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Effect of beetroot juice supplementation on aerobic and anaerobic capacities, and isokinetic muscle functions in power athletes

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Abstract

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The purpose of this study was to examine the effect of beetroot juice supplementation on aerobic and anaerobic capacities, and isokinetic muscle functions in power athletes. The participants were thirteen power athletes, and they received orally administered three different volume of beetroot juice by randomized crossover; placebo group (PG), low-volume beetroot juice intake group (LBG) and high-volume beetroot juice intake group (HBG). The aerobic capacity in power athletes was measured by the harvard step test, and the anaerobic capacity were measured through 20m sprint, side step, whole body reaction time, wingate test, and blood lactate test. In addition, the isokinetic muscle functions of knee and trunk in power athletes were measured by Humac Norm device, which is analyzed at 60°/sec and 240°/sec to confirm the knee extension and flexion functions, and at 30°/sec to check the trunk function. Significant differences between groups were determined by repeated-measures ANOVA. As a result of this study, there were no significant differences in the harvard step, side step, whole body reaction time, wingate test, blood lactate tests, and isokinetic muscular strength in knee and trunk. However, 20m sprint and isokinetic muscular endurance in knee at 240°/sec were significantly higher in LBG and HBG compared to PG. Taken together, oral supplementation of beetroot juice did not affect aerobic exercise performance, agility, reaction time, anaerobic power, fatigue, and isokinetic knee and trunk muscular strength, but had a positive effect on speed and isokinetic muscular endurance.

Therefore, our finding suggested scientific evidence that beetroot juice intake before the performance might be used as an ergogenic supplement to improve performance-related physical fitness (speed and muscular endurance) in power athletes.

CONTENTS

List of Tables

List of Figures

Ⅰ. INTRODUCTION

1. Research significance

Power sports refer to sports that mainly use power among skill-related fitness, including Taekwondo, Kendo, Badminton, Wrestling, Judo, Boxing, and Fencing. Power is a fitness element that requires both strength and speed, and it means the ability to exert high-intensity performance in a short time. For this reason, power athletes require anaerobic performance ability, which is the ability to perform short-term high-intensity performance (Zupan et al., 2009). Power athletes in modern sports require not only power but also power-endurance because they have to continue performing anaerobic exercise for several rounds or for a prolonged time period. Since power endurance requires both anaerobic and aerobic exercise capacities, these are important factors in determining performance for modern power athletes (Natera et al., 2020).

Anaerobic exercise capacity refers to the ability to perform the high-intensity exercise for a short period of fewer than three minutes (Plowman & Smith, 2007). Since anaerobic exercise generates adenosine triphosphate (ATP) through anaerobic energy metabolism, which is a method of generating ATP through glycolysis and lactate shuttle, much energy can be used within a short time, but when exercise continues, the blood lactate concentration rapidly rises, which limits muscle contraction (Enoka & Duchateau, 2008). Aerobic exercise capacity refers to the ability to continue low-intensity exercise for more than 3 minutes. Aerobic exercise generates energy through the krebs cycle and oxidative phosphorylation, it is easy to supply energy during low-intensity long-term exercise (Boulay et al., 1985).

Anaerobic and aerobic exercise performance is directly or indirectly affected by various factors, such as physical, environmental, and nutritional factors. Recently, studies that have been conducted on various training methods and periodization programs to improve physical fitness have been accepted in the field and contribute to the performance of athletes (Manchado et al., 2018; Rosenblat et al., 2020). Environmental factors, including temperature, humidity, light, and sleep status, affect performance on "game day" since these factors induce changes in autonomic nerves and introduce psychological factors (Corbett et al., 2014; Fullagar et al., 2015). Nutritional intake is as important to performance as training, and proper intake of three major nutrients, vitamins, and minerals is an important consideration to improve performance (Galanti et al., 2015). Changes in the concentration of metabolites and minerals in the blood can cause physiological changes in cells and blood vessels. Acute nutritional intake before competition as well as steady nutritional intake induces physiological changes (Bentley et al., 2015). Previous studies have reported that intake of vitamins and minerals changes muscle contraction, recovery from fatigue material, blood flow, and vessel diameter. Among the vitamins and minerals that cause these changes, nitrate intake has been reported to have a positive effect on anaerobic and aerobic capacity through vasodilation and increased blood flow (Coggan et al., 2015; Larsen et al., 2011; Lundberg et al., 2008).

Beetroot is a vegetable rich in nitrates, among various nutrients, and is reportedly an effective ergogenic aid (Arazi & Eghbali, 2021; Lidder & Webb, 2013; Zamani et al., 2021). Nitrate, through beetroot juice intake, is converted to nitrite by bacteria present in the gastrointestinal tract, while unconverted nitrate is converted to nitrite by oral bacteria via the entero-salivary system. The converted nitrite is then converted to nitric oxide (NO) in the acidic environment of the stomach, while unconverted nitrite is absorbed from the intestine into the systemic circulation and exists in the body in the form of nitrite. Unconverted nitrite is converted into bioactive NO in hypoxic or acidic conditions (Castello et al., 2006). NO produced through the above ‘nitrate-nitrite-NO’ pathway is a potent endogenous vasodilator and regulates blood pressure (Stamler & Meissner, 2001). The effect of beetroot on blood vessel and blood pressure control has been demonstrated by a study observing changes in blood pressure after intake of beetroot juice (Kapil et al., 2010; Webb et al., 2008). Increasing NO concentration through beet juice is effective for muscle blood flow and neurotransmission, in addition to blood pressure control (Aucouturier et al., 2015; Coggan et al., 2015; Ferguson et al., 2013; Lundberg et al., 2008). Improved blood flow and neurotransmission due to NO have a positive effect on exercise performance by improving intramuscular O_2 delivery, glycogen synthesis, mitochondrial efficiency, and muscle contraction (Andrade et al., 1998; Stamler & Meissner, 2001). A previous study investigating beetroot juice supplementation and aerobic exercise performance demonstrated the effects of lowering VO_2 by 6% in a swimming test performed at an intensity corresponding to the ventilation threshold (VT). Researchers have reported that beetroot juice intake reduced oxygen demand and consumption during submaximal exercise and improved exercise performance, such as cycling and running (Lansley et al., 2011; Larsen et al., 2007; Pinna et al., 2014). In addition, nitrate supplementation during aerobic exercise was effective in delaying fatigue, improving exercise performance, and reducing VO_2, suggesting that nitrate intake positively affects aerobic exercise capacity (Bailey et al., 2009; Larsen et al., 2007; Larsen et al., 2010). Therefore, nitrate supplementation via beetroot juice intake is related to aerobic exercise performance. Beetroot juice supplementation is reportedly related to anaerobic and aerobic capacity. Dominguez et al. (2018) reported that beetroot juice supplementation could improve muscle contractility by increasing calcium reabsorption in the sarcoplasmic reticulum of type II muscle fibers. Furthermore, sports that mainly employ type II muscle fibers improve muscular strength through NO supplementation, which leads to improvement in performance (Krustrup et al., 2006; Krustrup et al., 2009). This suggests that NO may provide physiological benefits when exercising using type II muscle fibers, such as high-intensity exercise (Hernández et al., 2012). It has also been reported that beets may be effective in delaying fatigue. Physiological changes through beetroot supplementation can prevent energy depletion by improving the rate of resynthesis of phosphocreatine by oxidative phosphorylation (Bogdanis et al., 1996; Haseler et al., 1999; Mosher et al., 2016). This rapid energy regeneration prevents the increase of adenosine diphosphate (ADP) and phosphate and is effective in delaying fatigue. By promoting the release and reabsorption of calcium from the sarcoplasmic reticulum, beetroot juice can have a positive effect on muscle endurance by improving muscle efficiency and contractility (Bloomer et al., 2010; Hernández et al., 2012; Vanhatalo et al., 2011). Taken together, research has shown that physiological changes caused by beetroot supplementation have a positive effect on anaerobic and aerobic capacity and fatigue delay. However, some studies show that the effect is insignificant, and the controversy regarding the effect of beetroot supplementation continues. Therefore, it is necessary to validate the effect of beetroot juice supplementation on anaerobic and aerobic capacity.

2. Research purpose

The purpose of this study was to investigate the effects of beetroot juice supplementation on cardiorespiratory endurance, speed, agility, reaction time, anaerobic power, blood lactate concentration, and isokinetic muscle functions in power athletes.

3. Ressearch hypothesis

To achieve the purpose of this study, the following research hypothesis were established.

1) Beetroot juice supplementation mayl affect cardiorespiratory endurance of power athletes.

2) Beetroot juice supplementation may affect the speed of power athletes.

3) Beetroot juice supplementation may affect the agility of power athletes.

4) Beetroot juice supplementation may affect the reaction time of power athletes.

5) Beetroot juice supplementation may affect the anaerobic power of power athletes.

6) Beetroot juice supplementation may affect the blood lactate concentration of power athletes.

7) Beetroot juice supplementation may affect the isokinetic muscle functions of power athletes.

4. Research limitations

This study has the following limitations.

1) Since this study has been designed around power athletes, it couldn't be possible to confirm the physical fitness factors affected by beetroot juice consumption by recreational athletes or endurance athletes.

2) The eating habits in power athletes couldn't be controlled.

3) Psychological factors of the participants were not completely controlled.

5. Operational definitions

The fllowing definitions and explanations of the terms were established for use in this study:

1) Anaerobic exercise performance

The ability to perform high-intensity exercise within a short time using anaerobic energy metabolism.

2) Aerobic exercise performance

The ability to continue low-intensity exercise using krebs cycle and oxidative phosphorylation.

3) Cardiorespiratory endurance

The ability of the circulatory system to sustain movement.

4) Anaerobic power

The ability to exert maximum power in a short time using anaerobic energy metabolism.

5) Isokinetic muscle function

Muscle function that can be maximally exerted within a constant angular velocity.

6) Speed

The ability to reach a set distance as quickly as possible.

7) Agility

The ability to change direction of any part or the entire body at maximum speed.

8) Quickness

The ability to move the body in response to visual, auditory, and tactile sensations.

9) Blood lactate concentration

The concentration at which lactate, a metabolite of anaerobic energy metabolism, cannot be reused and is released into the blood.

II. Literature reviw

1. Beetroot and nitrate

Beetroot is a biennial plant of the subfamily Chenopodiaceae that is native to southern Europe and has been consumed since ancient Roman times. Beetroots are a popular crop because both the leaves and roots are edible, and they are easy to grow. Beetroots grow well in warm climates, and thus grow abundantly on Jeju Island in Korea, and are positioned as a special product of Jeju Island. Beetroots are widely used in salads and pickles. In some countries, beetroot is made into juice or tablets and sold as a functional food. Beetroot is known to have many nutritional benefits, as it is low in calories and rich in various minerals and vitamins (Clifford et al., 2015). In addition, beetroot consumption is thought to be good for the cardiovascular system, immune system, metabolic diseases, anemia, and constipation, and the antioxidant and anticancer effects of beetroot pigments, such as anthocyanin and betanin, have been reported (Gliszczyńska-Świgło et al., 2006; Kanner et al., 2001; Kapadia et al., 2003). Beetroot is rich in nitrates, anthocyanins, and betanins. Nitrate is found in abundance in green vegetables, and is thought to improve vasodilation and vascular function by increasing NO concentration in the blood (Hobbs et al., 2012). Thus, beetroot is being consumed to improve vascular health and blood flow. The allowable daily intake (ADI) of nitrate set by the European Food Safety Administration is 3.7 mg/kg-1 (0.06 mmol/kg-1), and an adult weighing 70 kg should consume 4.2 mmol per day (Lidder & Webb, 2013). Nitrate absorption through beetroot supplementation causes physiological changes in the body by generating NO through the 'NO synthase-independent pathway' pathway (Lidder &

Webb, 2013). The 'NO synthase-independent pathway' refers to the process of digestion and absorption of nitrate obtained from the diet. Nitrate from beetroot juice is converted to nitrite by bacteria present in the gastrointestinal tract, and the unconverted nitrate is converted to nitrite by oral bacteria through the entero-salivary system. Nitrite is then converted to NO in the acidic environment of the stomach, but unconverted nitrite is absorbed from the intestine into systemic circulation and exists in the body as nitrite. Unconverted nitrite is converted into bioactive NO in hypoxic or acidic conditions (Castello et al., 2006).

