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COACHING & EXERCISE PHYSIOLOGY

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Beetroot extract improves specific performance and oxygen uptake in taekwondo athletes: A double-blind crossover study

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Key words: martial arts, aerobic exercise, sports performance, dietary supplement

Abstract

Background. Nitrate-rich supplements such as beetroot extract could improve aerobic performance by increasing neuromuscular functioning. However, little is known about the effects of beetroot extract on combat sports, such as taekwondo.

Problem and aim. This study investigated the acute effect of beetroot extract supplementation (1g) on taekwondo athletes undergoing a maximal aerobic test.

Methods. Twelve athletes (26.8±8.8 yrs.; 77.8±11.7 kg; 1.8±0.1 m; 25.3±3.2 kg/m^2; 10.0±5.3 Fat%) were submitted to a specific Taekwondo aerobic protocol. All participants performed an alternated kick (*bandal-chagi*) maximal protocol under two randomized conditions: a) beetroot extract; and b) Placebo.

Results. Beetroot condition showed a higher absolute VO_{2Peak} (4.0±0.6 vs. 3.6±0.5 L/min; p=0.048), absolute VO_{2max} at anaerobic threshold (3.7±0.6 vs. 3.2±0.6 L/min; p=0.044), and complete stages (10.9±2.6 vs. 8.3±1.7 L/min; p=0.009). Lactate concentration increased significantly between measurements taken before, after and 3 min after (p≤0.001) the test, without differences between conditions (p=0.46).

Conclusion. Our results suggest an ergogenic effect of beetroot extract supplementation (1 g) on aerobic capacity and specific test performance in taekwondo athletes.

Introduction

Similar to other combat sports, Olympic taekwondo is characterized by intermittent effort [Miarka *et al.* 2018] where high-intensity actions are those which punctuate or define combat [Miarka *et al.* 2018; Tornello *et al.* 2013]. However, creatine phosphate resynthesis occurs during low-intensity actions in which aerobic metabolism predominates [Kons *et al.* 2019] in order to be used for the next high-intensity action. Thus, it is essential that the athlete presents high aerobic capacity for high performance [Sant'Ana *et al.* 2018]. In a review, Ouergui *et al.* [2015] indicated that most studies point to the predominance of aerobic metabolism during taekwondo combat, However, few studies have been conducted regarding energy demand in this combat sport. According to Campos *et al.* [2012], approximately 66% of energy comes from aerobic metabolism.

A high aerobic capacity (VO_{2max}) enables an athlete to recover better in the intervals between rounds and during low-intensity actions [Lopes-Silva *et al.* 2015]. In this sense, an increase in endurance is essential when aiming to improve athletic performance. Taekwondo athletes' endurance can be enhanced by a nutritional ergogenic supplement [Stebbins 2016]. However, few studies have been conducted in this combat sport with this focus. Lopes-Silva *et al.* [2015] observed that caffeine supplementation (5 mg/kg) did not increase the VO_2, oxidative capacity, or performance in a combat simulation (3 rounds, 2 min X 1 min interval). Thus, it is relevant to carry out new studies focused on ergogenic supplements which can improve aerobic performance in taekwondo.

Nitrate (NO_3^-) is one of the possible supplements which can improve endurance in taekwondo athletes [Stebbins 2016]. A meta-analysis performed by McMahon *et al.* [2017] indicated that supplementation of NO_3^- rich nutrients resulted in improved aerobic performance, mainly in time-to-exhaustion. The ergogenic effect is associated with lower O_2 spent during exercise [Christensen *et al.* 2013], increased muscle deoxyhemoglobin [Breese *et al.* 2013], higher muscle efficiency for phosphocreatine resynthesis [Bailey *et al.* 2010] and vasodilation from nitric oxide production [Zafeiridis 2014]. Beetroot is among the richest foods with the highest NO_3^- concentration [Breese *et al.* 2013]. Beetroot juice has shown an ergogenic effect in some studies but failed in others [McMahon *et al.* 2017; Zafeiridis 2014]. Using a single dosage (140 ml, ~8.7 mmol NO_3^-) of beetroot juice Cermak *et al.* [2012] observed an increase in plasma nitrate concentration in cyclists, however, there was no difference compared to placebo for the 1h-time-trial and power output. However, the same dosage when ingested for six consecutive days resulted in an ergogenic effect in cyclists who exercised until failure [Lansley *et al.* 2011]. In general, studies have focused on beetroot juice supplementation [McMahon *et al.* 2017; Zafeiridis 2014], little is known about the effect of concentrated beetroot extract on sports performance. After an extensive search, we did not find scientific studies that have investigated the use of beetroot extract in athlete performance. Given the above, this study aims to investigate the effect of acute supplementation of beetroot extract (1g) on taekwondo athletes submitted to progressive maximal testing. To the best of our knowledge, this study has an original question regarding the possible ergogenic effect of beetroot extract supplementation on: a) a maximum taekwondo test; and b) spirometric variables measured during the test. We hypothesized that acute supplementation promoted an ergogenic effect on test performance and spirometric measurements.

