of 6.4 gram per day of beta-alanine on those with isometric endurance of the knee extensor muscles did not change body weight (Sale *et al.*, 2012a). Moreover, Smith et al. showed a reduction in body weight, percentage of body fat, and fat mass in those receiving 6.4 gram per day beta-alanine along with anaerobic exercise for 6 weeks although the results were non-significant (Smith *et al.*, 2019).

Currently, beta-alanine is used to improve athletic performance, On the other hand, weight and body composition are among the main concerns of athletes. As there is no prior systematic review and meta-analysis assessing the effect of beta-alanine on body composition indices, this comprehensive systematic review and meta-analysis of RCTs was performed to investigate the role of beta-alanine supplementation on body weight, fat mass, fat free mass and fat percentage in adult athletes.

## Materials and Methods

### *Evidence acquisition*

This systematic review and meta-analysis was performed and reported based on preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines, Cochrane handbook for systematic reviews of interventions, and Muka et al. guideline (Moher *et al.*, 2015, Muka *et al.*, 2020).



[ DOI: 10.18502/jnfs.v9i4.16907 ]

### Search strategy

PICOS components of this research were as follow: P: adults, I: beta alanine, C: placebo, O: body weight, fat mass, fat free mass, and fat percentage, S: RCTs (the I and O components were included in the search syntax). Electronic databases including PubMed/Medline, Scopus, Web of Science, Embase and Cochrane Library were searched to obtain relevant studies up to May 2021 based on the following search syntax: ("beta alanine" OR "β alanine") AND ("body composition" OR "body weight" OR "body mass index" OR "waist circumference" OR "fat mass" OR "fat free mass" OR "lean mass" OR "obese*" OR "overweight" OR "BMI" OR "lean body mass"). Moreover, the references of the included articles and reviews on beta-alanine were assessed to make sure no studies were missed. Conference papers, patents, and unpublished documents were excluded from the study.

### Selection criteria

The eligible articles had the following criteria: a) controlled clinical trials; b) full text in English; c) adult study population (both athletes and non-athletes); d) investigation of the effects of beta-alanine supplementation alone; and e) available data on body weight, fat mass, fat free mass and fat percentage before and after the intervention in both groups. Studies were excluded if they: a) were not designed as clinical trials; b) did not have a control group; c) were conducted on animals or other human populations (children, elderly, etc.); d) there was administration of beta-alanine in any way other than oral.

### Data extraction

Included studies were fully evaluated by two independent reviewers (Jamshidi S and Shahveghar Z), and controversies were resolved by a third reviewer (Zarezadeh M). Following information were extracted from studies using a standard form designed for data extraction: first author, publication year, location, study design (parallel or crossover), gender, study duration, dosage of prescribed beta alanine, study population, the mean age of participants, means, standard deviation [SD], and/or frequency for determined variables (body weight, fat percent, fat mass and fat free mass) at the baseline and the end of intervention or changes as well. For cross-over trials, only data from the first part of the study (before the washout period) was recorded for analysis.

### Quality assessment

The quality of studies was assessed by two independent reviewers (Heshmati J and Beheshteh Olang B) using Cochrane Collaboration's risk of bias assessment tool (Samimi *et al.*, 2016). This scale contains the following domains: random sequence generation, allocation concealment, reporting bias, performance bias, detection bias, and attrition bias, and other sources of bias. Finally, quality of studies was categorized as high, low, and unclear risk of bias.

### Data analysis

The data analysis was carried out using the Stata 16 software (Stata Corp, College Station, TX, USA) and p-value <0.05 was considered statistically significant. In order to perform meta-analysis, random-effect model was employed using restricted maximum likelihood (REML) method. Heterogeneity was evaluated using the $I^2$ index ($I^2 \geq 50\%$ and $I^2 < 50\%$ were considered heterogeneous and non-heterogeneous data, respectively) (Higgins *et al.*, 2019). Effect size was defined as standardized mean difference (SMD) and 95% confidence interval (CI). The effect sizes of meta-analysis were calculated based on mean differences and their relevant standard deviations (SDs) of changes in studied variables for intervention and control groups. If data were reported as standard error of the means (SEM), SDs were calculated through multiplying SEM by the square root of the sample size ($SD = SEM \times \sqrt{n}$). Sensitivity analysis was performed for assessing the influence of deleted studies on overall effect size using the leave-one-out method. Meta-regression analysis was performed to detect any linear relationship between effect size and the sample size, mean age, intervention duration, and the dosage. Predefined subgroup analysis was conducted based on mean age of participants, gender, study location,



[ DOI: 10.18502/jnfs.v9i4.16907 ]

intervention duration and defined dosages to investigate the effect of beta-alanine by different subgroups. Moreover, meta-regression and subgroup analyses were used to identify the source of heterogeneity, and small study effect was measured by Begg's adjusted rank correlation and Egger's regression asymmetry tests as well. Notably, visual inspection of funnel plot was used in order to discover publication bias through asymmetric distribution of the included studies. Trim and fill analysis was performed to amend the small study effect or the publication bias.

## Results

### *Study selection*

Out of a total of 875 publications, after removing the duplicated ones, 541 records were left for title and abstract screening. Thereafter, 458 articles were excluded (studies other than clinical trials such as editorials (n=2), review articles (n= 19), animal model or in-vitro studies (520). Out of the remaining 83 studies, 31 articles were not relevant to the current research question. 52 full-text articles were evaluated in details. Finally, 12 studies with 15 datasets investigating the effect of beta-alanine supplementation on body composition indices were analyzed (Askari and Rahmaninia, 2019, Gross *et al.*, 2014, Hill *et al.*, 2007, Kern and Robinson, 2011a, Kresta *et al.*, 2014, Outlaw *et al.*, 2016, Sale *et al.*, 2012b, Smith *et al.*, 2009, Stout *et al.*, 2007, Varanoske *et al.*, 2018, Wang *et al.*, 2019). Some studies assessed the outcomes in two or three different time points, or reported the results separately for men and women or other subgroups of the total population, and each result was added to the analysis as separate datasets. In 10 studies with 13 datasets, the effect of beta-alanine on weight was investigated, 4 studies with 5 datasets reported fat mass, 5 studies with 7 datasets provided the measured fat free mass, and 8 studies with 11 datasets reported body fat percentage. The study selection process has been demonstrated in **Figure 1**.