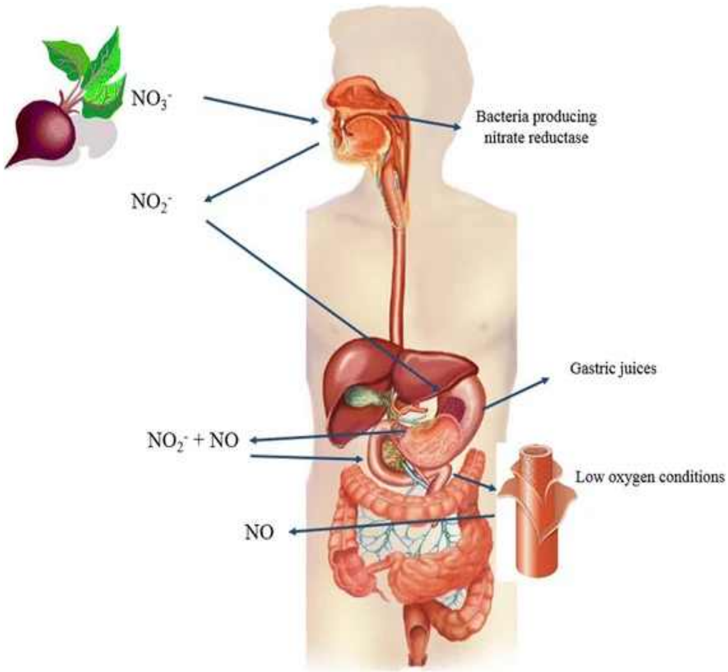


Figure 1. NO synthase-independent pathway
(Domínguez et al., 2018)

2. Nitrates and physiological effects

Nitrate intake through beetroot juice supplementation increases blood NO concentration, which activates soluble guanylate cyclase (sGC) in smooth muscle. By converting guanosine triphosphate (GTP) to cyclic guanosine monophosphate (cGMP), it inhibits intracellular calcium levels and myosin light chain kinase (MLCK) and opens K^+ channels to induce vasodilation (Higashi & Yoshizumi, 2004). NO produced through the above 'nitrate-nitrite-NO' pathway is a potent endogenous vasodilator and regulates blood pressure (Stamler & Meissner, 2001). Vascular endothelial cells surround the blood vessel wall, maintain vascular homeostasis, and play an important role in regulating the vascular outflow of immune cells from the bloodstream (Stevens et al., 2000). Vascular endothelial cells are damaged by oxidative stress due to the generation of reactive oxygen species (ROS) during exercise and rapid increase in blood flow velocity, but maintain vascular homeostasis by increasing NO secretion by endothelial nitric oxide synthase (eNOS) (Hambrecht et al., 2003; Sacheck & Blumberg, 2001). In the long term, improvement of vascular endothelial function and vascular homeostasis can contribute to lowering blood pressure (Bondonno et al., 2017; Carter et al., 2010). Supplementation with nitrate-rich beetroot juice has been reported to increase blood NO and nitrite via the NO synthase-independent pathway. It has been reported that the increased NO concentration had a positive effect on systolic and diastolic blood pressure (Kapil et al., 2010; Webb et al., 2008). According to a study by Carlström et al. (2018), nitrate intake may aid in lowering blood pressure by inhibiting the 'renin-angiotensin-aldosterone system' that contributes to increased blood pressure. Furthermore, Hrabak et al. (1996) reported that nitrate intake may positively affect blood pressure by inhibiting arginase, which inhibits nitrite.

3. Nitrates and Performance

In modern elite athletes, both aerobic and anaerobic performance are emphasized, and both types of exercise performance determine the energy system used through exercise time and intensity (Hultman et al., 1991; Ranković et al., 2010). In general, exercise for less than three minutes uses anaerobic energy metabolism that generates energy through the ATP system and glycolysis, and exercise for more than three minutes uses aerobic energy metabolism that generates energy through the Krebs cycle and oxidative phosphorylation process (Gastin, 2001; Swanwick and Matthews, 2018). Energy metabolism is determined not only by exercise time but also by exercise intensity. Methods for measuring exercise intensity include heart rate (HR), rating of perceived exertion (RPE), 1RM (one repetition maximum), and respiratory exchange ratio (RER) (Borg, 1998; Eston & Evans, 2009). The HR sets the exercise intensity through the ratio of the HRmax, while RPE does the same by expressing the perceived exercise intensity in 20 steps. 1RM is the maximum weight that can be performed once, and RER represents the ratio of the amount of oxygen inhaled and carbon dioxide emitted during one minute. RER can measure the metabolic contribution of three major nutrients during exercise. Carbohydrates, proteins, and fats, which are called the three major nutrients, each have different oxygen consumption and carbon dioxide emissions, thus the energy source used according to the exercise intensity can be measured through RER. The RERs of carbohydrate, protein, and fat are 1.0, 0.82, and 0.7, respectively (Goedecke et al., 2000). The higher the carbon dioxide emission, the higher the carbohydrate mobilization rate, which means that the higher the exercise intensity, the higher the carbohydrate mobilization rate. Decreased oxygen concentration and increased carbon dioxide due to increased exercise intensity induces hypoxic conditions in the body. When the body becomes hypoxic, the secretion of metabolites, such as lactate, K^+, adenosine, and NO, is increased in the blood and tissues (Zweier et al., 1995). Among various metabolites, an increase in blood NO concentration has a vasodilatory effect, reducing peripheral vascular resistance during exercise and increasing blood flow to skeletal muscle (Clifford & Hellsten, 2004; Landmesser & Drexler, 2007; Machha & Schechter, 2011; Shiva et al., 2007). Physiological changes in a hypoxic environment can also be caused by supplementation with nitrate. Beetroot contains large amounts of nitrate, which is absorbed through the 'nitrate-nitrite-NO' pathway in the body, and increases the blood NO concentration. According to a previous study, it was reported that nitrate intake through beetroot juice supplementation increases NO, which aids with efficient energy metabolism by increasing red blood cells in capillaries (Aucouturier et al., 2015; Ferguson et al., 2013). In addition, nitrate supplementation through beetroot juice intake showed a positive correlation between muscle blood flow and neurotransmission, and was closely related to an increase in ATP production rate for oxygen consumed in mitochondria of skeletal muscle (Larsen et al., 2011). Therefore, beetroot juice intake increases NO and nitrate, helping to dilate blood vessels, which increases blood flow and neurotransmission, producing a steady supply of energy, which positively affects anaerobic and aerobic performance (Coggan et al., 2015; Larsen et al., 2011; Lundberg et al., 2008).

4. Nitrate and aerobic capacity

Aerobic exercise capacity refers to exercise with a relatively low exercise intensity for a long time. Aerobic exercise uses the krebs cycle and oxidative phosphorylation to produce energy. Aerobic energy metabolism requires oxygen intervention because the metabolic process proceeds in the inner membrane of mitochondria. Continuous aerobic exercise increases capillary density of skeletal muscle, mitochondrial volume and density, oxidative capacity, and the amount of red blood cells and oxygen-carrying capacity. Methods for improving aerobic exercise performance include physical training and nutrition. It is recommended that physical exercise to improve aerobic exercise capacity should be performed for at least 30 minutes at an exercise intensity of 50 to 70% of the VO_2 max. Nutrition is as important as physical training. Nutritional intake to improve aerobic exercise performance includes carbohydrate loading and intake of various vitamins and minerals. Among them, nitrate supplementation has been reported as an effective mineral for physiological benefits and exercise performance. NO mediates smooth muscle relaxation, which promotes vasodilation and blood flow regulation and thereby improves oxygen delivery and mitochondrial respiration (Andrade et al., 1998; Bailey et al., 2009; Larsen et al., 2007; Larsen et al., 2010; Stamler & Meissner, 2001). Nitrate supplementation may benefit performance by improving maximum oxygen uptake, first and second ventilatory thresholds, and energy efficiency (Domínguez et al., 2017). In fact, several studies have reported improvement in aerobic exercise performance after nitrate intake.

5. Nitrate and anaerobic capacity

Anaerobic exercise capacity is the ability to perform high-intensity exercise within a short period of time and produces energy through anaerobic energy metabolism. Anaerobic energy metabolism is a method of generating energy without oxygen intervention during metabolic processes. The ATP-PC system and glycolysis belong to anaerobic energy metabolism. The ATP-PC system and glycogen use ATP stored in the cytoplasm or glycogen in the muscle as an energy source. After ATP use, energy is produced through the resynthesis of phosphocreatine (Pcr). Pcr is depleted during high-intensity exercise for more than three minutes, and it takes about three to five minutes to regenerate (Phillips, 2015; Tomlin & Wenger, 2001). The ability to resynthesize ATP as quickly as possible is emphasized because power athletes need to rapidly resynthesize ATP that has been depleted from high-intensity exercise and use it for the next round. Thus, resynthesis efficiency affects the performance of power athletes. Beetroot juice supplementation improves local muscle blood flow and oxygen-carrying capacity to skeletal muscle during recovery through vasodilation, thereby reducing muscle fatigue associated with high-intensity exercise and promoting phosphocreatine resynthesis (Bogdanis et al., 1996; Domínguez et al., 2018; Haseler et al., 1999; Mosher et al., 2016). Rapid energy regeneration prevents the increase of ADP, and phosphate and is effective for fatigue delay (Bloomer et al., 2010; Vanhatalo et al., 2011). Further, beetroot juice supplementation was found to be particularly effective for type II muscle fibers (Fergusonet et al., 2013). Beetroot juice intake enhances calcium release and reabsorption in the sarcoplasmic reticulum of type II muscle fibers (Hernández et al., 2012). The effect of beetroot juice improves muscle contractility of type II muscle fibers. Type II muscle fibers are mainly mobilized during high-intensity exercise. Therefore, beetroot juice supplementation may provide an advantage in high-intensity exercise.

Ⅲ. Materials and methods

1. Participants

This study was conducted on 13 power athletes residing in the J city. Power athletes are registered as athletes in sports council and have more than one year of athletic experience. Athletes who did not have cardiovascular and musculoskeletal diseases and food allergies within the last six months were selected. The purpose and method of the study were sufficiently explained to the selected athletes before the experiments, and the athletes who agreed to participate in the study were asked to sign the participation agreement. Athletes participating in the study visited the laboratory by 9:00 a.m. while maintaining an empty stomach for eight hours to obtain age, height, weight, fat mass, percent fat mass (% fat), fat-free mass (FFM), and body mass index (BMI) measurements. This study was conducted after approval by the Jeju National University Institutional Review Board (JJNU-IRB-2021-043-001). <Table 1> shows the physical characteristics of the participants in this study.

Table 1. Characteristics of participants

Variables	Mean±SD
Age (yrs)	21.77±1.83
Height (cm)	175.38±6.71
Weight (kg)	76.38±12.49
Fat mass (kg)	12.62±7.00
% Fat (%)	15.98±6.01
FFM (kg)	63.75±8.40
BMI (kg/m^2)	24.77±3.43

%Fat, percent fat mass; FFM, fat free mass; BMI, body mass index

2. Study design

This study was conducted with 13 male power athletes residing in the J city. Athletes who agreed to participate in the study received a placebo (70ml), low-volume beetroot juice intake group (70ml), and high-volume beetroot intake group (140ml) beetroot juice according to a randomized cross-over design. Thereafter, we determined aerobic capacity, SAQ (speed, agility, quickness) ability, isokinetic muscle functions, and anaerobic power. In order to minimize contamination between the three measurements for this study, measurements were taken at two-week intervals. <Figure 2> shows the experimental design in this study.

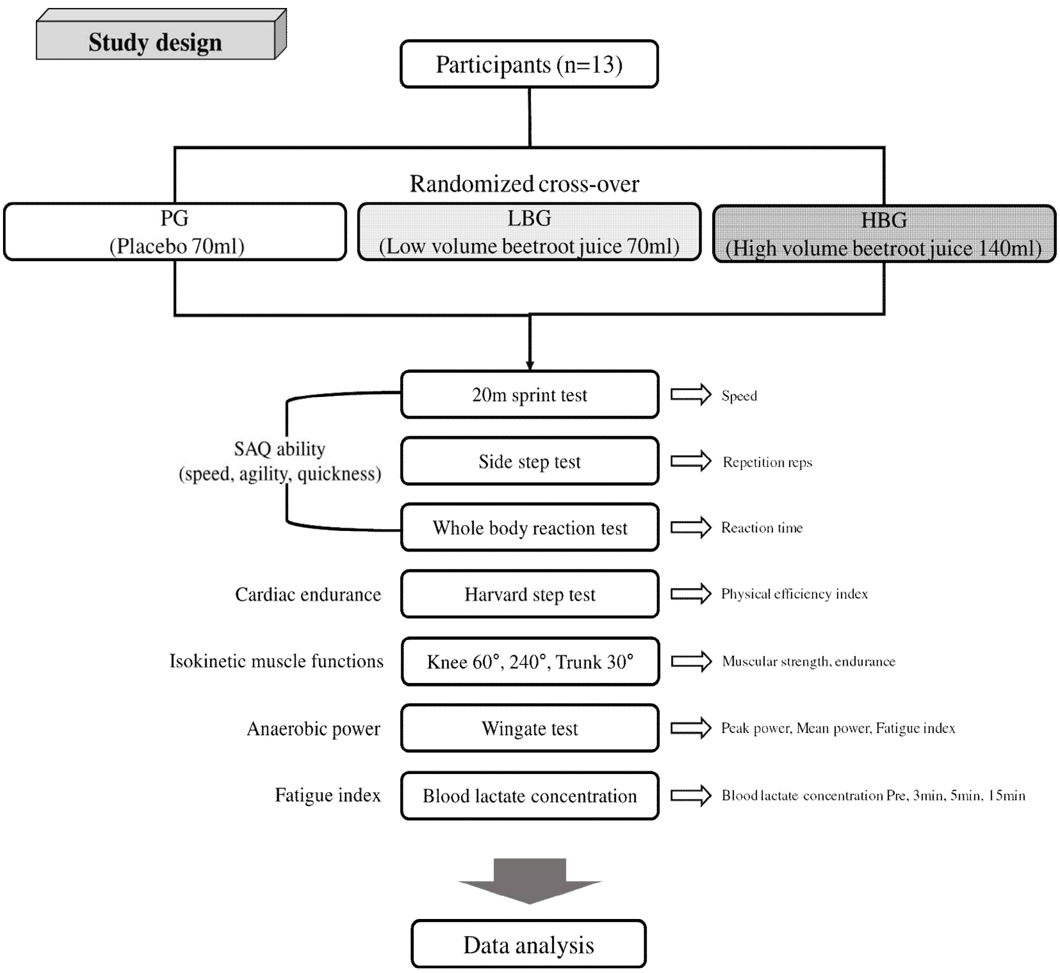


Figure 2. The study design

3. Beetroot juice intake

Juice extracted from beets grown in J city was used. Nutritional components and NO content of the beetroot juice were confirmed by requesting a component analysis from a specialized analysis institution. Athletes participating in the study were measured thrice at two-week intervals, and were instructed to consume 70ml of the placebo, 70ml of beetroot juice, and 140ml of beetroot juice. For the placebo, blackcurrant juice, which has been reported to have similar ingredients to beets, was used, and information on the type of juice consumed was not disclosed to the participants. Juice intake time was based on the application time of previous studies, and placebo and beet juice were ingested three hours before measurement. From the day before the measurement, drinking, caffeinated beverages, and juices other than beetroot juice, and consumption of health functional foods were suggested (Cuenca et al., 2018).