Methods

Experimental approach and participants

This cross-sectional study implemented a randomized, double-blind crossover design to investigate the supplementation of beetroot extract in taekwondo athletes. To do so, athletes were measured under two conditions: a) Beetroot extract, or b) Placebo. The experiment was divided into two days. On the first day, half of the participants were randomized to the Beetroot intake or the other Placebo, and then their conditions were reversed on the second day of the experiment (4-days after first test). All participants were initially informed of the procedures to be followed in the study and signed a free and informed consent form following the 1964 Helsinki statement. The ethics committee of the University in which the experiment was conducted approved this study (protocol 4072649).

After analyzing specific literature [Breese *et al.* 2013; Callahan *et al.* 2017; Zafeiridis 2014], we estimated a minimal sample size based on the VO_{2peak}. We calculated a minimum sample of 11 participants to reach a 0.3L/min when comparing the conditions in order to achieve 80% statistical power (5.2 Granmo, IMIM, Barcelona, Spain). The subjects were required to meet the following inclusion criteria in order to be eligible for this study: a) being male; b) being a taekwondo athlete; c) ≥18 yrs.; d) training ≥3 x per week; e) no consumption of any supplements or drugs; f) no history of using medications which could alter the hypothalamic-pituitary-gonadal (HPG) axis, such as anabolic steroids; g) no history of chronic disease, bronchospasm or atopy; h) no respiratory infections during the previous month; and i) no recognized asthma or allergy during the 3 years preceding the study. All participants were instructed by a nutritionist to maintain their habitual diet. The subjects were excluded if they: a) did not complete the entire protocol; b) had a problem during data collection; or c) did not reach the maximum on the testing. Thus, 20 athletes were invited to participate in this study, and 13 of them accepted, however, one was excluded due to errors during achieved the spirometric data. Therefore, the final sample consisted of 12 male athletes (26.8±8.8 yrs.; 77.8±11.7 kg; 1.8±0.1 m; 25.3±3.2 kg/m^2; 10.0±5.3 Fat%).

Test Procedures

Participants were separately randomized and instructed to perform a 2-hour fasting before data collection. Next, 1g of Beetroot extract (Nature's Way®, Green Bay, USA) or 1g of Placebo (dextrose) was consumed in capsules (double-blind), followed by a standard snack consisting of a medium-sized apple, chocolate milk, two slices of bread and two slices of ham (~430 Kcal). All conditions were packed in identical capsules. An independent researcher was involved and he/she was the only one who knew the processing order and the exact nature of the capsules.

After the anthropometry was performed, we measured body weight (Welmi® 104A Scale, SP, Brazil), height (Auturexata® Stadiometer, SP, Brazil) and skinfold thickness (Cescorf® caliper, SP, Brazil). We applied the seven-fold equations of Jackson and Pollock [1978] and Siri equation [Johnson 1996] to estimate the fat percentage.

Spirometric variables were measured during the Progressive Specific Taekwondo Test (PSTT), a specific test for Taekwondo athletes validated with the incremental treadmill test (r=0.86) by Sant'Ana *et al.* [2019]. It is a progressive test to exhaustion and the participants were familiarized with the PSTT and respective movements. The test was performed in an area of 2x2 meters and consisted of alternately kicking (*Bandal-tchagui*) a punching bag (height between the navel and nipples). The participant must remain in step (combat stance hopping) during the test. Six alternate kicks are performed (starting with the right leg) in the first stage, and then four kicks are added in each completed stage. An application developed for the test was used (ITSriker, ETS4.ME, Brazil) for intensity control. The test was interrupted when: a) the frequency of kicks was not maintained; b) they did not reach the mark determined on the punching bag; or c) they voluntarily stopped. Participants were advised to avoid exercise and refrain from caffeine and alcohol consumption 48 h before the experiment. Moreover, participants were instructed to maintain their regular dietary habits. The experimental protocol was carried out at an ambient temperature of 25°C.

The spirometer was calibrated before each test according to the manufacturer's indications (breath-to-breath gas analyzer, Metalyzer 3BR2, Cortex®, Leipzig, Germany). The following criteria described by Laursen *et al.* [2002] were followed for a test to be considered as maximum: a) Blood lactate ≥8.0 $mmol \cdot L^{-1}$ (Accutrend Plus, Roche®, Rotkreuz, Switzerland); b) respiratory exchange ratio (RER) >1.1; and c) heart rate (HR) > 90% of predicted (Polar®, RS800, Kempele, Finland). Figure 1 shows a chart of test procedures.

Spirometric measures were calculated after the test. The exported software spreadsheet was analyzed for each participant, and the outliers were removed every 15 s of measurement. VO_{2Peak} (absolute and relative) was the highest value observed at each of these intervals according to Sant'Ana *et al.* [2019]. VE/VO_2 and VE/VCO_2 were calculated according to Baba *et al.* [1996]. VO_2 at anaerobic threshold (AT) absolute and relative was calculated by the V-slope method according to Schneider *et al.* [1993].