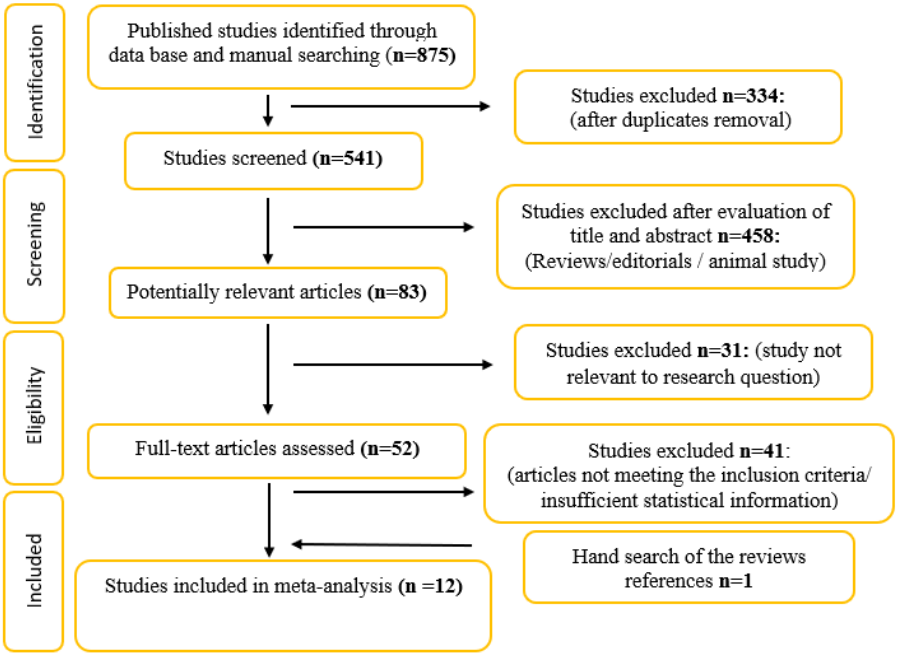


**Figure 1.** The flow diagram describing the process of screening and excluded articles

### *Study characteristics*

The largest population size was 36 participants, while the smallest one included 9 participants. Trials were published between 2007 and 2019 and conducted in the UK (Hill *et al.*, 2007, Sale *et al.*, 2012b), USA (Kern and Robinson, 2011a, Kresta *et al.*, 2014, Outlaw *et al.*, 2016, Sale *et al.*, 2012b, Smith *et al.*, 2019, Stout *et al.*, 2007), Switzerland



[ DOI: 10.18502/jnfs.v9i4.16907 ]

(Gross *et al.*, 2014), China (Wang *et al.*, 2019) and Iran (Askari and Rahmaninia, 2019). The mean age of participants ranged between 17 and 28. Dosage of beta-alanine supplementation varied from 3 to 12 g/day. Duration of intervention ranged between 3 to 10 weeks, and all trials were parallel. Characteristics of the included studies have been shown in **Table 1**.

***Quality of included studies and risk of bias***

Based on quality assessment, no study was categorized as low risk of bias. This was while 3 studies were considered as high risk and 9 studies as unclear risk of bias. 10 out of 12 studies had low risk of random sequence generation bias, and 10 studies provided unclear information about allocation concealment. Moreover, 10 studies had enough information about blinding processes, while two had high risk of performance bias, and the same number had detection bias as well. Additionally, 6 studies provided proper information about incomplete data outcome, and all the 12 studies had unclear risk of reporting bias (**Figure 2)**. Based on visual inspection of the funnel plot (**Figure 3**), there was no evidence of asymmetry for the included studies.

***Effect of beta-alanine on weight***

The results of this meta-analysis showed that there were no significant effects of beta-alanine supplementation on body weight (SMD= 0.08; 95% CI [−0.17, 0.33]; *P*=0.517); and also no significant heterogeneity was observed ($I^2$=0.0%, *P*=0.999, **Figure 4**). Subgroup analysis was performed based on participant's sex (male or female), dosages of beta-alanine (<6 or ≥6 g/day), intervention duration (<4 or ≥4 weeks) and mean age (<20 or ≥20). The results showed that there were no significant differences between subgroups. **Table 2** presents the results of the subgroup analyses. Based on visual inspection of the funnel plot, there was no evidence of asymmetry for included studies around the SMD (**Figure 3**). Similarly, there was no clue of small study effect detected by the Begg's linear regression test (*P*=0.855).