4. Measurement

Risks and precautions for injury were fully explained to all participants before the experiments, and an opportunity to practice at a low intensity before the measurement was given to familiarize themselves with the measurement method and to prevent injuries. Sufficient rest was allowed between measurements, and influences between measurements were minimized by allowing a two-week interval between measurement periods.

1) Body composition

Research participants arrived at the laboratory maintained at a room temperature of 22–25°C and a humidity of 40–45% by 9:00 a.m. in a state of fasting for at least eight hours 30 minutes before. Body composition measurements were then obtained from each participant. Height and weight were measured using an automatic height and weight measuring instrument (DS-103M, Dong San Jenic, Seoul, Korea). Fat mass, percent fat mass (% fat mass), fat-free mass (FFM), and body mass index (BMI) measurements were obtained using bioelectrical impedance (Inbody 720, Seoul, KOREA).

Figure 3. Body composition test

2) Aerobic capacity

Aerobic exercise performance was measured using the Harvard step test. In the Harvard step test, a 50.8 cm high box (Aerobic step box, Iwanna, China) was raised and lowered for five minutes. The physical efficiency index (PEI) calculation by using long-form equation - fitness index formula was as follows.

<Long Form Equation - Fitness Index = (100 x test duration in seconds) divided by (2 x sum of heart beats in the recovery periods)>

Figure 4. Harvard step test

3) Speed

The speed was measured using the 20m sprint test. In this test, after setting the distance between the starting line and the arrival line to 20m, the time to run 20m was measured. The 20m sprint was measured twice in total, and the minimum value of the two runs was recorded in units of 0.1 seconds.

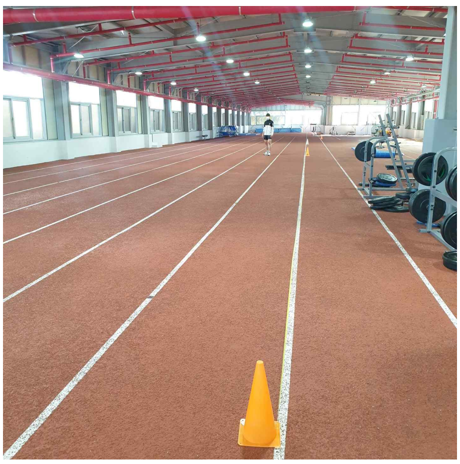


Figure 5. 20m sprint test

4) Agility

Agility was measured using a side step test using a side step meter (SC633015, SKARO, Korea). The side step is a method of moving a line 120cm apart from the center left and right for 20s in the order of left-center-right-center as quickly as possible. The number of times each line was passed was measured once, and if the line was not completely crossed, it was excluded from the count.

Figure 6. Side step test

5) Reaction time

The reaction time was measured using a whole-body reaction tester (T.K.K.-5408, SKARO, Korea). Whole-body reaction time was measured by the time that the participants made a preparatory action on the whole-body reaction meter and jumped off the mat as quickly as possible in response to light. During the whole-body reaction time test, the time for both feet to deviate was recorded in units of 0.1 seconds, and the fastest time was recorded after performing the movement a total of three times.

Figure 7. Whole body reaction time

6) Anaerobic power

Anaerobic power was measured using the Wingate test using a Monark bicycle (Ergomedic 823E, Monark Exercise AB, Vansbro, Sweden). During the Wingate test, the height of the saddle was adjusted so that when the participants extended the pedal to the 6 o'clock position with the heel from a sitting position on the saddle, it was bent about 5 degrees. Before measurement, the load was set at 0.075 kp per body weight, and after light pedaling for 3 min, the speed was gradually increased and measured for 30 s from the time the maximum speed was reached. The absolute and relative values of peak power, absolute and relative values of average power, and fatigue index were measured for 30 s. For the maximum power, the average of the power during the first 5 s was recorded in watts, and the average power was recorded as the average value of the power measured for 30 s in watts. The relative value of the maximum power and the average power was calculated by dividing the measured power by the body weight. The fatigue index was calculated using the formula [(maximum power-min power)/maximum power] * 100 and was recorded as a percentage (%).

Figure 8. Wingate test

7) Blood lactate concentration

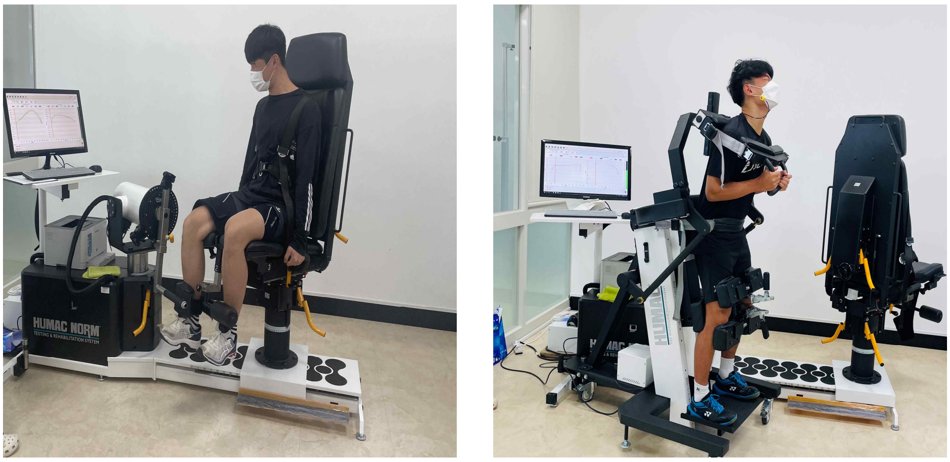
For blood lactate concentration, 25 μl of blood was collected each time at rest, 3 min, 5 min, and 15 min after exercise using a blood collector and a capillary tube (EKF Dianostics, Germany). The blood lactate concentration was analyzed using a lactate analyzer (Biosen C_line, EKF Dianostics, Germany).

$$\text{Lactate removal rate} = (\text{lactate}_{initial} - \text{lactate}_{delayed}) / \text{lactate}_{initial} \times 100$$

8) Isokinetic muscle function

Knee and trunk isokinetic muscle function was measured using HUMAC NORM (Humac Norm 776, CSMI, Boston, USA). In order to minimize the intervention of other muscle groups when measuring isokinetic muscle function of the knee, the chest and femur regions were fixed with a belt. Preliminary operation was performed three or more times before this measurement, and it was carried out after sufficient understanding of the measurement method. At the time of measurement, rotational velocity was set to 60°/sec and 240°/sec, and muscular strength and endurance of the knee extensor and flexor muscles were measured.

In order to minimize the intervention of other muscles when measuring the isokinetic muscle function of the lower back, the back, chest, waist, and thigh were fixed. Preliminary operation was performed three or more times before this measurement, and it was carried out after sufficient understanding of the measurement method. At the time of measurement, the rotational velocity is set to 30°/sec to measure the muscular strength of the waist.



(a) (b)

Figure 9. Isokinetic muscular function test
(a) Isokinetic knee function, (b) Isokinetic trunk function

Statistical analysis

For the results of this study, the mean and standard deviation of each variable were calculated using IBM SPSS Statistics 24.0 statistical program. Repeated-measures analysis of variance (ANOVA) was performed to analyze the differences between groups of all variables. Post-hoc analysis was conducted using contrast, and the statistical significance p was set as 0.05. Two-way repeated measures ANOVA was performed to verify the effect of interaction between groups and periods of blood lactate concentration. Post-hoc analysis was conducted using Tukey, and the statistical significance p was set as 0.05.

Ⅳ. RESULTS

1. Differences in aerobic performance factors according to beetroot juice supplementation

1) Aerobic performance factors

To investigate the effect of beetroot juice supplementation on the aerobic performance factors of power athletes, the physical efficiency index (PEI) was calculated after measuring the harvard step test.

<Table 2>, <Table 3>, and <Figure 10> show PEI results after conducting the harvard step test to analyze the difference in aerobic performance factors following beetroot juice supplementation.

Table 2. Descriptive statistics of PEI (score)

	PG	LBG	HBG	Total
PEI	53.38±8.02	54.05±6.75	54.91±8.42	54.12±7.59

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* PEI, *physical efficiency index*

Table 3. The result of repeated-measures ANOVA for PEI

	SS	df	MS	*F*	*p*
Between Subject	15.309	2	7.655	.836	.446
Error	219.846	24	9.160		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* PEI, *physical efficiency index*

The mean and standard deviation values of PEI according to the beetroot juice supplementation are presented in <Table 2>. <Table 3> shows the results of repeated measures ANOVA used to analyze differences between groups after calculating the PEI after the Harvard Step Test.

As a result of repeated measures ANOVA in <Table 3>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the aerobic performance factor (F=.836, p=.446).

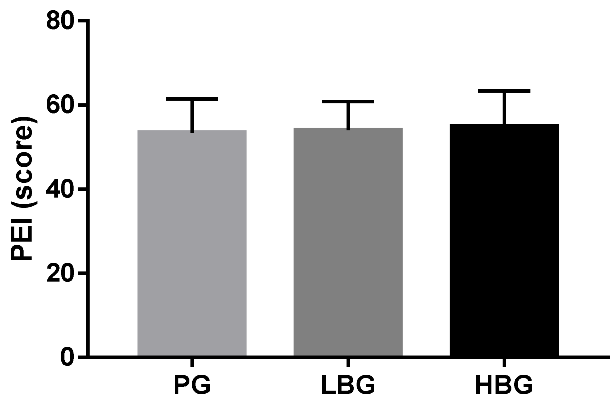


Figure 10. Comparison of PEI after harvard step test. PG, placebo group; LBG, *low-volume beetroot supplement group*; HBG, *high-volume beetroot supplement group*; PEI, *physical efficiency index*

2. Differences in anaerobic performance-related factors (SAQ ability) according to beetroot juice supplementation

The 20m sprint, side step, and reaction time tests were performed to investigate the effect of beetroot juice supplementation on the anaerobic performance factor (SAQ ability) of power athletes.

① Difference in speed according to beetroot juice supplementation

<Table 4>, <Table 5>, and <Figure 11> indicate the results of the 20 m sprint test to analyze the difference in speed following beetroot juice supplementation.

Table 4. Descriptive statistics of 20m sprint (sec)

	PG	LBG	HBG	Total
20m sprint	3.43±0.17	3.17±0.27*	3.26±0.24**	3.26±0.24

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* sec, *second*; *$p<.05$ and **$p<.01$ compared to PG*

Table 5. The result of repeated-measures ANOVA for 20m sprint

	SS	df	MS	*F*	*p*
Between Subject	.590	2	.295	8.401	.002
Error	.843	24	.035		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of the 20m sprint following beetroot juice supplementation are presented in <Table 4>. <Table 5> shows the results of repeated measures ANOVA to analyze the differences between groups after measuring the 20m sprint.

As indicated by the results of repeated measures ANOVA in <Table 5>, there was a significant difference between groups (F=8.401, p=.002). We found that beetroot juice supplementation with low-volume (p=.015) and high-volume (p=.004) was significantly lower than that observed in the placebo group.

