The effect of organic beetroot and black currant supplementation on adolescent female handball players' performance – pilot study

Bio cékla és fekete ribiszke szupplementáció hatása az utánpótláskorú kézilabdázók teljesítményére – előtanulmány

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Abstract

Athletes are under tremendous external mental pressure to improve their performance, which is materially leading to an increasing frequency of consumption of dietary supplements in elite sports, both in the adult and youth age groups. Adequate physical development of athletes, minimizing their health risks, and maintaining a clean playfulness in sports play are prerequisites for the safe performance optimization of junior athletes.

In our study, 14-17 years old, first-class classified adolescent and youth female handball players (n=12) with at least two years of sports training history were included. In the preparatory phase of the study, we measured their body composition (Inbody 720), handgrip strength and the participants performed a maxima type bicycle-ergometer load. The study was followed by a 10-day supplementation period with beet (n=8) and currant concentrate (n=4), after which the intervention effects were monitored by measuring their performance under the ergonomic load of the bicycle, measuring body composition and handgrip strength.

Formulations used in a double blind, placebo-controlled study were tested in an accredited laboratory for total polyphenol, nitrate and flavonoid content. The results before and after the intervention were compared with a one-sample *t*-test, the significance level was $p < 0.05$.

After 10 days of dietary supplementation, we found no difference in the relative muscle mass, relative fat mass, right handgrip strength of the participants in any of the groups studied. There was a significant increase in left handgrip strength in the currant concentrate group. There was no significant improvement in performance physiological parameters either. The low number of items and short-term supplementation have not been shown to be effective in improving the performance of female athletes.

Keywords: dietary supplement, beet concentrate, currant concentrate, antioxidant, performance enhancement

Összefoglaló

A sportolók teljesítménye és eredményessége számos tényező függvénye, így az étrend-kiegészítők fogyasztása jelentősen megnőtt az élsportban, a felnőtt és az utánpótlás korosztályban egyaránt. Az utánpótláskorú sportolók biztonságos teljesítményoptimalizálásának alapfeltétele az atléták megfelelő testi fejlődése, egészségi kockázatuk minimalizálása és a sportági játék tisztasági kívánalmának megőrzése.

Vizsgálatunkba 14-17 éves kor közötti, NB I. besorolású serdülő és ifi, legalább két év sportági edzésmúlttal rendelkező női kézilabdajátékos (n=12) került be. A vizsgálat előkészítő szakaszában megmértük testösszetételüket (Inbody 720), kézi szorítóerejüket, majd a résztvevők vita maxima típusú kerékpár-ergométeres terhelést végeztek. A vizsgálatot 10 napos cékla- (n=8), illetve ribiszkesűrítménnyel (n=4) történő szupplementációs periódus követte, majd az intervenciós hatásokat a kerékpár ergométeres terhelés alatt nyújtott teljesítményükkel, testösszetétel és szorítóerő méréssel monitoroztuk. A kettős vak, placebo kontrollált vizsgálati eljárásban alkalmazott készítmények akkreditált laborban

kerültek bevizsgálásra, összpolifenol-, nitrát-, és flavonoid tartalmukat tekintve. Az intervenció előtti és utáni eredményeket egymintás *t*-próbával hasonlítottuk össze, a szignifikanciaszint p<0,05 volt.

Szignifikánsan nőtt a bal kéz szorítóereje a ribiszkesűrítményt fogyasztó csoportban. Nem volt kimutatható szignifikáns javulás a teljesítményélettani paraméterekben. A 10 napos étrendkiegészítő alkalmazás után nem találtunk különbséget a résztvevők relatív izomtömegében, relatív zsírtömegében, valamint a jobb kéz szorítóerejében sem tapasztaltunk mérhető változást egyik vizsgált csoportban sem.

Az alacsony elemszám és a rövid ideig tartó szupplementáció is oka lehet annak, hogy nem sikerült szignifikáns változást kimutatni.