[ DOI: 10.18502/jnfs.v9i4.16907 ]

**Table 1.** Characteristics of the included studies.

| Author and year | Country | Study population | Sex | Dose | Duration (week) | Sample size | Mean Age(y) | Outcome |
|---|---|---|---|---|---|---|---|---|
| Smith C. R. et al. (2019) | USA | Collegiate athletes (Rugby) | M | 6.4 g/d | 6 | 15 | 21.0 ± 1.8 | Weight/ FP/ FM/ FFM |
| Kresta J. Y. et al. (2014) | USA | Recreationally active females | F | 6.1 ± 0.7 g/day | 3 | 15 | 21.5 ± 2.8 | FP/ Weight/ FM/ FFM |
| Smith A. E. et al (2009) | USA | College aged men | M | 6 g/d first 3 weeks<br>3 g/d second 3 weeks | 6 | 36 | 22.2 ± 2.7 | FP/ Weight/ FM/ FFM |
| Outlaw J. J. et al. (2016) | USA | Collegiate females | F | 3.4 g/d | 8 | 15 | 20 ± 1.9 | FP/ FM/ FFM |
| Kern B. D. et al (2011) | USA | Collegiate athletes (wrestlers & football players) | M | 4 g/d | 8 | 22 | 19.2 ± 1.7 | FP/ weight/ FFM |
| Hill C. A. et al (2007) | UK | Physically active males | M | from 4 to 6.4 g/d | 10 | 25 | 25.4 ± 2.1 | Weight |
| Sale C. et al (2012) | UK | Physically active males | M | 6.4 g/d | 4 | 10 | 23 ± 6 | Weight |
| Stout J. R. et al (2007) | USA | Healthy | F | from 3.2 to 6.4 g/d | 4 | 22 | 28.9 ± 8.1 | Weight |
| Gross M. et al (2014) | Switzerland | Skiers | M | 4.8 g/d | 5 | 9 | 19.5 ± 1.1 | FP/ weight |
| Wang R. et al (2018) | China | Healthy | M | 6.4 g/d | 4 | 19 | 22.6 ± 2.8 | FP/weight |
| Varanoske A. N. et al (2018) | USA | Military soldiers | M | 12 g/d | 3.5 | 19 | 22.4 ± 3.0 | Weight |
| Askari F. et al (2019) | Iran | Healthy | M | 4.8 g/d | 8 | 20 | 19.7 ± 1.0 | BMI/ FP |

**FP**: Fat Percent, **FM**: Fat Mass, **FFM**: Fat Free Mass, **M**: male, **F**: Female



[ DOI: 10.18502/jnfs.v9i4.16907 ]