Statistical analysis

We initially performed exploratory data to identify and correct extreme values. Normality and homoscedasticity were tested by the Kolmogorov-Smirnov test and by the Bartlett criterion, respectively. The two-way repeated measure ANOVA was applied to establish the difference for blood lactate and HR (for these variables we measured the isolated effect of the supplement, moment of measurement and interaction of supplement and moment of measurement). The Mauchly sphericity test was implemented (the Greenhouse-Geisser correction was used when necessary) for validating the repeated measurements. The post-hoc Bonferroni test was adopted when a significant difference was observed in ANOVA. The paired T-test was used for the other variables. Furthermore, the Eta squared (η^2) was calculated as effect size for ANOVA, presenting 0.01 (small), 0.09 (medium) and 0.25 (large). Cohen's d was also used to estimate the magnitude of the effect for the T-test, presenting 0.1 (small), 0.3 (medium) and 0.5 (large). Lastly, $p \leq 0.05$ significance level was adopted in all analyzes, and all analyses were performed with the Statistical Package for the Social Sciences (version 20.0, Chicago, IL, USA).

Results

The variables AT and RER presented 2 outliers each, for these the extreme values were replaced by the mean. Table 1 shows the results for spirometry and complete stages in the effort test. There was a difference between

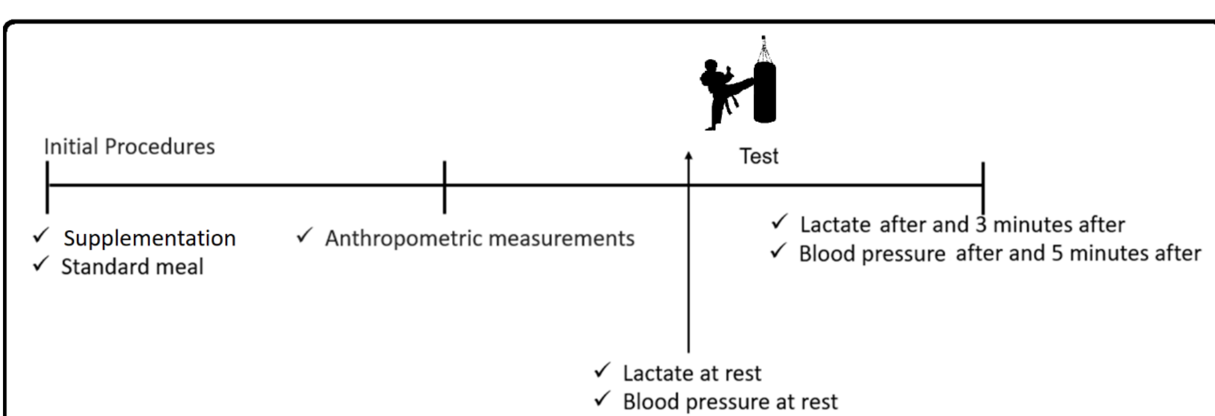

Figure 1. Procedures followed during Beetroot and Placebo tests.

Table 1. Results for spirometry variables and total stages completed by Beetroot and Placebo conditions.

Variable	Condition	Mean ± standard deviation	Statistic	Effect size
VO_{2Peak} (L/min)	Beetroot	4.0±0.6*	t=2.093; p=0.048	0.39
	Placebo	3.6±0.5		
VO_{2Peak} (mL/kg·min)	Beetroot	52.3±7.0	t=1.651; p=0.116	0.32
	Placebo	46.8±9.4		
Anaerobic threshold (L/min)	Beetroot	3.7±0.6*	t=2.136; p=0.044	0.39
	Placebo	3.2±0.6		
Anaerobic threshold (mL/kg·min)	Beetroot	47.9±5.1	t=1.99; p=0.059	0.38
	Placebo	43.2±6.3		
VE/VO_2/AT(mL/kg·min)	Beetroot	35.4±4.9	t=0.324; p=0.749	0.06
	Placebo	34.7±6.5		
VE/VCO_2/AT (mL/kg·min)	Beetroot	29.7±3,1	t=0.634; p=0.81	0.04
	Placebo	30.0±3.5		
RER Final Stage (a.u)	Beetroot	1.3±0.2*	t=0.388; p=0.609	0.05
	Placebo	1.3±0.3		

AT – anaerobic threshold. RER – respiratory exchange ratio. * p≤ 0.048 vs. PLA.

groups for the absolute VO_{2Peak} (p=0.048) and VO_2 at the anaerobic threshold (p=0.044) with a large effect size.

Figure 2 shows the results for complete stages for each condition; there was a difference between groups (p=0.009).