Kulcsszavak: étrend-kiegészítés, céklasűrítmény, ribiszkesűrítmény, antioxidáns, teljesítményfokozás

Introduction

Genetics, appropriate sports training methods, optimal body composition, age, psychosocial factors (e.g. stressors) and lifestyle, including nutrition, contribute to the athlete's success (Houston et al., 2011). The athletes are under tremendous external mental pressure to improve their performance, which is gradually leading to an increasing frequency of consumption of dietary supplements in elite sports, both in adult and youth age groups (Knapik et al., 2016).

In its 2018 consensus, the International Olympic Committee (IOC) described increased nitrate content in the diet as a high level, effective and safe dietary supplement (Maughan et al., 2018). The nitrate-nitrite-nitric oxide metabolic pathway improves the bioavailability of nitric oxide, which plays an important role in modulating skeletal muscle function. This performance enhancing effect is mainly in the Type II. muscle fibers (Bailey et al., 2015), which predominates in ball games, reduces ATP utilization, improves mitochondrial respiration efficiency, muscle blood supply and reduces oxygen utilization by increasing the expected onset time of muscle fatigue during physical performance at submaximal levels (Bailey et al., 2010).

Competitive handball is an alternating system of high intensity body to body team game, in which sports performance is aerobic and anaerobic provided through energy supply processes (Buchheit et al., 2009). For this reason, athletes also require explosiveness, endurance and speed force. Sources of nitrate include beet and celery from our root vegetables and spinach, lettuce, Chinese cabbage from our soup vegetables, which can accumulate larger amounts of inorganic nitrate in their tubers and leaves (McMahon et al., 2017). In sports physiology studies, beet juice, concentrate, gel or powder made mainly from beets (800-2 500 mg NO_3^-/kg) were used, which in addition to their favourable organoleptic properties, may result easier practical application due to the lower proportion of the required amount and constant market availability (Jonvik et al., 2018). Beets, in addition to be an available source of nitrate, also contain large amounts of betalaines that depend on antioxidant capability (Ormsbee et al., 2013). The length of the supplementation period varies in the studies, but several studies have reported positive results even after a 5-8 day supplementation period (Husmann et al., 2019; Nyakayiru et al., 2017; Olivera et al., 2018).

Previous studies have focused primarily on monitoring the performance of adult male athletes (Husmann et al., 2019; Nyakayiru et al., 2017; Porcelli et al., 2016.), with a negligible number of studies of adolescents (López-Samanes et al., 2020) and female subjects (Jonvik et al., 2018). So far, the performance of adolescent girls, especially handball players, in terms of consumption of beet or black currants supplementation has not been studied.

The aim of our study was to investigate the probable effect of short-time nitrate supplementation on anthropometric and performance diagnostic variables in adolescent handball players.

Material and Methods

Subjects

Elite adolescent handball players were studied based on a complex protocol. Only those athletes who play in an elite handball club and have been playing at least for three years in the sport could get in our sample. Female participants were included if they were: (a) not currently consuming beetroots or red berries; (b) 14-18 years of age (c) non-smoking, (d) free of any known cardiovascular, respiratory, metabolic or musculoskeletal diseases, and (e) were not consuming any other supplements or ergogenic aids. Participants were asked not to changed their diet during the procedures. Before cycling ergometer test, all participants were asked to avoid caffeine for 12 hours, eating 2 hours and alcohol and exercise for 24 hours. All investigation were performed at the same time of day, in the same place (University of Physical Education, Department of Health Sciences and Sport Medicine, Performance Laboratory). 21 youth athletes were included in our sample, however, due to incomplete fulfillment of the study protocol, we had to exclude 9 athletes before the end of the test method. All subjects (n=12) came from a sports association in Budapest. The reported descriptive data and subsequent statistical analyses do not include data on dropped out athletes.

The study was conducted in accordance with the Declaration of Helsinki for Human Research. The youth participated exclusively as volunteers. For each participant, written consent was given by one of their parents and collected before the study. All participants and their parents received written information about the goal of the survey and the procedures. Data management was conducted anonymously.

Ethical approval was obtained from the ethical committee of the University of Physical Education, Hungary (ID:TE-KEB/No29/2019).