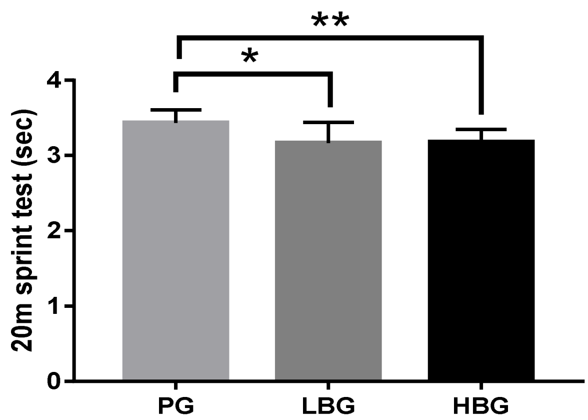


Figure 11. Comparison of 20m sprint test. PG, *placebo group*; LBG, *low-volume beetroot supplement group*; HBG, *high-volume beetroot supplement group;* *p<.05 and **p<.01 compared to PG

② Difference in agility according to beetroot juice supplementation

<Table 6>, <Table 7>, and <Figure 12> indicate the results of the side step test to analyze the difference in agility following beetroot juice supplementation.

Table 6. Descriptive statistics of side step (count)

	PG	LBG	HBG	Total
Side step	46.62±4.46	48.46±3.28	47.08±5.24	47.38±4.36

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 7. The result of repeated-measures ANOVA for side step

	SS	df	MS	*F*	*p*
Between Subject	24.000	2	12.000	1.217	.314
Error	236.667	24	9.861		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of side step according to the beetroot juice supplementation are presented in <Table 6>. <Table 7> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the side step.

As a result of repeated measures ANOVA in <Table 7>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the agility (F=1.217, p=.314).

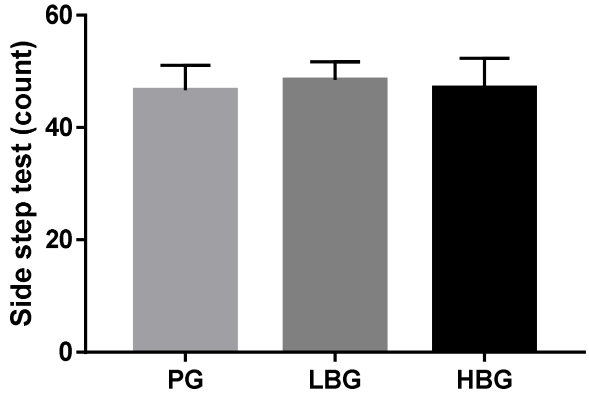


Figure 12. Comparison of side step test. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

③ Difference in reaction time according to beetroot juice supplementation

<Table 8>, <Table 9>, and <Figure 13> indicate the results of the whole body reaction time test to analyze the difference in reaction time following beetroot juice supplementation.

Table 8. Descriptive statistics of reaction time (sec)

	PG	LBG	HBG	Total
Reaction time	0.28±0.02	0.27±0.03	0.27±0.02	0.27±0.03

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* sec, *second*

Table 9. The result of repeated-measures ANOVA for reaction time

	SS	df	MS	*F*	*p*
Between Subject	.001	2	.000	.787	.467
Error	.012	24	.001		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of whole body reaction time test according to the beetroot juice supplementation are presented in <Table 8>. <Table 9> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the whole body reaction time.

As a result of repeated measures ANOVA in <Table 9>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the reaction time (F=.787, p=.467).

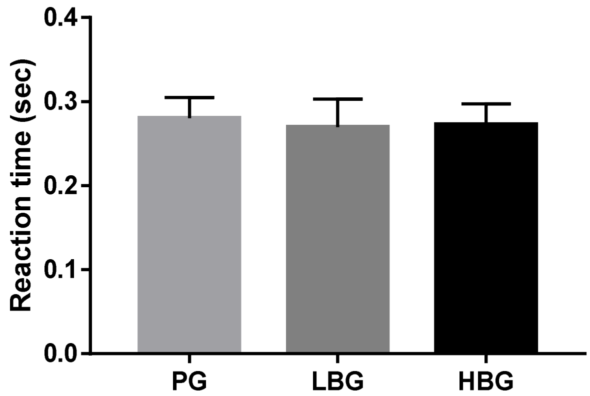


Figure 13. Comparison of reaction time. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* sec, *second*

3. Differences in anaerobic performance factors (anaerobic power) according to beetroot juice supplementation

The wingate test, blood lactate concentration test were performed to investigate the effect of beetroot juice supplementation on the anaerobic performance factor (anaerobic power) of power athletes.

① Difference in absolute values of peak power according to beetroot juice supplementation

<Table 10>, <Table 11>, and <Figure 14> indicate the results of the absolute values of peak power after wingate test to analyze the difference in anaerobic power following beetroot juice supplementation.

Table 10. Descriptive statistics of absolute values of peak power (W)

	PG	LBG	HBG	Total
Peak power	695.84±90.48	726.05±102.78	704.71±97.35	708.06±94.47

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W, *watt*

Table 11. The result of repeated-measures ANOVA for absolute values of peak power

	SS	df	MS	F	p
Between Subject	6267.980	2	3133.990	3.255	.056
Error	23107.525	24	962.814		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W, *watt*

The mean and standard deviation values of the absolute values of peak power according to the beetroot juice supplementation are presented in <Table 10>. <Table 11> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak power.

As a result of repeated measures ANOVA in <Table 11>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak power (F=3.255, p=.056).

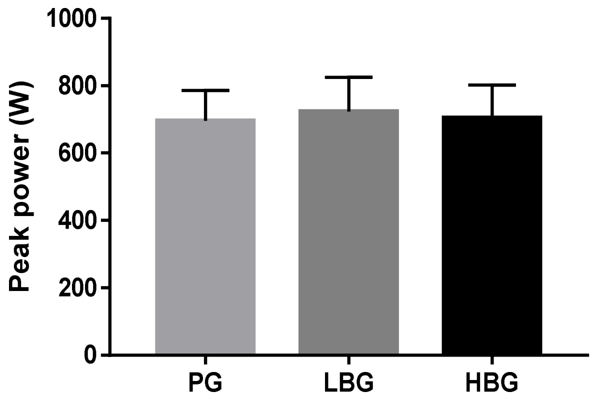


Figure 14. Comparison of absolute values of peak power. PG, *placebo group;* LBG, *low-volume beetroot supplement group*; HBG, *high-volume beetroot supplement group*; W, watt

② Difference in relative values of peak power according to beetroot juice supplementation

<Table 12>, <Table 13>, and <Figure 15> indicate the results of the relative values of peak power after wingate test to analyze the difference in anaerobic power following beetroot juice supplementation.

Table 12. Descriptive statistics of relative values of peak power (W/kg)

	PG	LBG	HBG	Total
Peak power	9.17±0.71	9.57±0.80	9.31±1.00	9.34±0.84

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group; W/kg, watt per kilogram*

Table 13. The result of repeated-measures ANOVA for relative values of peak power

	SS	df	MS	*F*	*p*
Between Subject	0.865	2	.433	3.326	.053
Error	3.123	24	.130		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W/kg, *watt per kilogram*

The mean and standard deviation values of the relative values of peak power according to the beetroot juice supplementation are presented in <Table 12>. <Table 13> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak power.

As a result of repeated measures ANOVA in <Table 13>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak power (F=3.326, p=.053).

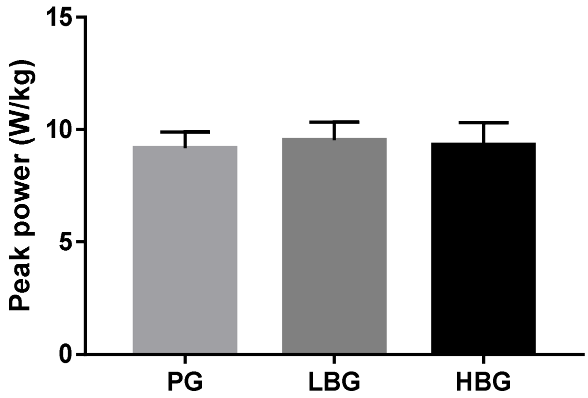


Figure 15. Comparison of relative values of peak power. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W/kg, *watt per kilogram*

③ Difference in absolute values of average power according to beetroot juice supplementation

<Table 14>, <Table 15>, and <Figure 16> indicate the results of the absolute values of average power after wingate test to analyze the difference in anaerobic power following beetroot juice supplementation.

Table 14. Descriptive statistics of absolute values of average power (W)

	PG	LBG	HBG	Total
Average power	533.75±79.74	548.30±74.10	541.66±75.89	541.23±74.81

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W, *watt*

Table 15. The result of repeated-measures ANOVA for absolute values of average power

	SS	df	MS	*F*	*p*
Between Subject	1380.558	2	690.279	2.026	.154
Error	8177.192	24	340.716		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W, *watt*

The mean and standard deviation values of the absolute values of average power according to the beetroot juice supplementation are presented in <Table 14>. <Table 15> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of average power.

As a result of repeated measures ANOVA in <Table 15>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of average power (F=2.026, p=.154).

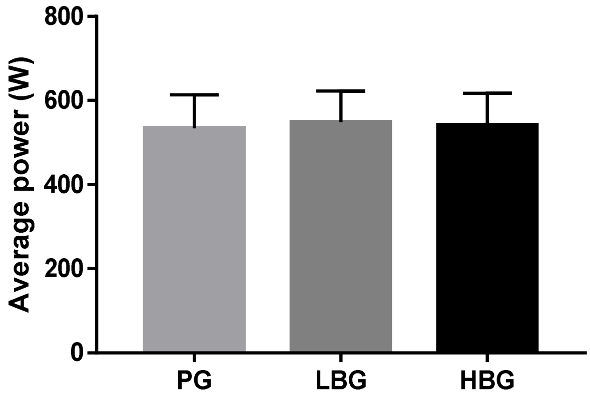


Figure 16. Comparison of absolute values of average power. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W, *watt*

④ Difference in relative values of average power according to beetroot juice supplementation

<Table 16>, <Table 17>, and <Figure 17> indicate the results of the relative values of average power after wingate test to analyze the difference in anaerobic power following beetroot juice supplementation.

Table 16. Descriptive statistics of relative values of average power (W/kg)

	PG	LBG	HBG	Total
Average power	7.02±0.54	7.24±0.72	7.14±0.71	7.13±0.65

Mean±Standard Deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; W/kg, watt per kilogram

Table 17. The result of repeated-measures ANOVA for relative values of average power

	SS	df	MS	*F*	*p*
Between Subject	.312	2	.156	2.731	.085
Error	1.372	24	.57		

Mean±standard deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; W/kg, watt per kilogram

The mean and standard deviation values of the relative values of average power according to the beetroot juice supplementation are presented in <Table 16>. <Table 17> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of average power.

As a result of repeated measures ANOVA in <Table 17>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of average power (F=2.731, p=0.085).

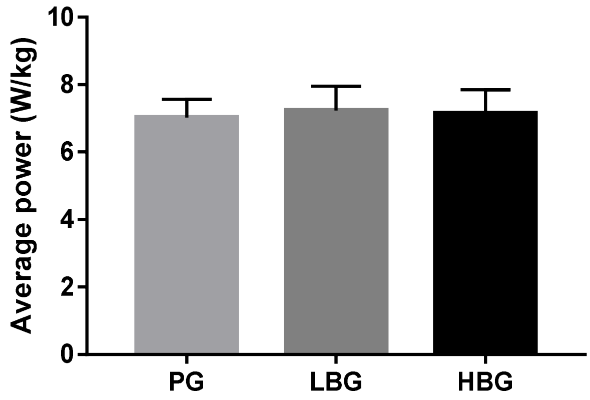


Figure 17. Comparison of relative values of average power. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* W/kg, *watt per kilogram*

⑤ Difference in fatigue index according to beetroot juice supplementation

<Table 18>, <Table 19>, and <Figure 18> indicate the results of fatigue index after wingate test to analyze the difference in fatigue index following beetroot juice supplementation.

Table 18. Descriptive statistics of fatigue index (%)

	PG	LBG	HBG	Total
Fatigue index	55.27±4.92	53.34±7.46	55.84±4.47	54.82±5.72

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 19. The result of repeated-measures ANOVA for fatigue index

	SS	df	MS	*F*	*p*
Between Subject	44.648	2	22.324	.804	.459
Error	666.326	24	27.764		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of fatigue index according to the beetroot juice supplementation are presented in <Table 18>. <Table 19> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the fatigue index.

As a result of repeated measures ANOVA in <Table 19>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the fatigue index (F=.804, p=.459).

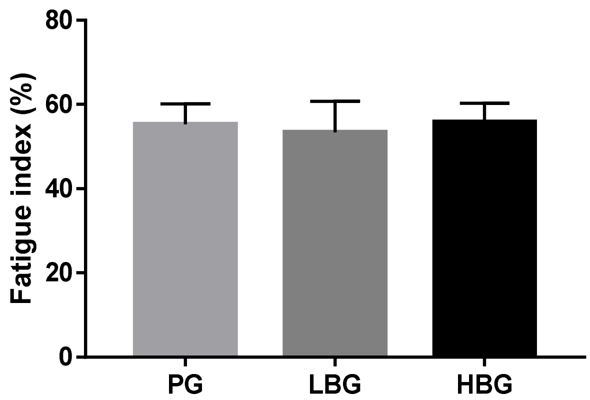


Figure 18. Comparison of fatigue index. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

⑥ Difference in blood lactate concentration according to beetroot juice supplementation

<Table 20>, <Table 21>, and <Figure 19> indicate the results of blood lactate concentration after wingate test to analyze the difference in blood lactate concentration following beetroot juice supplementation.