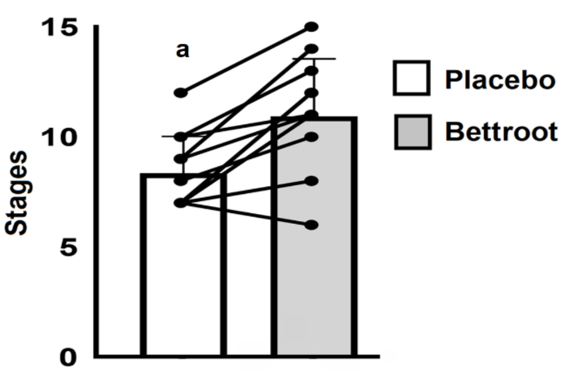

Figure 2. The final stage for Placebo (white bar) and Beetroot extract (gray bar). [a] p=0.009 vs. Beetroot.

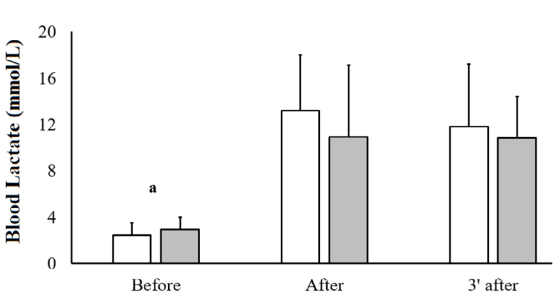

Figure 3. Blood lactate before, after, and 3minutes after the test, [a] p≤0.001 for this moment of measurement vs the others.

There was an isolated effect for the moment of measurement for the HR, with a large effect size ($F_{1,48}$=5.24; p≤0.001; η^2=0.6), where the means measured before were statistically lower compared to those after (106.4±5.4 and 104.0±5.9 vs. 204.6±5.6 and 205.6±6.5 BPM for Placebo and Beetroot before and after the test). All criteria considered for a test to be maximum were achieved. Figure 3 shows the results for blood lactate before the test, after and 3 minutes after the test. There was an isolated effect of the moment of measurement with a large effect size ($F_{1,72}$=52.515; p≤0.001; η^2=0.705), where the means observed before were statistically lower than those observed after and 3 minutes after (p≤0.001 for both comparisons).

Discussion

Due to the importance of aerobic metabolism for taekwondo athletes, supplements which increase aerobic capacity may result in better athletic performance [Lopes-Silva *et al.* 2015]. Thus, the present study investigated the effect of beetroot on the performance of athletes submitted to a specific maximal aerobic test. The main results indicated that the Beetroot condition presented a higher absolute VO_{2Peak} and VO_2 at AT. Furthermore, only one athlete (Figure 2) completed lower number of stages in the Beetroot condition compared to the Placebo. To the best of our knowledge, this is the first study with this research focus; although in a review study, Stebbins [2016] suggests there is an ergogenic effect of nitrate supplementation in taekwondo athletes, however, no article that directly investigated the effect in this combat sport was revised. Nonetheless, an ergogenic effect has been previously demonstrated in predominantly aerobic sports [Christensen *et al.* 2013; McMahon *et* *al.* 2017] and in intermittent exercise [Wylie *et al.* 2016; Wylie *et al.* 2013].

This study verified the sample size in order to minimize the bias associated with this data collection, controlling the data with a randomized, double-blind, placebo-controlled trial to minimize possible external factors. The observed results agree with a systematic review (nine papers) by Wylie *et al.* [2016], who observed that Beetroot supplementation may result in better performance in intermittent exercises by delaying the onset of fatigue and increased muscle power, but the mechanisms are poorly understood. The primary ergogenic mechanism of beetroot is associated with a large amount of NO_3^- per gram [Ormsbee *et al.* 2013]. NO_3^- improves aerobic performance via the organic conversion of this compound to nitric oxide (NO). NO acts as a vasodilator by increasing blood flow [Maiorana *et al.* 2003], which indirectly increases the oxygen supply to the muscle during exercise [Breese *et al.* 2013]. In addition, NO_3^- is effective in reducing the cost of muscle O_2 and ATP in submaximal exercises via increased mitochondrial production of esterified phosphate radicals, especially in type II fibers [Breese *et al.* 2013; Larsen *et al.* 2011]. Breese *et al.* [2013] observed that six days of supplementation with beetroot juice (140 ml/day) increased the kinetics of pulmonary and muscle VO_2. Our results indicate that this effect also occurred in supplemented athletes, as we observed a higher consumption of O_2 at the anaerobic threshold.

Despite numerous studies proving the effectiveness of Beetroot intake in VO_2 [Campos *et al.* 2012; Lopes-Silva *et al.* 2015; Ormsbee *et al.* 2013; Sant'Ana *et al.* 2018], the results of studies directly related to sports performance are inconsistent [McMahon *et al.* 2017]. This result is possibly associated with the heterogeneity of factors that interfere with sports performance [D'Isanto *et al.* 2019]. The heterodox characteristics of sports performance can also be seen in taekwondo athletes [Moreira *et al.* 2014], thus, even if there is an ergogenic effect of the supplement, the combat performance can be affected by technical or psychological barriers. In fact, two studies with supplementation in taekwondo showed opposite results in performance, caffeine [Lopes-Silva *et al.* 2015] and sodium bicarbonate [Lopes-Silva *et al.* 2018] improve the glycolytic metabolism, but only sodium bicarbonate increases the performance during combat.