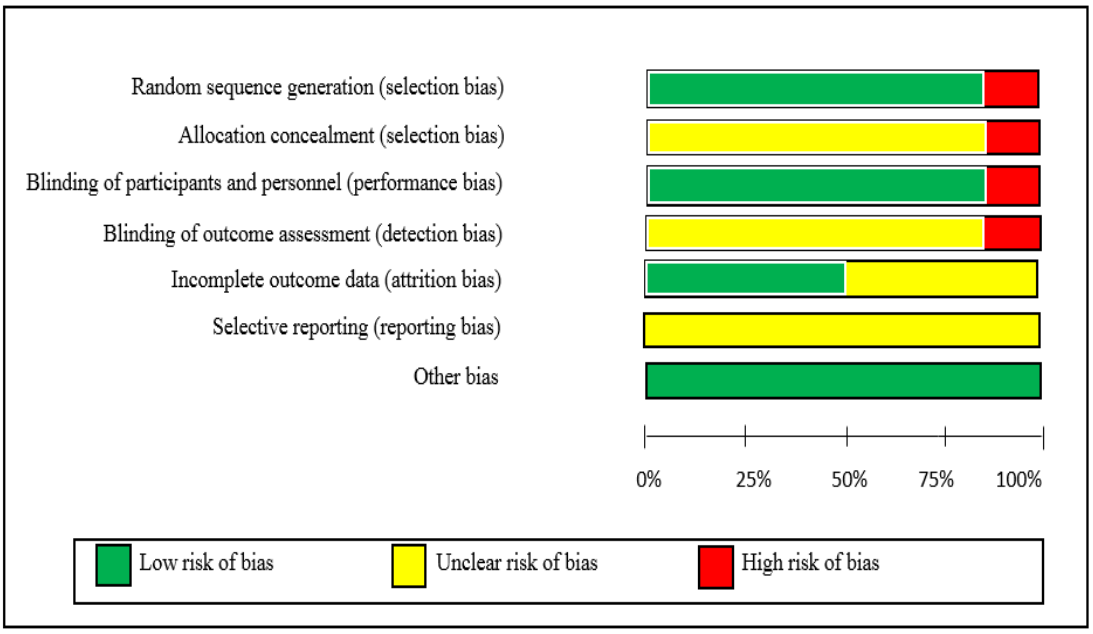


**Figure 2.** Assessment of quality of studies by the Cochrane collaboration's tool.

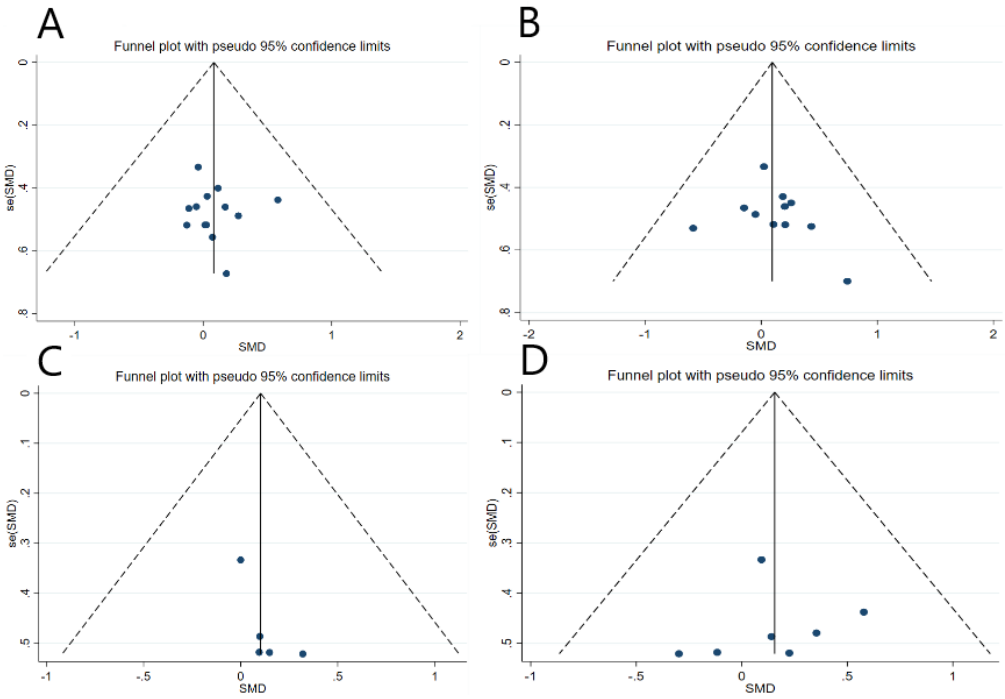


**Figure 3.** Funnel plot for weight (A), fat percent (B), fat mass (C) and fat free mass (D).



[ DOI: 10.18502/jnfs.v9i4.16907 ]

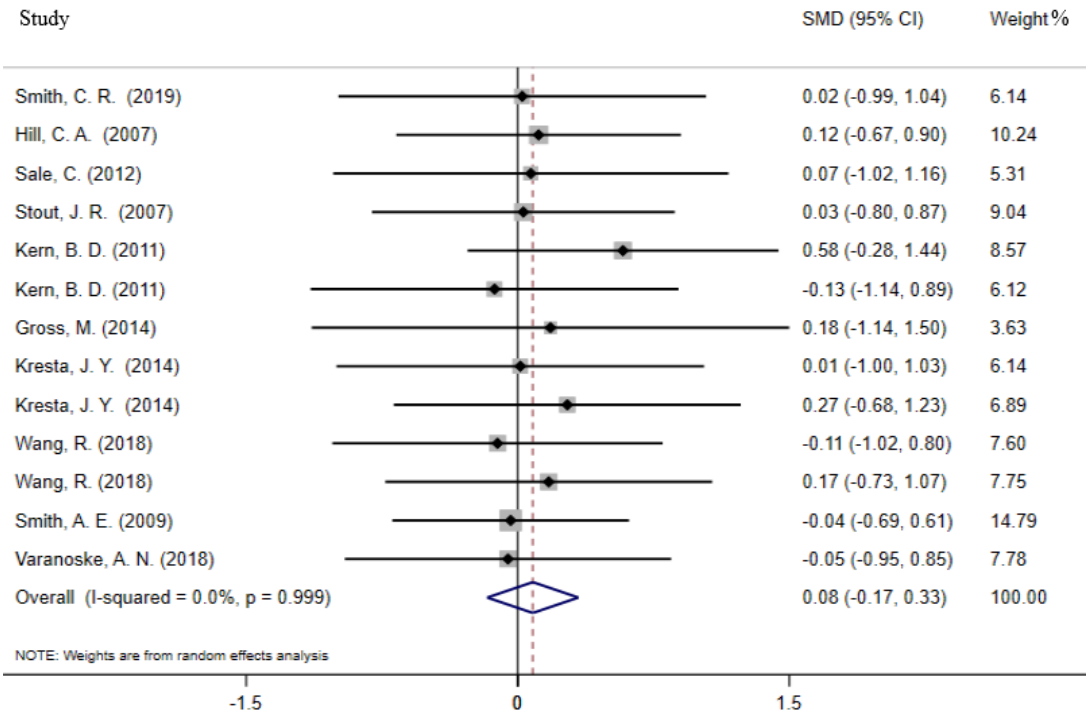


**Figure 4.** Forest plot presenting SM D and 95% CIs for the impact of beta-alanine supplementation on body weight.

### *Effect of beta-alanine on fat percent*

The pooled effect size showed that supplementation with beta-alanine had no significant effects on fat percentage (SMD, 0.09; 95% CI [−0.18, 0.37]; *P*=0.504). No heterogeneity was observed between studies ($I^2$=0.0%, *P*=0.964) (**Figure 5**). The results of subgroup analysis showed that beta-alanine dosage, duration of supplementation, and sex and mean age had no significant effect on fat percentage. The result of subgroup analyses is shown in **Table 2**. On the other hand, no small-study effect was observed performing Begg's linear regression test (p=0.470). Additionally, there was no evidence of asymmetry for included studies based on the funnel plot (**Figure 3**).

### *Effect of beta-alanine on fat mass*

The results of this study showed that supplementation with beta-alanine had no significant effect on fat mass (SMD, 0.10; 95% CI [−0.29, 0.50]; *P*=0.612). No significant heterogeneity was observed between the included studies ($I^2$=0.0%, *P*=0.991, **Figure 6**). As shown in **Table 2**, beta-alanine dosage, duration of supplementation, sex and mean age had no significant effect on fat mass based regarding subgroup analyses. Small-study effect was not observed while performing Begg's linear regression test (*P*=0.086). Moreover, in performing visual inspection of the funnel plot, no evidence of asymmetry for included studies was found (**Figure 3).**



[ DOI: 10.18502/jnfs.v9i4.16907 ]

**Table 2.** Subgroup analysis of the included RCTs in meta-analysis of the effect of beta-alanine supplementation on body composition.