Supplementations

850-850 mL of syrupy consistency supplements were prepared from 1 000 g of organic beet powder and 1 000 g organic blackcurrant powder (Origin: GPS Powder Élelmiszer-feldolgozó Kft., Budapest). The nitrate content of the supplements was determined with spectrophotometric procedure. The limit of quantitation was 1.0 μg/mL NO_3^-. The nitrate content was 18 μg for one scoop beetroot syrup and 28.3 μg for one scoop black currant syrup. One portion per day was 4 scoops. The polyphenol content of the supplements was also determined spectrophotometrically. The amount of the polyphenols in beetroot supplementation was 30.68±0.64 mmol GAE/L and 188.07±4.9 mmol GAE/L in black currant syrup. The total antioxidant potential of the samples was determined using the ferric reducing ability of plasma FRAP assay. The stronger antioxidant property was in black currant syrup (167.2±1.7 mmol AAE/L). In beetroot syrup this value was 16.28±0.19 mmol AAE/L. Analytical measurements of the supplements were performed in the laboratory of the Faculty of Food Science of Szent István University.

Experimental design

The subjects underwent a 10-day-long supplementation period in a randomized, double-blind design. All athletes were allowed to take over a bottle of supplement after performing pre-supplementation studies, with the type of supplement completed by a letter (“A” or “B”). Initially, nearly to the same number was included in the group of beet/ blackcurrant consumers, but the study protocol was not completed by 9 cases which randomly favoured the majority of the group consuming beet juice to a greater extent. 8 of the beet consumers (Group A) and 4 of the blackcurrant consumers (Group B) completed the full study protocol. The intake of the supplementation began on the day after the pre-intervention measurement. Only 1 person was aware of which athlete received which supplement. The consistency and colour of the concentrates were extremely similar. Each bottle was labelled with dosing and storage instructions. The supplement had to be stored in a refrigerator. The daily prescribed amount of the supplement was 4 scoops, each day at breakfast, which could be dissolved in 2-2.5 dl of water and freely sweetened. Before the supplementation period the baseline anthropometric characteristics were measured; (Inbody 720) and handgrip strength were performed to determine whole body and segmental data. After that we measured the endurance during a maximal intensity cycling exercise. Two-four hours after ingestion of the last supplemental dose (on the 10th supplementation day), subjects arrived to the laboratory for the second test day. On the second test day we measured the body composition with Inbody 720, the handgrip strength and their endurance with cycle ergometer. A resting blood pressure (OMRON M6 Comfort HEM-7223-E) and ECG measurement (MDE Diagnostics Cardiosys H-01) was performed before each ergometer test.

Anthropometry

Anthropometric measurements were taken according to the suggestions of the International Biological Program (Weiner and Lourie, 1981). The instruments were calibrated prior to use and all measurements were taken on the subjects’ right side. Anthropometric variables, including body mass, body height, seven skinfolds (biceps, triceps, subscapular, suprailiac, abdominal, thigh, and medial calf), two widths (elbow and knee), and seven girths (chest, upper arm, lower arm, wrist, ankle, thigh, calf) were measured using the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al., 2006).

Body height (BH) was measured with a stadiometer (model 214, Seca-Bodymorph, Birmingham, UK) to the nearest 0.1 cm, and body weight (BW) was recorded on a portable scale (Model 707, Seca Corporation, Columbia, Maryland) to the nearest 0.1 kg. Skinfolds were measured with the use of a caliper (Harpenden CE0120, West Sussex, UK) to the nearest 0.2 mm. Widths were taken with a sliding caliper (Rosscraft), girths were measured with a flexible metallic tape (Lufkin W606PM) to the nearest 0.1 cm. All measurements were taken by skilled anthropometrist.

Nutritional status was calculated with body mass index (BMI, kg/m^2). A body fat percentage (Fat%) estimation followed the procedure set out by Pařižková (1961). Body composition was assessed with the Drinkwater and Ross technique (1980).

Bioelectrical impedance analysis

To assess abdominal obesity, the visceral fat area (VFA – cm^2) was also estimated by bioelectrical impedance analysis equipment (Inbody 720 analyser).