Few studies investigated the effect of beetroot supplementation in intermittent exercises. Possibly, ergogenic effects are associated with the vasodilator capacity of nitric oxide and higher creatine phosphocreatine resynthesis [Dominguez *et al.* 2018], since, the deficiency of O_2 supply results in a lower muscle creatine resynthesis [McMahon, Jenkins 2002]. In team sports athletes who performed intermittent sprints on a cycloergometer, Wylie *et al.* [2013] observed an ergogenic effect (70mL, 8.2 mmol NO_3^-) only in very short sprints (24 x 6s) vs. short sprints (7 x 30s and 6 x 60s). Williams *et al.* [2020] observed an increase in power, velocity and performance until failure in the bench press (28.0±5.6 vs. 30.6± 5.8 reps.). In a systematic review (9 papers), Dominguez *et al.* [2018] observed that single or repeated doses tend to increase the work output in intermittent exercises, but the ergogenic mechanisms are speculative. In combat sports specifically, which also have the main characteristic of intermittence [Miarka *et al.* 2018], no study to the best of our knowledge has tested this type of supplementation.

An important result of the present study was the better performance test in the beetroot condition (Figure 2). This result is in agreement with other studies that showed the ergogenic effect of beet in efforts until failure [Breese *et al.* 2013; Callahan *et al.* 2017; McMahon *et al.* 2017; Ormsbee *et al.* 2013]. Recently, Cocksedge *et al.* [2020] observed in 10 healthy male subjects undergoing moderate submaximal exercise, that beetroot juice (210 mL, 18.6 mmol NO_3^-) increases the transport of O_2 to the muscle under hypoxia condition, without improving physical performance. Similarly, Breese *et al.* [2013] observed an increase of 22% in the kinetics rate of deoxyhemoglobin in exercise until failure, when compared six days of supplementation (140 ml~ 8mmol of NO_3^-) versus placebo, but the same did not occur in submaximal exercise. Therefore, we hypothesized that the difference between the Placebo and Beetroot observed in our study is related to the higher capacity to use oxygen in the final stages of the test, thus increasing the resynthesis capacity of muscle phosphocreatine [Bailey *et al.* 2010].

Our results for the lactate showed only a significant effect of the moment of measurement. The effect of supplementation on blood lactate is unclear. Our results are in agreement with others previously published [Bond *et al.* 2012; Wylie *et al.* 2013]. In a study with sport team athletes, 490 mL (8.2 mmol NO_3^-) beetroot juice resulted in a higher performance in the Yo-Yo test [Wylie *et al.* 2013]. However, other studies have found an ergogenic effect of supplementation, especially in the final stages of exercise [Dominguez *et al.* 2017; Wylie *et al.* 2016]. Possibly, vasodilation from supplementation may increase the speed of lactate buffering [Wylie *et al.* 2016], thus, it is expected that the increased blood flow to the type II fibers will result in an increased strength close to fatigue [Williams *et al.* 2020]. We believe that further studies are needed to clarify the effect of supplementation on blood lactate, as there are studies, with a single dosage [Dominguez *et al.* 2017], or multiple dosages [Wylie *et al.* 2016], that show ergogenic effects. However, the mechanisms are speculative.

The protocol adopted in the present study is one of the first to use beetroot extract, however, Callahan *et al.* [2017] previously observed an increased NO_3^- buffer in cyclists supplemented with beetroot crystals (300 mg) and sodium bicarbonate (0.3 g/kg), but there was no difference in performance when submitted to 4 km Time Trial. There was a difference between the total activity time, where the study mentioned the athletes performed approximately 5 min of effort (~338 s), whereas the athletes in the beetroot condition in our protocol performed about 11 stages (~800 s). Thus, the ergogenic effect of supplementation possibly demands longer physical stimulation time. In this line, the metanalysis by McMahon *et al.* [2017] on nitrate supplementation and performance indicated that time trial tests generally have no beneficial effect by supplementation, but tests up to exhaustion tend to have a beneficial effect from beetroot (ES=0.33, 95%CI = 0.15–0.5, p≤0.01). Specifically, for taekwondo supplementation benefits can be obtained under training and competition conditions. Official matches are disputed in 3 rounds of 2 min. with 1 min. interval [Bridge *et al.* 2014], in addition, in the world championship it is necessary to win 5 combats to be champion. Thus, the athlete's ability to recover between rounds and combats is very important. In this sense, the use of supplementation, as it shows an ergogenic effect regarding the improvement of aerobic capacity, can assist the athlete in moments of recovery and also increase performance in moments close to fatigue. In addition, ergogenic effects are also observed in high-intensity efforts [Dominguez *et al.* 2018; Wylie *et al.* 2016] and muscle power [Williams *et al.* 2020], thus, the ergogenic effect can benefit during the competition, as the athlete will perform more strikes at high power.