| Variables | Trial duration | | Mean age | | Supplementation dose | | Participant's sex | |
|---|---|---|---|---|---|---|---|---|
| | **< 4 weeks** | **≥ 4 weeks** | **< 20** | **≥ 20** | **< 6 g/day** | **≥ 6 g/day** | **Male** | **Female** |
| **Weight** | | | | | | | | |
| Number of comparisons | 7 | 6 | 3 | 10 | 4 | 9 | 10 | 3 |
| WMD (95% CI) | 0.05 (-0.03, 0.41) | 0.11 (-0.24, 0.47) | 0.26 (-0.32, 0.85) | 0.07 (-0.53, 0.61) | 0.13 (-0.31, 0.57) | 0.03 (-0.25, 0.37) | 0.08 (-0.21, 0.36) | 0.10 (-0.43, 0.64) |
| P-value | 0.767 | 0.534 | 0.377 | 0.821 | 0.562 | 0.701 | 0.593 | 0.708 |
| $I^2$ (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P-heterogeneity | 0.998 | 0.901 | 0.574 | 0.896 | 0.999 | 1.000 | 0.992 | 0.914 |
| **Fat mass** | **< 6 weeks** | **≥ 6 weeks** | **< 20** | **≥ 20** | **< 6 g/day** | **≥ 6 g/day** | **Male** | **Female** |
| Number of comparisons | 2 | 3 | - | - | 2 | 3 | 2 | 3 |
| WMD (95% CI) | 0.20 (-0.50, 0.90) | 0.06 (-0.43, 0.54) | - | - | 0.04 (-0.51, 0.59) | 0.17 (-0.41, 0.74) | 0.03 (-0.52, 0.58) | 0.18 (-0.39, 0.76) |
| P-value | 0.571 | 0.823 | - | - | 0.877 | 0.568 | 0.920 | 0.529 |
| $I^2$ (%) | 0.0 | 0.0 | - | - | 0.0 | 0.0 | 0.0 | 0.0 |
| P-heterogeneity | 0.756 | 0.968 | - | - | 0.809 | 0.940 | 0.877 | 0.950 |
| **Fat-free mass** | **< 6 weeks** | **≥ 6 weeks** | **< 20** | **≥ 20** | **< 6 g/day** | **≥ 6 g/day** | **Male** | **Female** |
| Number of comparisons | 2 | 5 | 3 | 4 | 4 | 3 | 4 | 3 |
| WMD (95% CI) | -0.06 (-0.76, 0.63) | 0.22 (-0.16, 0.61) | 0.31 (-0.23, 0.85) | 0.06 (-0.38, 0.49) | 0.22 (-0.19, 0.64) | 0.03 (-0.55, 0.60) | 0.28 (-0.14, 0.70) | -0.08 (-0.66, 0.49) |
| P-value | 0.858 | 0.256 | 0.258 | 0.797 | 0.294 | 0.923 | 0.187 | 0.783 |
| $I^2$ (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P-heterogeneity | 0.538 | 0.859 | 0.588 | 0.849 | 0.901 | 0.745 | 0.847 | 0.825 |
| **Fat percentage** | **< 6 weeks** | **≥ 6 weeks** | **< 20** | **≥ 20** | **< 6 g/day** | **≥ 6 g/day** | **Male** | **Female** |
| Number of comparisons | 5 | 6 | 5 | 6 | 6 | 5 | 8 | 3 |
| WMD (95% CI) | 0.16 (-0.28, 0.61) | 0.05 (-0.30, 0.41) | 0.13 (-0.32, 0.57) | 0.07 (-0.18, 0.37) | 0.09 (-0.27, 0.46) | 0.10 (-0.33, 0.37) | 0.07 (-0.25, 0.39) | 0.18 (-0.39, 0.76) |
| P-value | 0.474 | 0.777 | 0.576 | 0.684 | 0.616 | 0.659 | 0.675 | 0.533 |
| $I^2$ (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| P-heterogeneity | 0.810 | 0.868 | 0.608 | 0.973 | 0.735 | 0.935 | 0.882 | 0.796 |

**WMD**: Weighted mean difference. **CI**: Confidence interval. **BMI**: Body mass index.



[ DOI: 10.18502/jnfs.v9i4.16907 ]