Table 20. The result of descriptive statistics and repeated-measures ANOVA for blood lactate concentration (mmol)

	Pre	3 minutes	5 minutes	15 minutes	Total
PG	1.65±0.42	13.80±2.00	13.72±2.24	10.73±1.96	9.97±5.31
LBG	1.95±0.43	13.43±1.88	13.30±2.19	10.51±2.22	9.80±5.05
HBG	1.82±0.35	14.82±2.43	14.68±2.56	11.96±3.07	10.82±5.83
Total	1.80±0.41	14.02±2.14	13.90±2.35	11.70±2.48	10.20±5.39
F	1.841	1.509	1.205	1.311	-
p	.173	.235	.311	.282	-

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 21. The result of two-way repeated ANOVA for blood lactate concentration

	SS	df	MS	*F*	*p*	η^2	*B*
Between Subject							
Group	31.284	2	15.642	1.396	.261	.072	.280
Error	403.491	36	11.208				
Within Subject							
Period	3880.173	1.829	2121.844	785.941	.001	.956	1.000
Group×Period	11.836	3.657	3.236	1.199	.319	.062	.340
Error	177.731	65.832	2.700				

<Table 20> shows the mean and standard deviation values of blood lactate concentration and one-way ANOVA used to analyze differences between groups after measuring the blood lactate concentration. <Table 21> shows the results of the two-way repeated measures ANOVA confirming the interaction effect between the group and the time period. There was no significant difference in the interaction effect between group and period (F=1.199 p=.319) and groups (F=1.205, p=.311). However, a significant difference was noted between periods (F=785.941, p=.001).

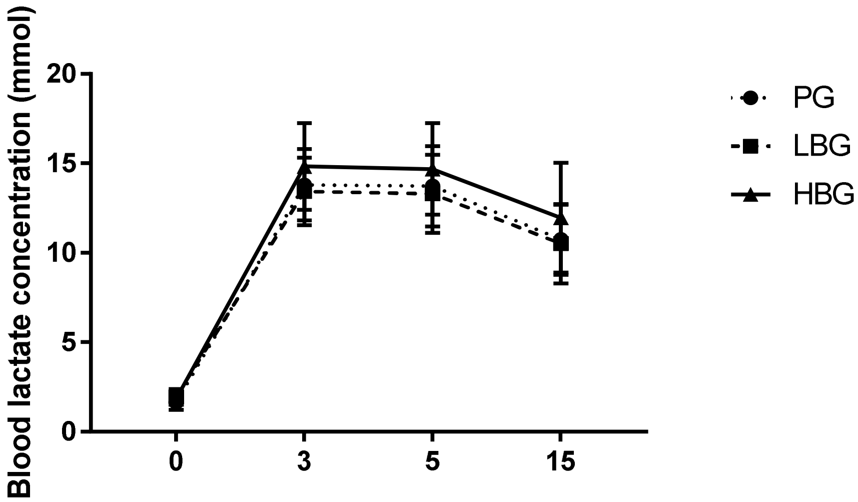


Figure 19. Comparison of blood lactate concentration. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

⑦ Difference in bloodlactate removal rate according to beetroot juice supplementation

<Table 22>, <Table 23>, and <Figure 20> indicate the results of blood lactate removal rate after wingate test to analyze the difference in lactate removal rate following beetroot juice supplementation.

Table 22. Descriptive statistics of blood lactate removal rate (%)

	PG	LBG	HBG	Total
Lactate removal rate	23.14±11.09	25.73±9.16	22.86±11.60	24.20±10.18

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 23. The result of repeated-measures ANOVA for blood lactate removal rate

	SS	df	MS	*F*	*p*
Between Subject	64.806	2	32.403	.349	.709
Error	2228.464	24	92.853		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of blood lactate removal rate according to the beetroot juice supplementation are presented in <Table 22>. <Table 23> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the blood lactate removal rate.

As a result of repeated measures ANOVA in <Table 23>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the blood lactate removal rate (F=.349, p=.709).

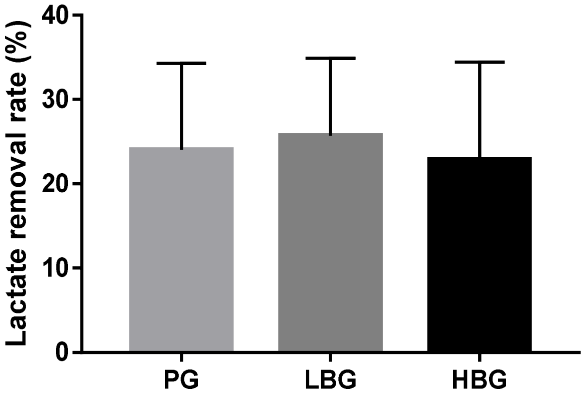


Figure 20. Comparison of blood lactate removal rate. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

4. Differences in isokinetic muscle functions according to beetroot juice supplementation

The isokinetic muscle functions test in knee and trunk were performed to investigate the effect of beetroot juice supplementation on the isokinetic muscular functions of power athletes.

(1) Difference in isokinetic muscular strength in knee according to beetroot juice supplementation

① Absolute values of peak torque in right knee flexor

<Table 24>, <Table 25>, and <Figure 21> indicate the results of absolute values of peak torque in right knee flexor at 60°/sec to analyze the difference in isokinetic muscular strength in right knee following beetroot juice supplementation.

Table 24. Descriptive statistics of absolute values of peak torque in right knee flexor at 60°/sec (N·m)

	PG	LBG	HBG	Total
Right flexor	138.69±35.87	136.92±36.79	134.92±30.69	136.85±33.67

Mean±Standard Deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; N·m, newton meter

Table 25. The result of repeated-measures ANOVA for absolute values of peak torque in right knee flexor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	92.462	2	46.231	.346	.711
Error	3209.538	24	133.731		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in right knee flexor at 60°/sec according to the beetroot juice supplementation are presented in <Table 24>. <Table 25> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in right knee flexor at 60°/sec.

As a result of repeated measures ANOVA in <Table 25>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in right knee flexor at 60°/sec (F=.346, p=.711).

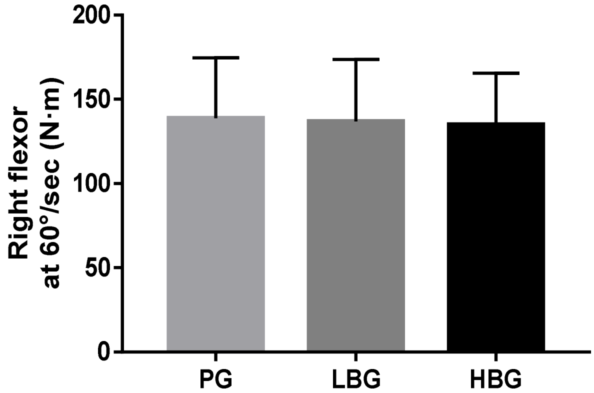


Figure 21. Comparison of absolute values of peak torque in right knee flexor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

② Relavie values of peak torque in right knee flexor

<Table 26>, <Table 27>, and <Figure 22> indicate the results of relative values of peak torque in right knee flexor at 60°/sec to analyze the difference in isokinetic muscular strength in right knee following beetroot juice supplementation.

Table 26. Descriptive statistics of relative values of peak torque in right knee flexor at 60°/sec (%BW)

	PG	LBG	HBG	Total
Right flexor	182.46±43.53	180.85±44.27	178.69±33.25	180.67±39.61

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 27. The result of repeated-measures ANOVA for relative values of peak torque in right knee flexor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	92.974	2	46.487	.199	.821
Error	5603.026	24	233.459		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of peak torque in right knee flexor at 60°/sec according to the beetroot juice supplementation are presented in <Table 26>. <Table 27> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in right knee flexor.

As a result of repeated measures ANOVA in <Table 27>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in right knee flexor (F=.199, p=.821).

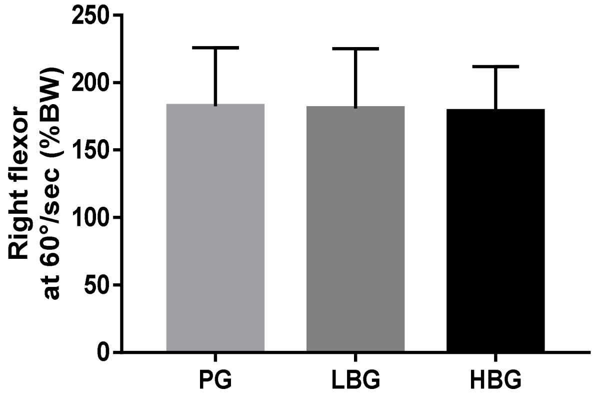


Figure 22. Comparison of relative values of peak torque in right knee flexor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

③ Absolute values of peak torque in right knee extensor

<Table 28>, <Table 29>, and <Figure 23> indicate the results of absolute values of peak torque in right knee extensor at 60°/sec to analyze the difference in isokinetic muscular strength in right knee following beetroot juice supplementation.

Table 28. Descriptive statistics of absolute values of peak torque in right knee extensor at 60°/sec (N·m)

	PG	LBG	HBG	Total
Right extensor	210.00±47.00	224.00±52.78	224.92±49.40	219.64±48.95

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 29. The result of repeated-measures ANOVA for absolute values of peak torque in right knee extensor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	1818.051	2	909.026	2.093	.145
Error	10422.615	24	434.276		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in right knee extensor at 60°/sec according to the beetroot juice supplementation are presented in <Table 28>. <Table 29> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in right knee extensor.

As a result of repeated measures ANOVA in <Table 29>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in right knee extensor (F=2.093, p=.145).

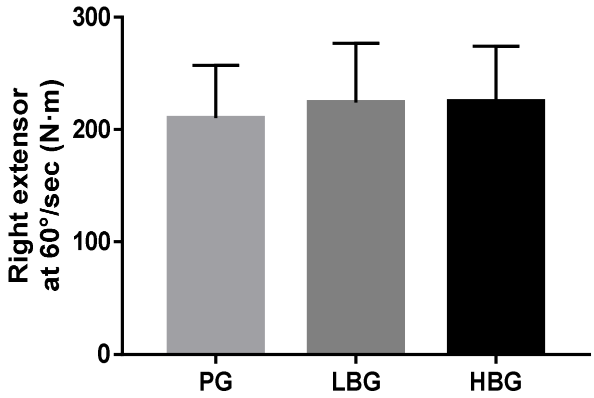


Figure 23. Comparison of absolute values of peak torque in right knee extensor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

④ Relative values of peak torque in right knee extensor

<Table 30>, <Table 31>, and <Figure 24> indicate the results of relative values of peak torque in right knee extensor at 60°/sec to analyze the difference in isokinetic muscular strength in right knee following beetroot juice supplementation.

Table 30. Descriptive statistics of relative values of peak torque in right knee extensor at 60°/sec (%BW)

	PG	LBG	HBG	Total
Right extensor	276.85±47.83	297.54±65.10	297.15±47.01	290.51±53.43

Mean±Standard Deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; %BW, percent body weight

Table 31. The result of repeated-measures ANOVA for relative values of peak torque in right knee extensor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	3643.128	2	1821.564	2.498	.103
Error	17497.538	24	729.064		

Mean±standard deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; %BW, percent body weight

The mean and standard deviation values of relative values of peak torque in right knee extensor at 60°/sec according to the beetroot juice supplementation are presented in <Table 30>. <Table 31> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in right knee extensor.

As a result of repeated measures ANOVA in <Table 31>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in right knee extensor (F=2.498, p=.103).

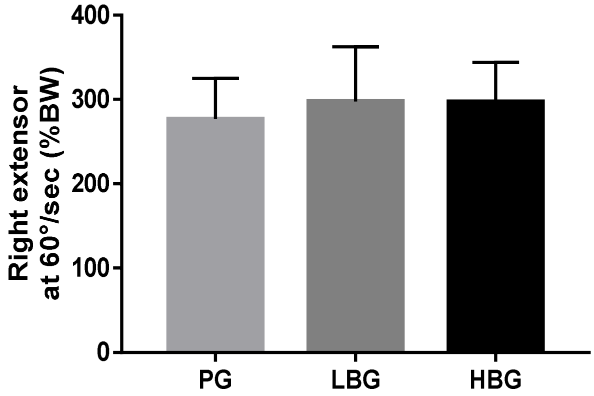


Figure 24. Comparison of relative values of peak torque in right knee extensor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

⑤ Absolute values of peak torque in left knee flexor

<Table 32>, <Table 33>, and <Figure 25> indicate the results of absolute values of peak torque in left knee flexor at 60°/sec to analyze the difference in isokinetic muscular strength in left knee following beetroot juice supplementation.