Table 1. Descriptive statistics
1. táblázat. Leíró statisztika

Variables	Groups	Mean±SD (min-max)
Chronological age (yrs)	Group A	16.35±1.5 (14-18)
	Group B	16.13±1.7 (14-17)
	Both	16.27±1.5 (14-17)
Morphological age (yrs)	Group A	16.9±0.46 (14.57-17.90)
	Group B	16.84±0.60 (15.66-17.95)
	Both	16.93±1.20 (14.57-17.90)
Sport age (yrs)	Group A	7.62±1.50 (5-10)
	Group B	8.25±1.85 (5-10)
	Both	7.83±1.75 (5-10)
Exercise hours per week	Group A	7.43±0.82 (6-8.5)
	Group B	8.25±1.85 (7-11)
	Both	7.7±1.23 (6-11)
Body height (cm)	Group A	167.53±5.7 (158.6-173.6)
	Group B	174.0±3.4 (170.3-177.5)
	Both	169.7±5.8 (158.6-177.5)
Endomorphy	Group A	4.60±0.96
	Group B	1.84±3.45
	Both	4.21±1.35
Mesomorphy	Group A	3.68±1.09
	Group B	3.92±1.63
	Both	3.76±1.22
Ectomorphy	Group A	2.25±0.85
	Group B	2.32±1.89
	Both	2.27±1.20

Subjects were placed barefoot in an anatomical position with their hands and feet on the electrodes, wearing light clothes and without metal accessories. This position was maintained until the evaluator finished the test. The impedance between the body segments was measured while an alternating current (1,5, 50, 250, 500, 1000 kHz) passed through the lower and upper body. Participants were informed in advance of the conditions that had to be sustained prior to measurement: no exhausting exercise for at least 12 h prior, no food or drink for at least 2 h prior, and urination immediately before the measurement. The following data were used: weight, body mass index, lean body mass, body fat mass, body fat percentage, segmental lean analysis (right arm, left arm, trunk, right leg, left leg). Segmental fat-free body weight and segmental fat mass ratios were also calculated from the obtained data (Segmental fat-free body weight % = (Segmental fat-free body mass/Total body weight)*100; Segmental fat mass%=(Segmental fat mass/Total body weight)*100).

Handgrip strength test

Handgrip strength was measured with a standard handheld dynamometer (Electronic Hand Dynamometer Model: CAMRY 200 Lbs/90 kg digital hand model with adjustable grip). Participants were asked to hold the dynamometer while having their arm aligned with the trunk and pointing downward. The maximal isometric contraction was set to last 2 sec and participants completed two trials with a break in between. The assessment was done for both hands, handgrip strength obtained from the preferred hand was rounded to the nearest 0.1 kg and the maximum values of the tests were involved in the further analysis.

Cycling ergometer

The maximum exercise capacity was measured as maximum power relative to body weight was reached in the graded exercise test. The test was performed until voluntary exhaustion on a bicycle ergometer (SCHILLER CS-200, Ergo-spiro, ergoline bicycle). Prior to the physical performance test, participants were asked not to do any strenuous activities 12 h prior the performance diagnostics. Subjects were requested to maintain their usual diet. After a warm-up period of 2 min at 25 W, the workload increased by 25 W per 2 minutes. Heart rate (HR) was measured continuously beat-to-beat throughout all testing sessions with an HR-monitor (RS800 CX Polar, Finland). To ensure that the subjects achieve their maximum performance, they were verbally motivated by personnel, but they were not allowed to get out of the saddle. Before and after the test, arterialized capillary blood samples were taken from the earlobe at rest and at termination of the test. Lactate concentrations were directly analyzed by a lactate biosensor (NOVA Biomedical Lactate test strips).

Questionnaires

Athletes completed a health status questionnaire as well as a food frequency questionnaire (FFQ; compiled and evaluated by a qualified nutritionist) on both the first and second measurement days.

Statistics

Data were expressed as mean ± SD. To compare pre- and postintervention data, all test data were performed by paired *t*-test. Pearson-correlation was used in comparative measurements. The significance level was set at $p<0.05$. Statistical analysis was performed by a software package (IBM SPSS Statistics V. 25).