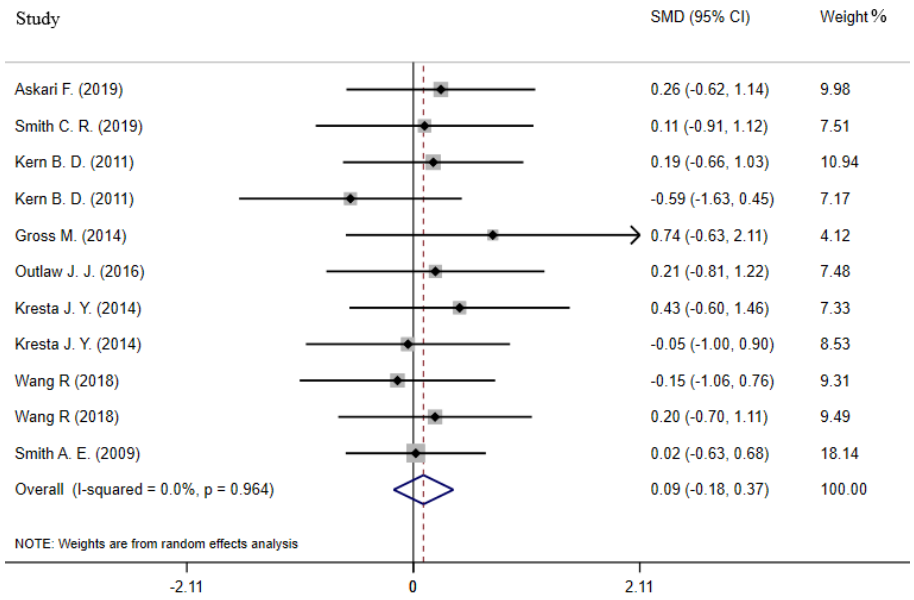


**Figure 5.** Forest plot presenting SMD and 95% CIs for the impact of beta-alanine supplementation on fat percent.

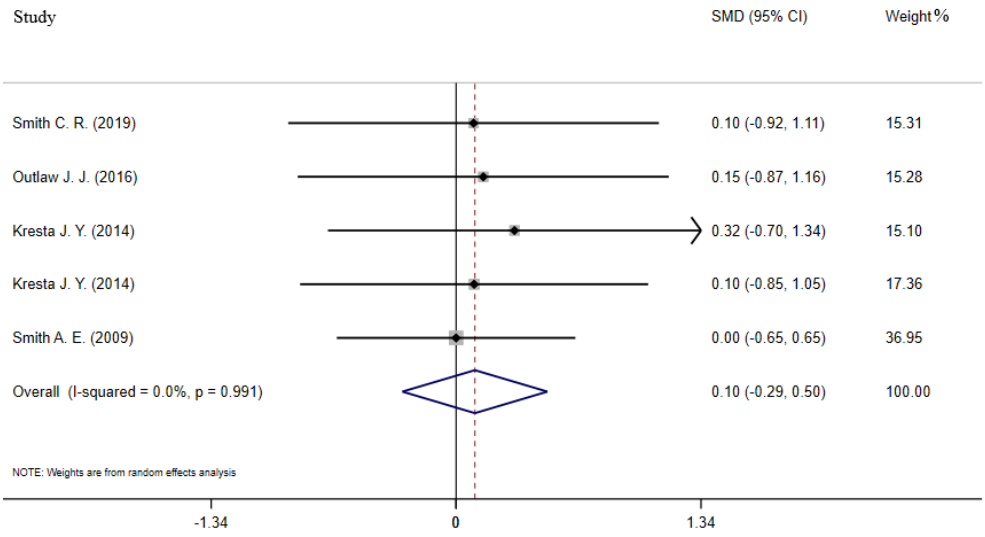


**Figure 6.** Forest plot presenting SMD and 95% CIs for the impact of beta-alanine supplementation on fat mass.

### *Effect of beta-alanine on fat free mass*

Beta-alanine supplementation had no significant impact on fat free mass (SMD, 0.16; 95% CI [−0.18, 0.49]; *P*=0.517). Furthermore, no heterogeneity was observed between the studies ($I^2$=0.0%, *P*=0.901, **Figure 7**). The results of subgroup analysis showed that beta-alanine dosage, duration of supplementation, sex, and mean age did not have any significant effect on fat free mass (**Table 2).** On the other hand, no small-study effect was observed after performing Begg's linear regression test (*P*=0.230). Also, based on visual inspection of the funnel plot, there was no evidence of asymmetry for included studies (**Figure 3**).



[ DOI: 10.18502/jnfs.v9i4.16907 ]

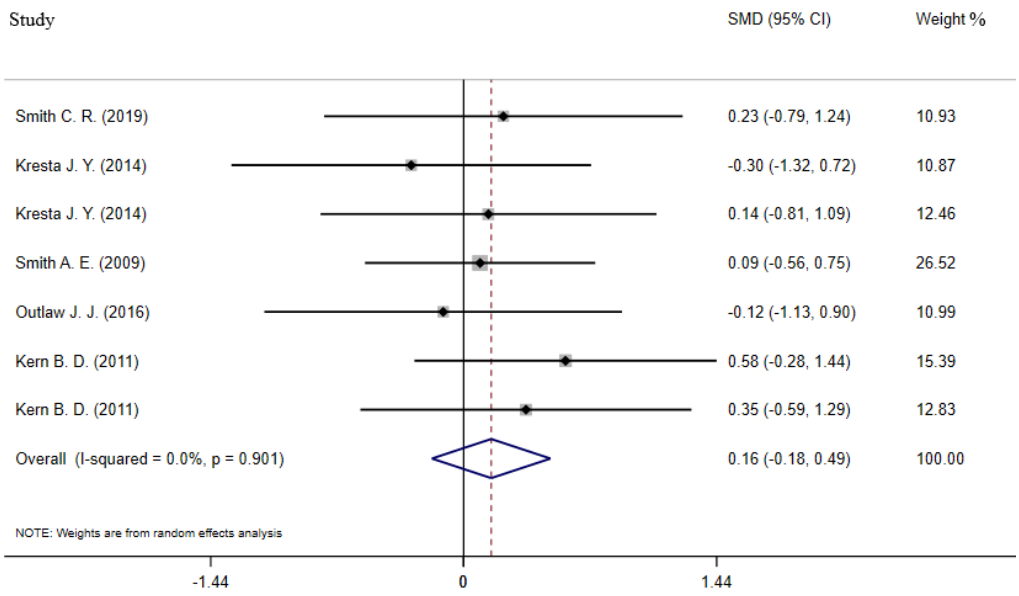


**Figure 7.** Forest plot presenting SMD and 95% CIs for the impact of beta-alanine supplementation on fat free mass.

### *Meta regression and sensitivity analysis*

To evaluate the effect of potential factors on the pooled estimate, random-effect meta-regression analysis was performed. The results from meta-regression analysis demonstrated no linear relationship between effect size, age, sample size, dose, and duration of supplementation. In sensitivity analysis, the pooled effect size was not dependent on a single or a few studies.

## Discussion

The results of this systematic review and meta-analysis of 12 RCTs indicated that beta-alanine had no significant effect on body weight, fat mass, fat free mass and fat percentage in adults. Subgroup analysis of sex, dosages of beta-alanine (<6 or ≥6 g/day), intervention duration (<4 or ≥4 weeks) and mean age of participants (<20 or ≥20) did not seem to make any remarkable difference either. It should also be noted that the subgroups were determined based on the dispersion and mean value of the variable among the included studies.