Table 32. Descriptive statistics of absolute values of peak torque in left knee flexor at 60°/sec (N·m)

	PG	LBG	HBG	Total
Left flexor	130.85±32.80	127.15±30.61	127.77±24.2	128.59±28.70

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 33. The result of repeated-measures ANOVA for absolute values of peak torque in left knee flexor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	101.744	2	50.872	.262	.771
Error	4652.923	24	193.872		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in left knee flexor at 60°/sec according to the beetroot juice supplementation are presented in <Table 32>. <Table 33> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in left knee flexor.

As a result of repeated measures ANOVA in <Table 33>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in left knee flexor (F=.262, p=.771).

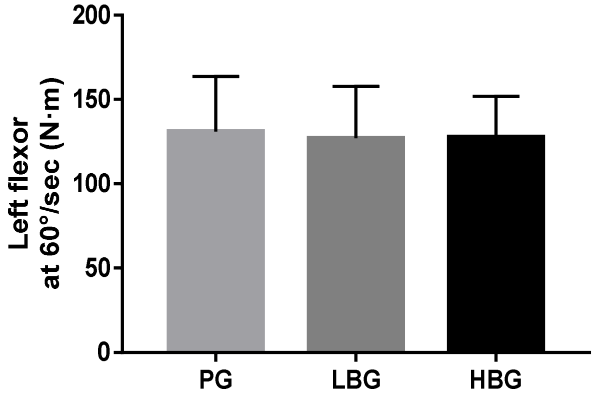


Figure 25. Comparison of absolute values of peak torque in left knee flexor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑥ Relative values of peak torque in left knee flexor

<Table 34>, <Table 35>, and <Figure 26> indicate the results of relative values of peak torque in left knee flexor at 60°/sec to analyze the difference in isokinetic muscular strength in left knee following beetroot juice supplementation.

Table 34. Descriptive statistics of relative values of peak torque in left knee flexor at 60°/sec (%BW)

	PG	LBG	HBG	Total
Left flexor	172.30±36.43	167.46±29.59	169.54±26.60	169.77±30.39

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 35. The result of repeated-measures ANOVA for relative values of peak torque in left knee flexor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	153.692	2	76.846	.214	.809
Error	8612.308	24	358.846		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of peak torque in left knee flexor at 60°/sec according to the beetroot juice supplementation are presented in <Table 34>. <Table 35> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in right knee extensor.

As a result of repeated measures ANOVA in <Table 35>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in right knee extensor (F=.214, p=.809).

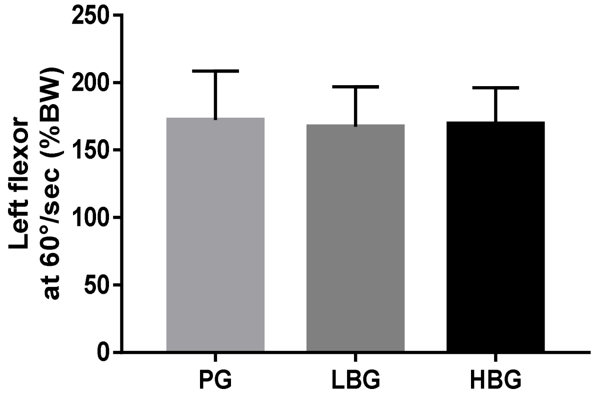


Figure 26. Comparison of relative values of peak torque in left knee flexor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

⑦ Absolute values of peak torque in left knee extensor

<Table 36>, <Table 37>, and <Figure 27> indicate the results of absolute values of peak torque in left knee extensor at 60°/sec to analyze the difference in isokinetic muscular strength in left knee following beetroot juice supplementation.

Table 36. Descriptive statistics of absolute values of peak torque in left knee extensor at 60°/sec (N·m)

	PG	LBG	HBG	Total
Left extensor	201.92±50.17	218.84±51.17	211.31±48.90	210.69±49.26

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 37. The result of repeated-measures ANOVA for absolute values of peak torque in left knee extensor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	1868.923	2	934.462	2.868	.076
Error	7821.077	24	325.878		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in left knee extensor at 60°/sec according to the beetroot juice supplementation are presented in <Table 36>. <Table 37> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in left knee extensor.

As a result of repeated measures ANOVA in <Table 37>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in left knee extensor (F=2.868, p=.076).

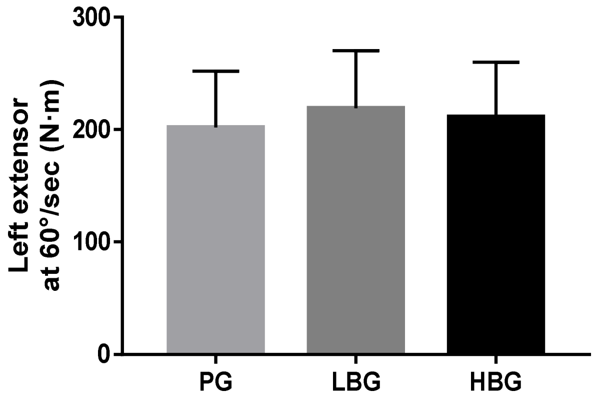


Figure 27. Comparison of absolute values of peak torque in left knee extensor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑧ Relative values of peak torque in left knee extensor

<Table 38>, <Table 39>, and <Figure 28> indicate the results of relative values of peak torque in left knee flexor at 60°/sec to analyze the difference in isokinetic muscular strength in left knee following beetroot juice supplementation.

Table 38. Descriptive statistics of relative values of peak torque in left knee extensor at 60°/sec (%BW)

	PG	LBG	HBG	Total
Left extensor	266.15±50.65	289.38±56.95	278.30±46.38	277.95±51.05

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 39. The result of repeated-measures ANOVA for relative values of peak torque in left knee extensor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	3510.359	2	1755.179	3.044	.066
Error	13840.308	24	576.679		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of peak torque in left knee extensor at 60°/sec according to the beetroot juice supplementation are presented in <Table 38>. <Table 39> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in left knee extensor.

As a result of repeated measures ANOVA in <Table 39>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in left knee extensor (F=3.044, p=.066).

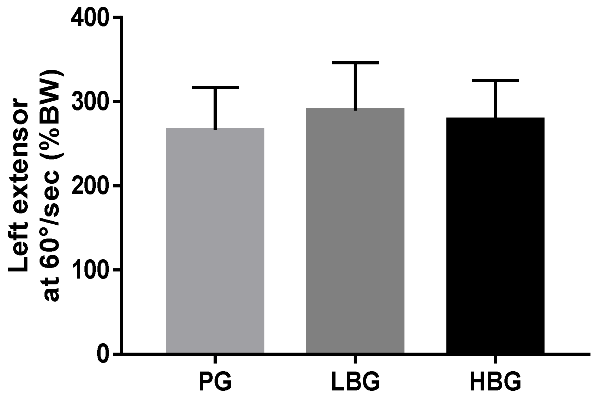


Figure 28. Comparison of relative values of peak torque in left knee extensor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

⑨ Bilateral balance ratio of knee flexor

<Table 40>, <Table 41>, and <Figure 29> indicate the results of bilateral balance ratio of knee flexor at 60°/sec to analyze the difference in bilateral balance ratio of knee flexor following beetroot juice supplementation.

Table 40. Descriptive statistics of bilateral balance ratio of knee flexor at 60°/sec (%)

	PG	LBG	HBG	Total
Bilateral balance ratio for flexor	8.92±4.57	12.15±8.02	7.30±4.06	9.46±6.04

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 41. The result of repeated-measures ANOVA for bilateral balance ratio of knee flexor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	158.308	2	79.154	2.715	.087
Error	699.692	24	29.154		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of bilateral balance ratio of knee flexor at 60°/sec according to the beetroot juice supplementation are presented in <Table 40>. <Table 41> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the bilateral balance ratio of knee flexor.

As a result of repeated measures ANOVA in <Table 41>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the bilateral balance ratio of knee flexor ($F=2.715$, $p=.087$).

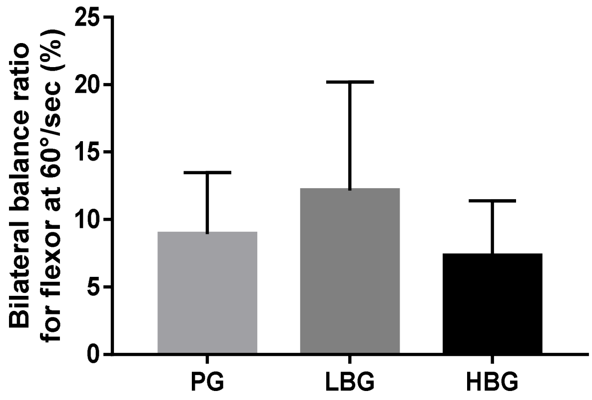


Figure 29. Comparison of 60° bilateral balance ratio for knee flexor at 60°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group*

⑩ Bilateral balance ratio of knee extensor

<Table 42>, <Table 43>, and <Figure 30> indicate the results of bilateral balance ratio of knee extensor at 60°/sec to analyze the difference in bilateral balance ratio of knee extensor following beetroot juice supplementation.

Table 42. Descriptive statistics of bilateral balance ratio for extensor at 60°/sec (%)

	PG	LBG	HBG	Total
Bilateral balance ratio for extensor	5.62±5.74	7.15±6.68	9.69±8.20	7.48±6.97

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 43. The result of repeated-measures ANOVA for bilateral balance ratio for extensor at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	110.205	2	55.103	2.394	.113
Error	552.462	24	23.019		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of bilateral balance ratio of knee extensor at 60°/sec according to the beetroot juice supplementation are presented in <Table 42>. <Table 43> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the bilateral balance ratio of knee extensor.

As a result of repeated measures ANOVA in <Table 43>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the bilateral balance ratio of knee extensor (F=2.394, p=.113).

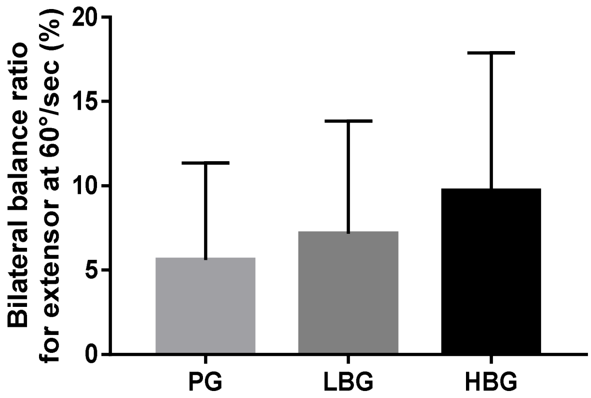


Figure 30. Comparison of bilateral balance ratio for knee extensor at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

⑪ H:Q ratio for right knee

<Table 44>, <Table 45>, and <Figure 31> indicate the results of H:Q ratio for right knee at 60°/sec to analyze the difference in H:Q ratio for right knee following beetroot juice supplementation.

Table 44. Descriptive statistics of H:Q ratio for right knee at 60°/sec (%)

	PG	LBG	HBG	Total
H:Q ratio for right knee	65.85±10.92	62.30±16.75	60.69±11.48	62.95±13.14

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* H:Q, *hamstring :quadriceps*

Table 45. The result of repeated-measures ANOVA for H:Q ratio for right knee at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	180.667	2	90.333	1.562	.230
Error	1388.00	24	57.833		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* H:Q, *hamstring :quadriceps*

The mean and standard deviation values of H:Q ratio for right knee at 60°/sec according to the beetroot juice supplementation are presented in <Table 44>. <Table 45> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the H:Q ratio for right knee.

As a result of repeated measures ANOVA in <Table 45>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the H:Q ratio for right knee (F=1.562, p=.230).

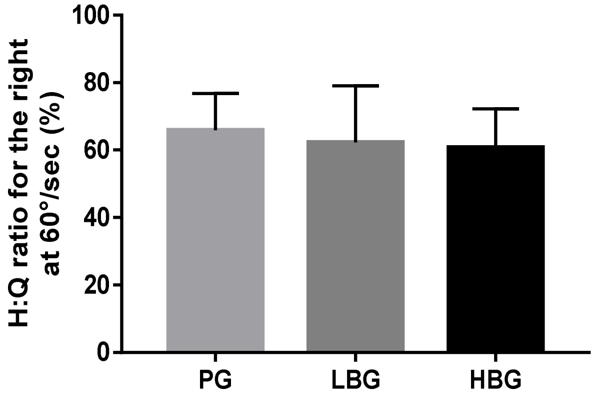


Figure 31. Comparison of H:Q ratio for right knee at 60°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* H:Q, *hamstring:quadriceps*

⑫ H:Q ratio for left knee

<Table 46>, <Table 47>, and <Figure 32> indicate the results of H:Q ratio for left knee at 60°/sec to analyze the difference in H:Q ratio for left knee following beetroot juice supplementation.