We believe that future studies can test this supplementation protocol in training or competition models. We also observed in the literature the absence of studies with female athletes. We also recommend measuring NO_3^- concentration, which was a limitation of the present study. The results of studies have been consistent in showing an ergogenic effect in healthy subjects [McMahon *et al.* 2017] and athletes [Dominguez *et al.* 2018]. However, in highly trained athletes, studies have failed to show the benefits of NO_3^- [Bourdillon *et al.* 2015; MacLeod *et al.* 2015; Nyback *et al.* 2017]. Our study was carried out in regional level athletes, we also recommend for future studies, to test if the ergogenic effects also occur in high-level taekwondo athletes. Finally, this was the first study to use beetroot capsules, we chose to use the dosage indicated by the manufacturer of the supplement. However, we do not know the amount of NO_3^- in each capsule. The absence of this measure should be interpreted as a limitation.

Conclusion

Through the established aims and applied methods in this study, we concluded that the supplementation of 1g of beetroot increased the O_2 uptake in taekwondo athletes submitted to a maximum aerobic test.

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References

1. Baba R., Nagashima M., Goto M., Nagano Y., Yokota M., Tauchi N., Nishibata K. (1996), *Oxygen uptake efficiency slope: a new index of cardiorespiratory functional reserve derived from the relation between oxygen uptake and minute ventilation during incremental exercise*, "Journal of the American College of Cardiology", vol. 28, no. 6, pp. 1567-1572.
2. Bailey S.J., Fulford J., Vanhatalo A., Winyard P.G., Blackwell J.R., DiMenna F.J., Wilkerson D.P., Benjamin N., Jones A.M. (2010), *Dietary nitrate supplementation enhances muscle contractile efficiency during knee-extensor exercise in humans*, "Journal of Applied Physiology", vol. 109, no. 1, pp. 135-148.
3. Bond H., Morton L., Braakhuis A.J. (2012), *Dietary nitrate supplementation improves rowing performance in well-trained rowers*, "International Journal of Sport Nutrition and Exercise Metabolism", vol. 22, no. 4, pp. 251-256.
4. Bourdillon N., Fan J.-L., Uva B., Muller H., Meyer P., Kayser B. (2015), *Effect of oral nitrate supplementation on pulmonary hemodynamics during exercise and time trial performance in normoxia and hypoxia: a randomized controlled trial*, "Frontiers in Physiology", vol. 6, no., pp. 288.
5. Breese B.C., McNarry M.A., Marwood S., Blackwell J.R., Bailey S.J., Jones A.M. (2013), *Beetroot juice supplementation speeds O2 uptake kinetics and improves exercise tolerance during severe-intensity exercise initiated from an elevated metabolic rate*, "American Journal of Physiology-Regulatory, Integrative and Comparative Physiology", vol. 305, no. 12, pp. R1441-R1450.
6. Bridge C.A., da Silva Santos J.F., Chaabene H., Pieter W., Franchini E. (2014), *Physical and physiological profiles of taekwondo athletes*, "Sports Medicine", vol. 44, no. 6, pp. 713-733.
7. Callahan M.J., Parr E.B., Hawley J.A., Burke L.M. (2017), *Single and combined effects of beetroot crystals and sodium bicarbonate on 4-km cycling time trial performance*, "International Journal of Sport Nutrition and Exercise Metabolism", vol. 27, no. 3, pp. 271-278.
8. Campos F.A.D., Bertuzzi R., Dourado A.C., Santos V.G.F., Franchini E. (2012), *Energy demands in taekwondo athletes during combat simulation*, "European Journal of Applied Physiology", vol. 112, no. 4, pp. 1221-1228.
9. Cermak N.M., Res P., Stinkens R., Lundberg J.O., Gibala M.J., Van Loon L.J. (2012), *No improvement in endurance performance after a single dose of beetroot juice*, "International Journal of Sport Nutrition and Exercise Metabolism", vol. 22, no. 6, pp. 470-478.