Although the exact mechanisms underlying the effect of beta-alanine on body composition is not clear, previous RCTs suggested neutral effects of this substance on some biomarkers and variables (Askari and Rahmaninia, 2019, Hill *et al.*, 2007, Kern and Robinson, 2011b, Outlaw *et al.*, 2016). Contrary to the current results, Hoffman et al. indicated that beta-alanine co-supplementation with creatine had remarkable effects on body fat reduction and lean body mass improvements during a 10 week training program in soccer players (Hoffman *et al.*, 2006) although these significant results may have occurred due to co-administration of beta-alanine and creatine. In addition, Kresta *et al.* showed that beta-alanine administration caused a reduction in fat mass and body fat percentage, along with an increase in fat free mass. However, the results were not statistically significant (Kresta *et al.*, 2014). In a study conducted by Askari *et al.* (Askari and Rahmaninia, 2019) on the effect of beta-alanine on body composition and physical performance, body fat percentage decreased significantly in both intervention and placebo group, without any changes in BMI values. This result might have been affected by small sample size and short duration of the study. Moreover, Ormsbee *et al.* showed that beta-alanine, among a series of other supplements, improved the lean body mass of male athletes (Ormsbee *et al.*, 2012). However, small sample size and co-administration with whey protein, casein protein, branched-chain amino acids, and creatine might have led to significant results.



[ DOI: 10.18502/jnfs.v9i4.16907 ]

Different mechanisms through which beta-alanine may improve physical performance have been suggested. beta-alanine supplementation may lead to a 60% increase in carnosine muscle level due to the acid-base homeostasis maintenance in muscle cells (Artioli *et al.*, 2010, Gross *et al.*, 2014). On the other hand, beta-alanine supplementation affects force-frequency by enhancing $Ca^{2+}$ release from the sarcoplasmic reticulum and delaying fatigue by increasing carnosine concentrations (Everaert *et al.*, 2013, Rubtsov, 2001). As the improvement in physical performance without any weight gain is very important for many athletes, beta-alanine may be an effective supplement, as it has a possible fatigue delaying effects with no consequences on body fat mass the latter was obtained from the current meta-analysis.

This study had a few limitations: First, adults played different types of sports such as rugby, football and ski, and therefore, had different levels of physical activity, while some studies were done on ordinary healthy participants who were not athletes at all. In addition, although most studies had an acceptable quality, adherence of athletes to the study protocol was not carefully assessed in the included studies. Also, in some studies, body composition outcomes were the secondary outcome, and hence, the sufficiency of the sample size might not have been met. Among the strengths of this research are the comprehensive search strategy and risk of bias assessment using a reliable tool. It is suggested that future systematic reviews and meta-analyses focus on the effect of this supplement on athletes playing a certain type of sport, and to investigate this effect on new body composition indices such as body adiposity index (BAI) or a body shape index (ABSI).

## Conclusions

Beta-alanine could not affect body weight, fat mass, fat free mass and fat percentage in adults. Sex, intervention duration (<4 or ≥4 weeks), dosages of beta-alanine (<6 or ≥6 g/day), and mean age of participants (<20 or ≥20) did not seem to affect the result of this intervention. Future studies should be conducted by evaluating the impact of beta-alanine on body composition in specific populations, age groups, and conditions.

## Acknowledgements

Not Applicable.

## Conflict of interest

The authors declared no conflicts of interest.

## Authors' contributions

Khorshidi M, Ostadrahimi A and Zarezadeh M contributed to the conception and design of the work. Data extraction was done by Jamshidi S. and Heshmati J, Ostadrahimi A and Khorshidi M performed the quality assessment. Shahveghar Z, Moradi Moghaddam O and Sajadi Hezaveh Z. participated in statistical analysis and interpretation of the data. Olang B and Ghoreishi Z drafted the work. All authors critically revised the manuscript and provided the final approval of the version to be published. All authors are accountable for all aspects of the work, and ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## Funding

There is not any funding.

## References

**Al-Sawalha NA, Alshogran OY, Awawdeh MS & Almomani BA** 2019. The effects of l-Carnosine on development of metabolic syndrome in rats. *Life sciences.* **237**: 116905.

**Anderson EJ, et al.** 2018. A carnosine analog mitigates metabolic disorders of obesity by reducing carbonyl stress. *Journal of clinical investigation.* **128 (12)**: 5280-5293.

**Artioli GG, Gualano B, Smith A, Stout J & Lancha Jr AH** 2010. Role of beta-alanine supplementation on muscle carnosine and exercise performance. *Medicine & science in sports & exercise.* **42 (6)**: 1162-1173.

**Askari F & Rahmaninia F** 2019. The effect of 8 weeks beta-alanine supplementation and resistance training on maximal-intensity exercise performance adaptations in young males. *Physical education of students.* **23 (1)**: 4-8.



[ DOI: 10.18502/jnfs.v9i4.16907 ]

**Baguet A, Bourgois J, Vanhee L, Achten E & Derave W** 2010. Important role of muscle carnosine in rowing performance. *Journal of applied physiology.* **109**: 1096-1101.

**Baye E, et al.** 2017. Effect of carnosine supplementation on the plasma lipidome in overweight and obese adults: a pilot randomised controlled trial. *Scientific reports.* **7 (1)**: 1-7.

**Boldyrev AA, Aldini G & Derave W** 2013. Physiology and pathophysiology of carnosine. *Physiological reviews.* **93 (4)**: 1803-1845.

**Everaert I, Stegen S, Vanheel B, Taes Y & Derave W** 2013. Effect of beta-alanine and carnosine supplementation on muscle contractility in mice. *Medicine and science in sports and exercise.* **45 (1)**: 43-51.

**Furst T, et al.** 2018. β-Alanine supplementation increased physical performance and improved executive function following endurance exercise in middle aged individuals. *Journal of the international society of sports ntrition.* **15 (1)**: 32.