Table 46. Descriptive statistics of H:Q ratio for left knee at 60°/sec (%)

	PG	LBG	HBG	Total
H:Q ratio for left knee	64.85±10.42	59.08±12.39	61.69±10.14	61.87±11.00

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* H:Q, *hamstring :quadriceps*

Table 47. The result of repeated-measures ANOVA for H:Q ratio for left knee at 60°/sec

	SS	df	MS	*F*	*p*
Between Subject	216.974	2	108.487	1.150	.334
Error	2264.359	24	94.348		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* H:Q, *hamstring:quadriceps*

The mean and standard deviation values of H:Q ratio for left knee at 60°/sec according to the beetroot juice supplementation are presented in <Table 46>. <Table 47> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the H:Q ratio for left knee.

As a result of repeated measures ANOVA in <Table 47>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the H:Q ratio for left knee (F=1.150, p=.334).

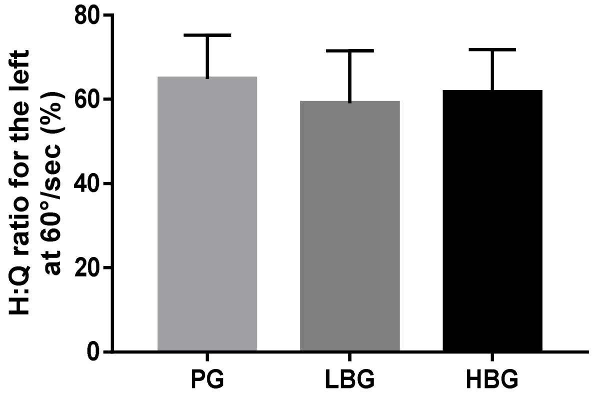


Figure 32. Comparison of H:Q ratio for left knee at 60°/sec among all groups. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* H:Q*, hamstring:quadriceps*

(2). Difference in isokinetic muscle endurance in knee according to beetroot juice supplementation

① Absolute values of total work in right knee flexor

<Table 48>, <Table 49>, and <Figure 33> indicate the results of absolute values of total work in right knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 48. Descriptive statistics of absolute values of total work in right knee flexor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Right flexor	1886.46±465.46	1759.69±519.36	1757.92±430.46	1801.36±464.57

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 49. The result of repeated-measures ANOVA for absolute values of total work in right knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	141248.051	2	70624.026	1.039	.369
Error	1631445.282	24	67976.887		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of total work in right knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 48>. <Table 49> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of total work in right knee flexor.

As a result of repeated measures ANOVA in <Table 49>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of total work in right knee flexor (F=1.039, p=.369).

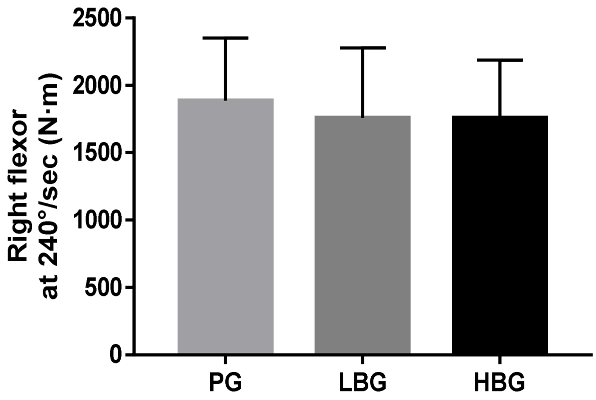


Figure 33. Comparison of absolute values of total work in right knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

② Relative values of total work in right knee flexor

<Table 50>, <Table 51>, and <Figure 34> indicate the results of relative values of total work in right knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 50. Descriptive statistics of relative values of total work in right knee flexor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Right flexor	2419.77±488.27	2338.15±639.37	2339.00±538.86	2365.64±545.51

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 51. The result of repeated-measures ANOVA for relative values of total work in left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	57136.974	2	28568.487	.255	.777
Error	2686217.026	24	111925.709		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of total work in right knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 50>. <Table 51> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of total work in right knee flexor.

As a result of repeated measures ANOVA in <Table 51>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of total work in right knee flexor (F=.255, p=.777).

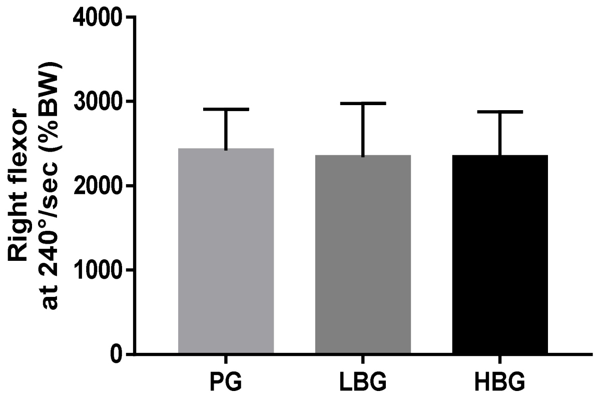


Figure 34. Comparison of relative values of total work in right knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

③ Absolute values of total work in right knee extensor

<Table 52>, <Table 53>, and <Figure 35> indicate the results of absolute values of total work in right knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 52. Descriptive statistics of absolute values of total work in right knee extensor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Right extensor	2578.23±446.20	2857.54±602.96*	3014.61±497.78***	2816.79±537.92

*Mean±Standard Deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; N·m, newton meter; *p<.05 and ***p<.001 compared to PG*

Table 53. The result of repeated-measures ANOVA for absolute values of total work in right knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	1270175.744	2	635087.872	11.232	.001
Error	1356995.590	24	56541.483		

Mean±standard deviation; PG, placebo group; LBG, low-volume beetroot supplement group; HBG, high-volume beetroot supplement group; N·m, newton meter

The mean and standard deviation values of absolute values of total work in right knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 52>. <Table 53> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of total work in right knee extensor.

As a result of repeated measures ANOVA in <Table 53>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of total work in right knee extensor (F=11.232, p=.001). We found that LBG (p=.041) and HBG (p=.001) was significantly higher than that observed in the PG.

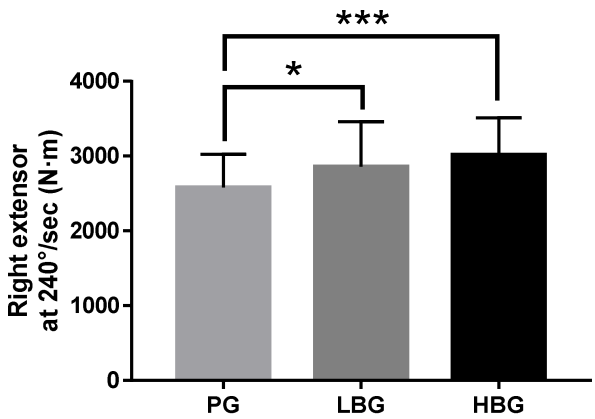


Figure 35. Comparison of absolute values of total work in right knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter;* $^{*}p<.05$ and $^{***}p<.001$ compared to PG

④ Relative values of total work in right knee extensor

<Table 54>, <Table 55>, and <Figure 36> indicate the results of relative values of total work in right knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 54. Descriptive statistics of relative values of total work in right knee extensor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Right extensor	3334.15±481.95	3802.30±730.70	4000.69±447.18***	3712.38±620.69

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* ****p<.001 compared to PG*

Table 55. The result of repeated-measures ANOVA for relative values of total work in right knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	3045458.000	2	1522729.000	9.987	.001
Error	3659188.667	24	152466.194		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of total work in right knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 54>. <Table 55> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of total work in right knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 55>, there was a significant difference between groups (F=9.987, p=.001). We found that HBG (p=.001) was significantly higher than that observed in the PG.

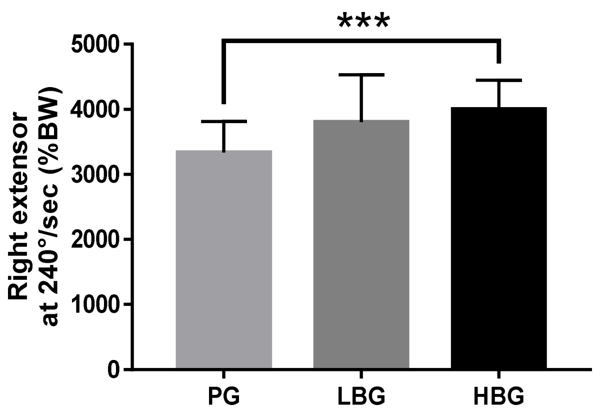


Figure 36. Comparison of relative values of total work in right knee extensor at 240°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* %BW*, percent body weight;* ***p<.001 compared to PG

⑤ Absolute values of total work in left knee flexor

<Table 56>, <Table 57>, and <Figure 37> indicate the results of absolute values of total work in left knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 56. Descriptive statistics of absolute values of total work in left knee flexor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Left flexor	1794.46±360.20	1756.00±548.78	1738.31±457.55	1762.92±450.28

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 57. The result of repeated-measures ANOVA for absolute values of total work in left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	21430.769	2	10715.385	.119	.888
Error	2154575.897	24	89773.996		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of total work in left knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 56>. <Table 57> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of total work in left knee flexor.

As a result of repeated measures ANOVA in <Table 57>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of total work in left knee flexor (F=.119, p=.888).

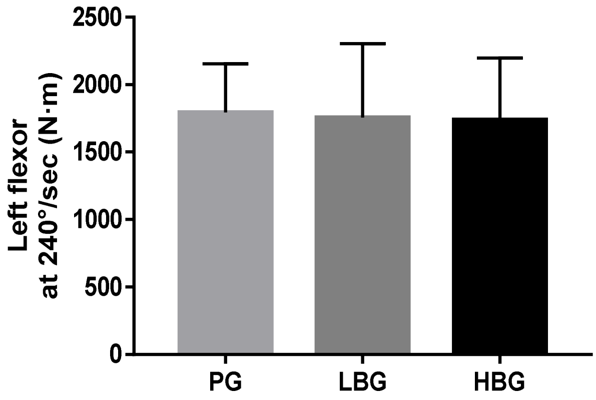


Figure 37. Comparison of absolute values of total work in left knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑥ Relative values of total work in left knee flexor

<Table 58>, <Table 59>, and <Figure 38> indicate the results of relative values of total work in left knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 58. Descriptive statistics of relative values of total work in left knee flexor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Left flexor	2407.23±534.94	2324.00±651.72	2325.85±644.90	2352.36±597.81

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 59. The result of repeated-measures ANOVA for relative values of total work in left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	58734.971	2	29367.487	.192	.827
Error	3676923.692	24	153205.154		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of total work in left knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 58>. <Table 59> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of total work in left knee flexor.

As a result of repeated measures ANOVA in <Table 59>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of total work in left knee flexor (F=.192, p=.827).

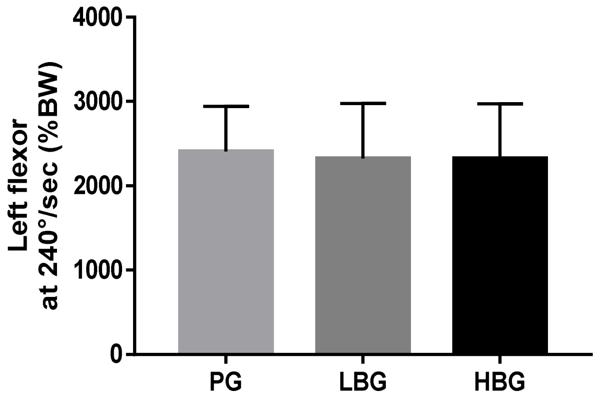


Figure 38. Comparison of relative values of total work in left knee flexor at 240°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* %BW*, percent body weight*

⑦ Absolute values of total work in left knee extensor

<Table 60>, <Table 61>, and <Figure 39> indicate the results of absolute values of total work in left knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 60. Descriptive statistics of absolute values of total work in left knee extensor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Left extensor	2595.46±457.24	2808.77±593.08	2940.23±471.06	2781.49±517.57

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 61. The result of repeated-measures ANOVA for absolute values of total work in left knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	787141.897	2	393570.949	4.593	.020
Error	2056620.103	24	85692.504		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of total work in left knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 60>. <Table 61> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of total work in left knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 55>, there was a significant difference between groups (F=4.593, p=.020).

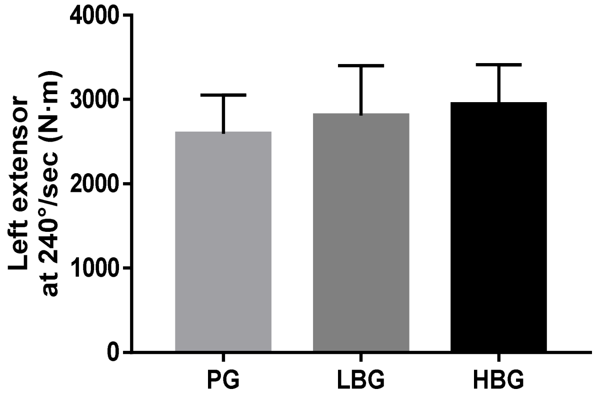


Figure 39. Comparison of absolute values of total work in left knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑧ Relative values of total work in left knee extensor

<Table 62>, <Table 63>, and <Figure 40> indicate the results of relative values of total work in left knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 62. Descriptive statistics of relative values of total work in left knee extensor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Left extensor	3352.00±429.23	3726.92±629.17*	3901.46±381.82**	3660.13±532.12

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* *$p<.05$ and **$p<.01$ *compared to PG*

Table 63. The result of repeated-measures ANOVA for relative values of total work in left knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	2049402.205	2	1024701.103	8.787	.001
Error	2798835.795	24	116618.158		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of total work in left knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 62>. <Table 63> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of total work in left knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 63>, there was a significant difference between groups (F=8.787, p=.001). We found that LBG (p=0.026) and HBG (p=0.002) was significantly higher than that observed in the PG.