10. Christensen P.M., Nyberg M., Bangsbo J. (2013), *Influence of nitrate supplementation on VO2 kinetics and endurance of elite cyclists*, "Scandinavian Journal of Medicine & Science in Sports", vol. 23, no. 1, pp. e21-e31.
11. Cocksedge S.P., Breese B.C., Morgan P.T., Nogueira L., Thompson C., Wylie L.J., Jones A.M., Bailey S.J. (2020), *Influence of muscle oxygenation and nitrate-rich beetroot juice supplementation on O2 uptake kinetics and exercise tolerance*, "Nitric Oxide", vol. 99, pp. 25-33.
12. D'Isanto T., D'Elia F., Raiola G., Altavilla G. (2019), *Assessment of sport performance: Theoretical aspects and practical indications*, "Sport Mont", vol. 17, no. 1, pp. 79-82.
13. Dominguez R., Garnacho-Castano M.V., Cuenca E., Garcia-Fernandez P., Munoz-Gonzalez A., De Jesus F., Lozano-Estevan M.D.C., Fernandes da Silva S., Veiga-Herreros P., Mate-Munoz J.L. (2017), *Effects of beetroot juice supplementation on a 30-s high-intensity inertial cycle ergometer test*, "Nutrients", vol. 9, no. 12, pp. 1360.
14. Dominguez R., Mate-Munoz J.L., Cuenca E., Garcia-Fernandez P., Mata-Ordonez F., Lozano-Estevan M.C., Veiga-Herreros P., da Silva S.F., Garnacho-Castano M.V. (2018), *Effects of beetroot juice supplementation on intermittent high-intensity exercise efforts*, "Journal of the International Society of Sports Nutrition", vol. 15, no. 1, pp. 2.
15. Jackson A.S., Pollock M.L. (1978), *Generalized equations for predicting body density of men*, "British Journal of Nutrition", vol. 40, no. 3, pp. 497-504.
16. Johnson R.W. (1996), *Fitting percentage of body fat to simple body measurements*, "Journal of Statistics Education", vol. 4, no. 1, pp. 1-8.
17. Kons R.L., Orssatto L.B., Detanico D. (2019), *Acute performance responses during repeated matches in combat sports: A systematic review*, "Journal of Science and Medicine in Sport", vol. 23, no. 5, pp. 512-518.
18. Lansley K.E., Winyard P.G., Bailey S.J., Vanhatalo A., Wilkerson D.P., Blackwell J.R., Gilchrist M., Benjamin N., Jones A.M. (2011), *Acute dietary nitrate supplementation improves cycling time trial performance*, "Medicine & Science in Sports & Exercise", vol. 43, no. 6, pp. 1125-1131.
19. Larsen F.J., Schiffer T.A., Borniquel S., Sahlin K., Ekblom B., Lundberg J.O., Weitzberg E. (2011), *Dietary inorganic nitrate improves mitochondrial efficiency in humans*, "Cell Metabolism", vol. 13, no. 2, pp. 149-159.
20. Laursen P.B., Shing C.M., Peake J.M., Coombes J.S., Jenkins D.G. (2002), *Interval training program optimization in highly trained endurance cyclists*, "Medicine & Science in Sports & Exercise", vol. 34, no. 11, pp. 1801-1807.
21. Lopes-Silva J.P., Da Silva Santos J.F., Artioli G.G., Loturco I., Abbiss C., Franchini E. (2018), *Sodium bicarbonate ingestion increases glycolytic contribution and improves performance during simulated taekwondo combat*, "European journal of sport science", vol. 18, no. 3, pp. 431-440.
22. Lopes-Silva J.P., da Silva Santos J.F., Branco B.H.M., Abad C.C.C., de Oliveira L.F., Loturco I., Franchini E. (2015), *Caffeine ingestion increases estimated glycolytic metabolism during taekwondo combat simulation but does not improve performance or parasympathetic reactivation*, "PLoS one", vol. 10, no. 11, pp. e0142078.
23. MacLeod K.E., Nugent S.F., Barr S.I., Koehle M.S., Sporer B.C., MacInnis M.J. (2015), *Acute Beetroot Juice Supplementation Does Not Improve Cycling Performance in Normoxia or Moderate Hypoxia*, "International Journal of Sport Nutrition and Exercise Metabolism", vol. 25, no. 4, pp. 359; doi: 10.1123/ijsnem.2014-0129.
24. Maiorana A., O'Driscoll G., Taylor R., Green D. (2003), *Exercise and the nitric oxide vasodilator system*, "Sports Medicine", vol. 33, no. 14, pp. 1013-1035.
25. McMahon N.F., Leveritt M.D., Pavey T.G. (2017), *The effect of dietary nitrate supplementation on endurance exercise performance in healthy adults: a systematic review and meta-analysis*, "Sports Medicine", vol. 47, no. 4, pp. 735-756.
26. McMahon S., Jenkins D. (2002), *Factors affecting the rate of phosphocreatine resynthesis following intense exercise*, "Sports Medicine", vol. 32, no. 12, pp. 761-784.
27. Miarka B., Brito C.J., Moreira D.G., Amtmann J. (2018), *Differences by ending rounds and other rounds in time-motion analysis of mixed martial arts: implications for assessment and training*, "The Journal of Strength & Conditioning Research", vol. 32, no. 2, pp. 534-544.
28. Moreira P.V.S., Crozara L.F., Goethel M.F., de Paula L.V., Vieira F. (2014), *Talent detection in taekwondo: which factors are associated with the longitudinal competitive success?*, "Archives of Budo", vol. 10, pp. 295-306.
29. Nyback L., Glannerud C., Larsson G., Weitzberg E., Shannon O.M., McGawley K. (2017), *Physiological and performance effects of nitrate supplementation during roller-skiing in normoxia and normobaric hypoxia*, "Nitric Oxide", vol. 70, no., pp. 1-8.
30. Ormsbee M.J., Lox J., Arciero P.J. (2013), *Beetroot juice and exercise performance*, "Nutrition and Dietary Supplements", vol. 5, pp. 27-35.
31. Ouergui I., Haddad M., Padulo J., Bouhlel E., Behm D. (2015), *Physiological Responses to Taekwondo Competition and Specific Training* [in:] M. Haddad [ed.], *Performance Optimization in Taekwondo: From Laboratory to Field* (vol. 1), Omics Group, Foster City, pp. 1-9.
32. Sant'Ana J., Franchini E., Murias J.M., Diefenthaeler F. (2019), *Validity of a Taekwondo-Specific Test to Measure VO2peak and the Heart Rate Deflection Point*, "The Journal of Strength & Conditioning Research", vol. 33, no. 9, pp. 2523-2529.
33. Sant'Ana J., Franchini E., Sakugawa R.L., Diefenthaeler F. (2018), *Estimation equation of maximum oxygen uptake in taekwondo specific test*, "Sport Sciences for Health", vol. 14, no. 3, pp. 699-703.
34. Schneider D.A., Phillips S.E., Stoffolano S. (1993), *The simplified V-slope method of detecting the gas exchange threshold*, "Medicine and Science in Sports and Exercise", vol. 25, no. 10, pp. 1180-1184.
35. Stebbins C.L. (2016), *Dietary Nitrate Supplementation and Exercise Performance: Implications for Taekwondo Athletes*, "Acta Taekwondo et Martialis Artium", vol. 3, no. 1, pp. 1-10.