**Gross M, Bieri K, Hoppeler H, Norman B & Vogt M** 2014. Beta-alanine supplementation improves jumping power and affects severe-intensity performance in professional alpine skiers. *International journal of sport nutrition and exercise metabolism.* **24 (6)**: 665-673.

**Higgins JP, et al.** 2019. Cochrane handbook for systematic reviews of interventions. John Wiley & Sons: Chichester (UK).

**Hill C, et al.** 2007. Influence of β-alanine supplementation on skeletal muscle carnosine concentrations and high intensity cycling capacity. *Amino acids.* **32 (2)**: 225-233.

**Hoffman J, et al.** 2006. Effect of creatine and ß-alanine supplementation on performance and endocrine responses in strength/power athletes. *International journal of sport nutrition and exercise metabolism.* **16 (4)**: 430-446.

**Kern BD & Robinson TL** 2011a. Effects of β-alanine supplementation on performance and body composition in collegiate wrestlers and football players. *Journal of strength and conditioning research.* **25 (7)**: 1804-1815.

**Kern BD & Robinson TL** 2011b. Effects of β-alanine supplementation on performance and body composition in collegiate wrestlers and football players. *The Journal of Strength & Conditioning Research.* **25 (7)**: 1804-1815.

**Kresta JY, et al.** 2014. Effects of 28 days of beta-alanine and creatine supplementation on muscle carnosine, body composition and exercise performance in recreationally active females. *Journal of the international society of sports nutrition.* **11**: 1-15.

**Manore MM** 2015. Weight management for athletes and active individuals: a brief review. *Sports medicine.* **45 (1)**: 83-92.

**Moher D, et al.** 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews.* **4 (1)**: 1.

**Muka T, et al.** 2020. A 24-step guide on how to design, conduct, and successfully publish a systematic review and meta-analysis in medical research. *European journal of epidemiology.* **35 (1)**: 49-60.

**Ormsbee MJ, et al.** 2012. The effects of six weeks of supplementation with multi-ingredient performance supplements and resistance training on anabolic hormones, body composition, strength, and power in resistance-trained men. *Journal of the international society of sports nutrition.* **9 (1)**: 1-12.

**Outlaw JJ, et al.** 2016. Effects of β-alanine on body composition and performance measures in collegiate women. *Journal of strength and conditioning research.* **30 (9)**: 2627-2637.

**Quesnele JJ, Laframboise MA, Wong JJ, Kim P & Wells GD** 2014. The effects of beta-alanine supplementation on performance: a systematic review of the literature. *International journal of sport nutrition and exercise metabolism.* **24 (1)**: 14-27.

**Regazzoni L, et al.** 2016. A carnosine intervention study in overweight human volunteers: bioavailability and reactive carbonyl species sequestering effect. *Scientific reports.* **6 (1)**: 27224.



[ DOI: 10.18502/jnfs.v9i4.16907 ]

**Rubtsov A** 2001. Molecular mechanisms of regulation of the activity of sarcoplasmic reticulum Ca-release channels (ryanodine receptors), muscle fatigue, and Severin's phenomenon. *Biochemistry (moscow).* **66 (10)**: 1132-1143.

**Sale C, Hill CA, Ponte J & Harris RC** 2012a. β-alanine supplementation improves isometric endurance of the knee extensor muscles. *Journal of the international society of sports nutrition.* **9 (1)**: 26.

**Sale C, Hill CA, Ponte J & Harris RC** 2012b. β-alanine supplementation improves isometric endurance of the knee extensor muscles. *Journal of the International Society of Sports Nutrition.* **9**.

**Sale C, Saunders B & Harris RC** 2010. Effect of beta-alanine supplementation on muscle carnosine concentrations and exercise performance. *Amino acids.* **39 (2)**: 321-333.

**Samimi M, et al.** 2016. The effects of vitamin D plus calcium supplementation on metabolic profiles, biomarkers of inflammation, oxidative stress and pregnancy outcomes in pregnant women at risk for pre-eclampsia. *Journal of human nutrition and dietetics.* **29 (4)**: 505-515.

**Smith AE, et al.** 2009. Effects of β-alanine supplementation and high-intensity interval training on endurance performance and body composition in men; a double-blind trial. *Journal of the international society of sports nutrition.* **6 (1)**: 5.

**Smith CR, Harty PS, Stecker RA & Kerksick CM** 2019. A Pilot Study to Examine the Impact of Beta-Alanine Supplementation on Anaerobic Exercise Performance in Collegiate Rugby Athletes. *Sports.* **7 (11)**: 231.

**Spriet LL** 2019. Performance Nutrition for Athletes. *Sports medicine.* **49 (1)**: 1-2.

**Stout JR, et al.** 2007. Effects of β-alanine supplementation on the onset of neuromuscular fatigue and ventilatory threshold in women. *Amino acids.* **32 (3)**: 381-386.

**Varanoske AN, et al.** 2018. Effects of β-alanine supplementation on physical performance, cognition, endocrine function, and inflammation during a 24 h simulated military operation. *Physiological reports.* **6 (24)**: e13938.

**Wang R, et al.** 2019. Distinct Effects of Repeated-Sprint Training in Normobaric Hypoxia and beta-Alanine Supplementation. *Journal of the American College of Nutrition.* **38 (2)**: 149-161.

**Zhang X, et al.** 2013. Increased 4-hydroxynonenal formation contributes to obesity-related lipolytic activation in adipocytes. *PLoS One.* **8 (8)**: e70663.

**Zhou J-p, et al.** 2020. Obesity-Induced Upregulation of ZBTB7A Promotes Lipid Accumulation through SREBP1. *BioMed research international.* **2020 (1)**: 4087928.



[ DOI: 10.18502/jnfs.v9i4.16907 ]