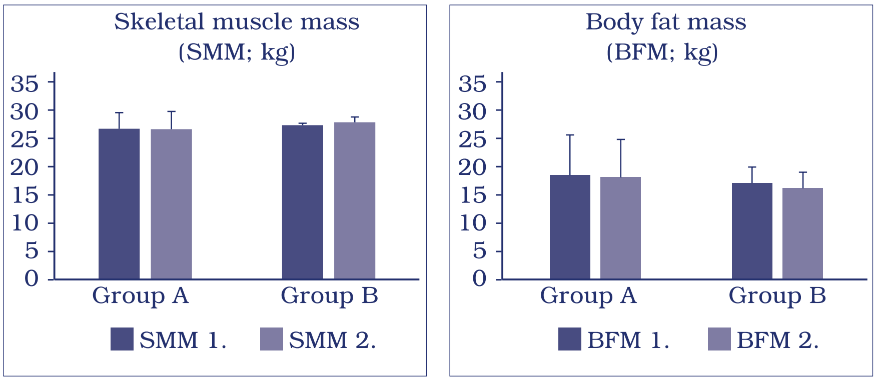

Figure 1. Changes in body composition during the intervention
1. ábra. A testösszetétel változásai az intervenció alatt

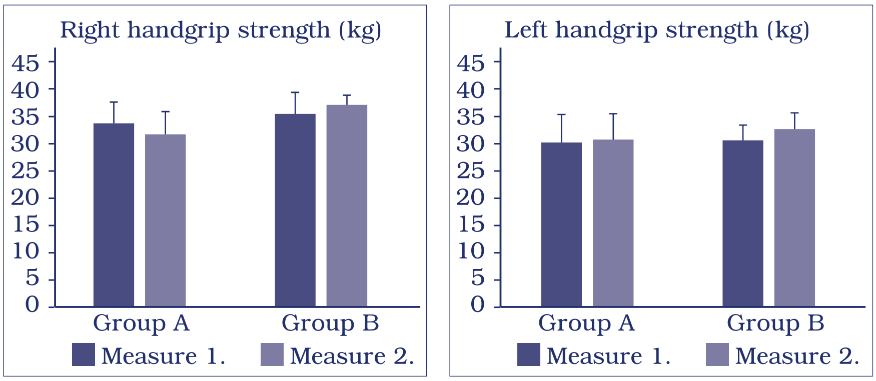

Figure 2. Changes in handgrip strength during the intervention
2. ábra. A szorítóerő változásai az intervenció alatt

Results

Descriptive statistics

The average chronological age of the measured 12 woman was 16.35±1.5 years, the morphological age was 16.8±1.2 years and the sport age was 7.83±1.75 years. The average exercise time per week were 7.7±1.23 hours. The height of the athletes was 169.7±5.8 cm and the weight was 66.5±1.43 kg on the first day. Group A consisted 1 centre back, 3 pivots, 3 backs and 1 goalkeeper. and Group B had 3 backs and 1 wing. All subjects marked the right side of the dominant hand. The grouping of the general descriptive data sets is shown in **Table 1.** No significant difference between the two groups could be detected in any of the examined variables.

The skeletal muscle mass did not change measurably during the intervention either in Group A [t(7)=-0.384; p=0.237] or in Group B [t(3)=1.376; p=0.236]. A similar trend was observed for body fat mass in Groups A [t(7)=1.292; p=0.237] and Groups B [t(3)=2.714; p=0.073], respectively (**Figure 1**).

The handgrip strength of the right hand did not change significantly in the studied groups A t(7)=1.615; p=0.157] and B [t(3)=-0.548; p=0.638]. The handgrip strength of the left hand did not differ before and after supplementation in group A [t(7)=0.655; p=0.537], but there was significant improvement in group B [t(3)=14.912; p=0.004*] (**Figure 2**).