36. Tornello F., Capranica L., Chiodo S., Minganti C., Tessitore A. (2013), *Time-motion analysis of youth Olympic Taekwondo combats*, "The Journal of Strength & Conditioning Research", vol. 27, no. 1, pp. 223-228.
37. Williams T.D., Martin M.P., Mintz J.A., Rogers R.R., Ballmann C.G. (2020), *Effect of Acute Beetroot Juice Supplementation on Bench Press Power, Velocity, and Repetition Volume*, "The Journal of Strength & Conditioning Research", vol. 34, no. 4, pp. 924-928.
38. Wylie L.J., Bailey S.J., Kelly J., Blackwell J.R., Vanhatalo A., Jones A.M. (2016), *Influence of beetroot juice supplementation on intermittent exercise performance*, "European Journal of Applied Physiology", vol. 116, no. 2, pp. 415-425.
39. Wylie L.J., Mohr M., Krustrup P., Jackman S.R., Ermıdis G., Kelly J., Black M.I., Bailey S.J., Vanhatalo A., Jones A.M. (2013), *Dietary nitrate supplementation improves team sport-specific intense intermittent exercise performance*, "European Journal of Applied Physiology", vol. 113, no. 7, pp. 1673-1684.
40. Zafeiridis A. (2014), *The effects of dietary nitrate (beetroot juice) supplementation on exercise performance: A review*, "American Journal of Sports Science", vol. 2, no. 4, pp. 97-100.

Ekstrakt z buraka ćwikłowego poprawia swoistą wydolność i pobór tlenu u zawodników taekwondo: Badanie typu crossover z podwójnie ślepą próbą

Słowa kluczowe: sztuki walki, ćwiczenia aerobowe, wydolność sportowa, suplement diety

Streszczenie

Wprowadzenie. Suplementy bogate w azotany, takie jak ekstrakt z buraka ćwikłowego, mogą poprawić wydolność aerobową poprzez zwiększenie funkcjonowania nerwowo-mięśniowego. Jednakże niewiele wiadomo na temat wpływu ekstraktu z buraka na sporty walki, takie jak taekwondo.

Problem i cel. W niniejszej pracy badano ostry efekt suplementacji ekstraktu z buraka ćwikłowego (1g) na zawodników taekwondo poddanych maksymalnemu testowi aerobowemu.

Metody. Dwunastu sportowców (26,8±8,8 lat; 77,8±11,7 kg; 1,8±0,1 m; 25,3±3,2 kg/m2; 10,0±5,3 Fat%) poddano szczegółowemu protokołowi aerobowemu taekwondo. Wszyscy uczestnicy wykonywali naprzemienny protokół maksymalnych kopnięć (*bandal-chagi*) w dwóch randomizowanych warunkach, pod wpływem: a) ekstraktu z buraka; oraz b) placebo.

Wyniki. Przy zastosowanie ekstraktu z buraka zanotowano wyższą bezwzględną wartość VO_{2Peak} (4,0±0,6 vs. 3,6±0,5 L/min; p=0,048), bezwzględną wartość VO_{2max} na progu beztlenowym (3,7±0,6 vs. 3,2±0,6 L/min; p=0,044) oraz całkowite/zakończone etapy (10,9±2,6 vs. 8,3±1,7 L/min; p=0,009). Stężenie mleczanów wzrastało istotnie pomiędzy pomiarami wykonanymi przed, po i 3 min po (p≤0,001) teście, bez różnic pomiędzy warunkami (p=0,46).

Wnioski. Uzyskane wyniki sugerują ergogeniczny wpływ suplementacji ekstraktu z buraka ćwikłowego (1 g) na wydolność tlenową i wyniki testów specjalnych u zawodników taekwondo.