Additional pre-intervention and post-intervention measurements are detailed in **Table 2.**

The maximum aerobic performance (VO_2 max) in Group A consuming beet concentrate decreased significantly at the 2nd measurement [t(7)=-2,708; p=0.030]. In Group B this change was not detectable [t(3)=0.251; p=0.818]. Power expressed in Watts decreased significantly both in Group A [t(7)=3.386; p=0.012] and Group B [t(3)=4.446; p=0.021] compared to the first measurement.

The relative VO_2 decreased significantly in Group A [t(7)=2.859; p=0.024] after the supplementation period, while there was no detectable change in Group B [t(3)=-0.215; p=0.843]. The workload time was demonstrably shorter in Group A compared to the first measurement [t(7)=-3.964; p=0.005], while Group B showed no significance here either [t(3)=-1.706; p=0.187]. Maximal heart rate did not change measurably in either Group A [t(7)=1.332; p=0.224] or Group B [t(3)=0.397; p=0.718].

Table 2. Summary table of relevant results before and after the intervention
2. táblázat. Az intervenció előtti és utáni releváns eredmények összefoglalása

	1. measure (Before the intervention)	2. measure (After the intervention)
Body weight (kg)		
Group A	66.66±8.30	66.04±8.60
Group B	66.35±2.85	66.25±3.77
Fat-free mass/fat mass of right arm (kg)		
Group A	2.49±0.30/1.14±0.60	2.48±0.33/1.10±0.56
Group B	2.49±0.12/1.00±0.22	2.57±0.18/0.92±0.24
Fat-free mass/fat mass of left arm (kg)		
Group A	2.43±0.31/1.30±0.67	2.43±0.34/1.10±0.54
Group B	2.46±0.10/0.98±0.22	2.54±0.20/0.90±0.22
Fat-free mass/fat mass of trunk (kg)		
Group A	21.28±1.98/8.76±3.70	21.26 ± 2.00/8.59±3.53
Group B	21.75±0.66/8.10±1.60	22.20±1.06/7.70±1.61
Fat-free mass/fat mass of right leg (kg)		
Group A	7.66±0.80/2.70±0.94	7.60±0.94/2.65±0.85
Group B	8.17±0.33/2.57±0.33	8.22±0.23/2.40±0.35
Fat-free mass/fat mass of left leg (kg)		
Group A	7.67±0.82/2.70±0.94	7.61±0.93/2.64±0.83
Group B	8.06±0.37/2.52±0.38	8.12±0.28/2.40±0.35
Power (W)		
Group A	204.25±13.60	177.25±20.27
Group B	208.50±11.48	194.80±6.80
VO_2 max (l/min)		
Group A	2.44±0.58	1.69±0.41*
Group B	2.19±0.47	2.27±0.70
Relative VO_2 (ml/kg/min)		
Group A	37.05±9.50	25.67±7.20*
Group B	33.25±8.10	34.22±10.23
Workload time (s)		
Group A	1242.50±72.00	1095.00±80.36*
Group B	1265.00±59.20	1182.50±45.70
Maximum heart rate (beat/min)		
Group A	194.50±11.71	188.63±13.20
Group B	189.75±4.10	189.75±2.22

The correlation measures in some cases can be divided into two groups: those based on pre-intervention measurement data and those based on post-intervention data. Where taking two measurements was necessary, number I. was used for pre-intervention measurement and number II. was used for the post-intervention measurement. The Sport Age (7.83±1.75 years) and the weekly exercise hours (7.7±1.23 hours) were positively correlated with each other [r(10)=0.599; p=0.011].

In terms of the body composition measurement data, body height (169.7±5.8 cm) was positively correlated with skeletal muscle mass I. (27.34±2.57 kg) [r(10)= 0.705; p=0.002] and fat mass I. [r(10)= 0.679; p=0.003], furthermore body weight I. correlated (66.5±6.8 kg) with skeletal muscle mass I. and fat mass of trunk I. [r(10)=0.809; p<0.001].

The fat-free body mass of the right and left legs (I. and II.) shows no significant correlation with the performance indicators as VO_2 max I.[r(10)=-0.561; p=0.058 and r(10)=-0.571; p=0.053] and VO_2 max II. [r(10)=0.234; p=0.463 and r(10)=0.242; p=0.448] or power I. [r(10)=0.215; p=0.501 and r(10)= 0.205; p=0.523] and power II. [r(10)=0.190; p= 0.555 and r(10)=0.194; p=0.545] A negative correlation was also confirmed in the first measurement for the relative VO_2max (I.) and fat free mass of the right [r(10)= -0.670; p=0.17] and left legs [r(10)=

-0.682; p=0.014]. In the post-intervention measurement (relative VO_2 max II.) these correlations were not detected in either the fat-free mass of the right [r(10)=0.376; p=0.228]and left legs [r(10)=0.386; p=0.215].

There was no detectable correlation between fat-free body weight of the right and left arms (I., II.) and handgrip strength (I., II.) [right side: r(10)=0.217; p=0.547; r(10)=0.482; p=0.113; left side: r(10)= 0.46; p=0.181; r(10)=0.455; p=0.138].

Discussion

We examined the effects of 10 days' administration of beetroot and black currant supplementation on body composition, handgrip strength and performance in elite adolescent and youth female handball players.

No significant difference in body composition was detected in any of the groups during the study period (which can be traced back to insufficient study length); it is not negligible that the nitrate was shown to have anti-obesity and anti-diabetic properties. Rather, this positive effect can be achieved by improving the metabolic fitness of severely obese individuals (Roberts, 2015).

Handgrip strength did not improve significantly in the beet syrup group during the 10-day supplementation period. In contrast, a measurable positive change was reported by Oliveira et al. (2018): in their study, the consumption of an 8-day beet gel supplementation improved handgrip strength and the oxygen saturation of the forearms. In the group consuming black currants, the handgrip strength of the left hand increased significantly during the study period. This may be related to anthocyanin, which is also a major biologically active compound in blackcurrants, also affecting the oxygen supply (Potter et al., 2019). In line with our ideas, in further studies, we will also use a third type of supplementation that eliminates any influencing factors regarding the antioxidant effect.

Contrary to expectations, performance parameters deteriorated. In several studies (with 5-8 days supplementation period), beetroot juice or beetroot gel did not significantly improve performance in physiological parameters, but no performance impairment was detected (Boorsman et al., 2014; Perez, 2017). It is conceivable that the unfortunate evolution of external circumstances may have contributed to the events. During the study, the cohesive strength of the study population, the handball team, decreased. During this period, there was a change of coach, which may have negatively affected the running of the study period. In addition to the team, the coach has a prominent role in improving team performance, envisioning the definition of group norms and goals, as well as strategies for behaviour within the group. The coach's task orientation also includes leadership behaviour and focusing on the athletes individually (Kleinert et al., 2012). Among the external influences on the athlete, the athlete-coach relationship is a cardinal representative of the factors that determine the athlete's motivation (Mageau and Valle rand, 2003). This hypothetical attenuation in motivation explain why nearly 43% of the total number did not complete the study period, despite regular information and accurate logistics. Furthermore, the coach's motives have a big impact on the athlete's performance and satisfaction levels (Jowett, 2008). This may support the idea that one of the triggers for poorer performance in athletes who complete the study is a decrease in motivation. It may also have contributed to the failure of the study that nitrate-based supplementation is primarily an advantage in sports using the aerob energy system, while handball also uses „mixed energy": aerobic and anaerobic energy processes.

Study limitations

First, a low number of cases completed a study protocol. An additional increase in the number of cases would be needed to support the results. A change of coach in the middle of the test protocol was an unfortunate circumstance, so the athletes' control by the coach was impaired. With this background factor, it cannot be ruled out, that the reason for the poorer performance was not dietary intake; but a change in motivation. To rule out this suggestion, it is recommended to repeat the protocol on an independent sample. The design of the study is not suitable for the full tracking of individual changes that cross over design offers.

Conclusions

The results of our study did not confirm the positive changes in performance described in the international literature. The consequences that can be drawn from the results require further research; however, it can be assumed that the results were influenced by the change in the background management level in the life of the association.

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