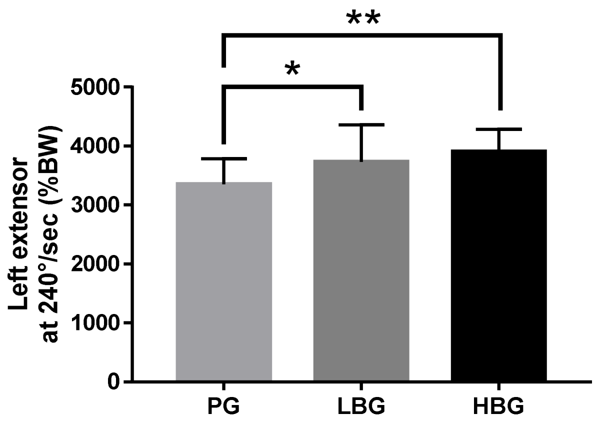


Figure 40. Comparison of relative values of total work in left knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* *p<.05 and **p<.01 compared to PG

⑨ Absolute values of average power in right knee flexor

<Table 64>, <Table 65>, and <Figure 41> indicate the results of absolute values of average power in right knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 64. Descriptive statistics of absolute values of average power in right knee flexor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Right flexor	182.46±37.13	169.23±41.25	176.15±40.53	175.95±39.00

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 65. The result of repeated-measures ANOVA for absolute values of average power in right knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	1138.667	2	569.333	1.610	.221
Error	8487.333	24	353.639		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of average power in right knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 64>. <Table 65> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of average power in right knee flexor.

As a result of repeated measures ANOVA in <Table 65>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of average power in right knee flexor (F=1.610, p=.221).

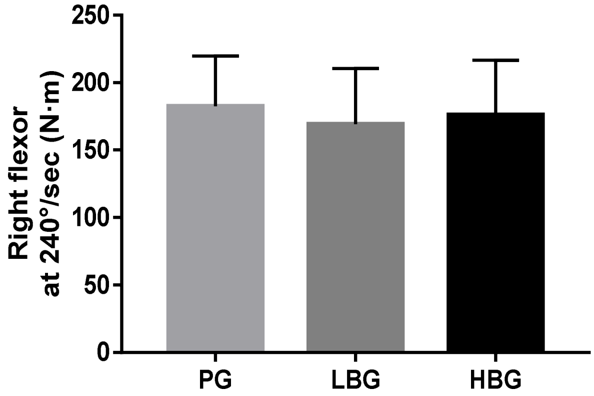


Figure 41. Comparison of absolute values of average power in right knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑩ Relative values of average power in right knee flexor

<Table 66>, <Table 67>, and <Figure 42> indicate the results of relative values of average power in right knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 66. Descriptive statistics of relative values of average power in right knee flexor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Right flexor	235.31±39.90	224.46±49.93	234.54±51.93	231.44±46.54

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 67. The result of repeated-measures ANOVA for relative values of average power in right knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	952.359	2	476.179	.595	.559
Error	19199.641	24	799.985		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of average power in right knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 66>. <Table 67> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of average power in right knee flexor.

As a result of repeated measures ANOVA in <Table 67>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of average power in right knee flexor (F=.595, p=.559).

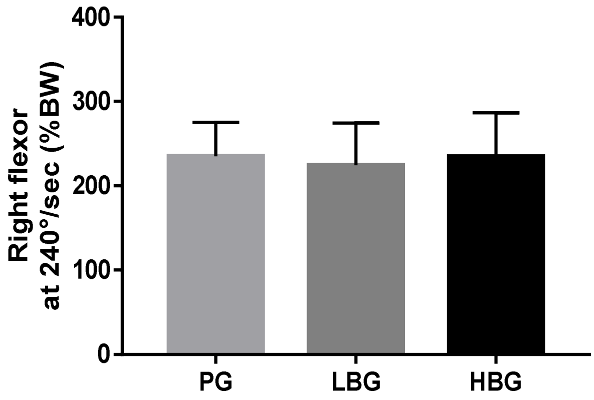


Figure 42. Comparison of relative values of average power in right knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

⑪ Absolute values of average power in right knee extensor

<Table 68>, <Table 69>, and <Figure 43> indicate the results of absolute values of average power in right knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 68. Descriptive statistics of absolute values of average power in right knee extensor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Right extensor	231.30±44.89	255.54±56.92	275.85±51.59	254.23±53.29

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter;* ***$p<.001$ *compared to PG*

Table 69. The result of repeated-measures ANOVA for absolute values of average power in right knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	12927.231	2	6463.615	12.035	.001
Error	12890.103	24	537.088		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of average power in right knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 68>. <Table 69> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of average power in right knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 69>, there was a significant difference between groups (F=12.035, p=.001). We found that HBG (p=.001) was significantly higher than that observed in the PG.

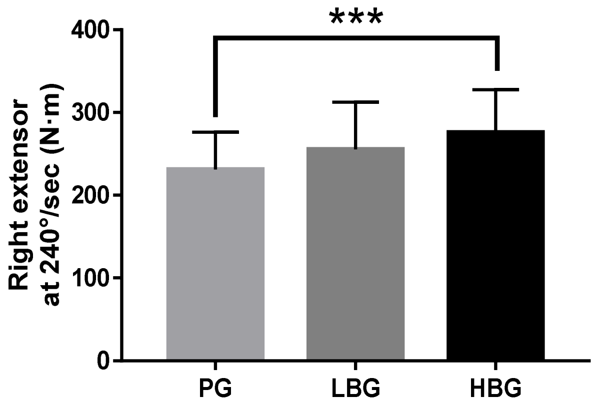


Figure 43. Comparison of absolute values of average power in right knee extensor at 240°/sec. PG*, placebo group;* LBG, *low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* N·m*, newton meter;* $^{***}p<.001$ compared to PG

⑫ Relative values of average power in right knee extensor

<Table 70>, <Table 71>, and <Figure 44> indicate the results of relative values of average power in right knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 70. Descriptive statistics of relative values of average power in right knee extensor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Right extensor	297.92±44.87	341.38±75.25	365.77±50.62***	335.03±63.57

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* ****p<.001 compared to PG*

Table 71. The result of repeated-measures ANOVA for relative values of average power in right knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	30708.667	2	15354.333	11.301	.001
Error	32607.333	24	1358.639		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of average power in right knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 70>. <Table 71> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of average power in right knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 71>, there was a significant difference between groups (F=11.301, p=.001). We found that HBG (p=.001) was significantly lower than that observed in the PG.

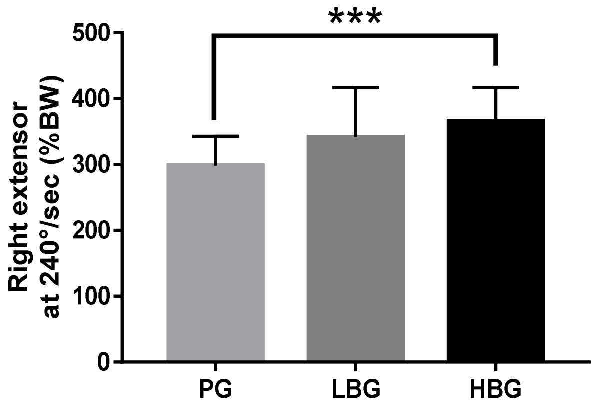


Figure 44. Comparison of relative values of average power in right knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* $^{***}p<.001$ compared to PG

⑬ Absolute values of average power in left knee flexor

<Table 72>, <Table 73>, and <Figure 45> indicate the results of absolute values of average power in left knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 72. Descriptive statistics of absolute values of average power in left knee flexor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Left flexor	177.31±34.38	168.46±48.06	164.38±38.27	170.05±39.94

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 73. The result of repeated-measures ANOVA for absolute values of average power in left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	1134.821	2	567.410	.921	.412
Error	14783.846	24	615.994		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of average power in left knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 72>. <Table 73> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of average power in left knee flexor.

As a result of repeated measures ANOVA in <Table 73>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of average power in left knee flexor (F=.921, p=.412).

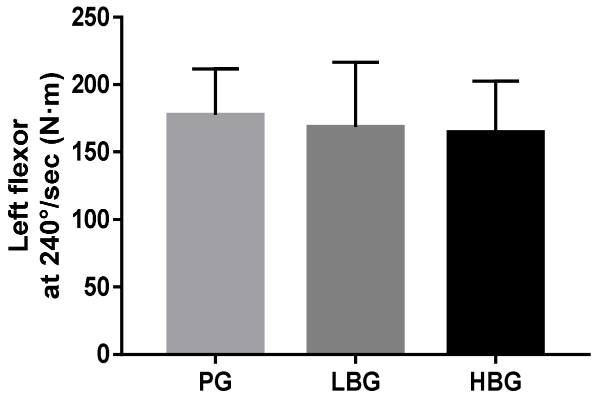


Figure 45. Comparison of absolute values of average power in left knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

⑭ Relative values of average power in left knee flexor

<Table 74>, <Table 75>, and <Figure 46> indicate the results of relative values of average power in left knee flexor at 240°/sec to analyze the difference in isokinetic muscle endurance in left knee following beetroot juice supplementation.

Table 74. Descriptive statistics of relative values of average power in left knee flexor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Left flexor	228.54±35.75	222.69±55.01	219.85±54.49	223.69±48.07

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 75. The result of repeated-measures ANOVA for relative values of average power in left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	510.615	2	255.308	.257	.776
Error	23862.718	24	994.280		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of average power in left knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 74>. <Table 75> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of average power in left knee flexor.

As a result of repeated measures ANOVA in <Table 75>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of average power in left knee flexor (F=.257, p=.776).

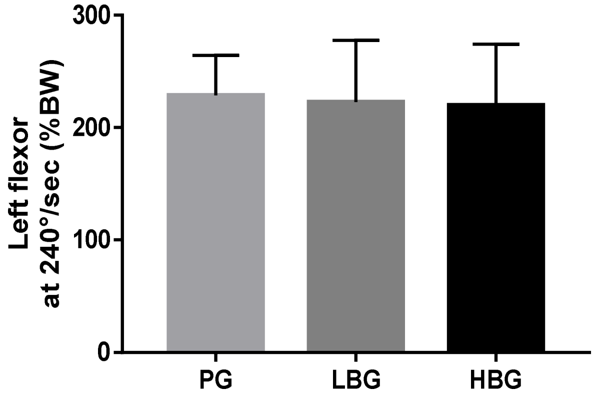


Figure 46. Comparison of relative values of average power in left knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

⑮ Absolute values of average power in left knee extensor

<Table 76>, <Table 77>, and <Figure 47> indicate the results of absolute values of average power in left knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 76. Descriptive statistics of absolute values of average power in left knee extensor at 240°/sec (N·m)

	PG	LBG	HBG	Total
Left extensor	229.00±44.57	249.69±56.27	262.77±43.93	247.15±49.34

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 77. The result of repeated-measures ANOVA for absolute values of average power in left knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	7538.000	2	3769.000	3.989	.032
Error	22677.333	24	944.889		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of average power in left knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 76>. <Table 77> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of average power in left knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 77>, there was a significant difference between groups (F=3.989, p=.032).

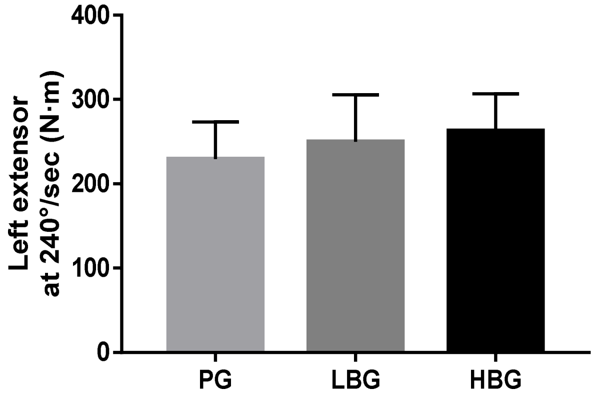


Figure 47. Comparison of absolute values of average power in left knee extensor at 240°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* N·m*, newton meter*

⑯ Relative values of average power in left knee extensor

<Table 78>, <Table 79>, and <Figure 48> indicate the results of relative values of average power in left knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 78. Descriptive statistics of relative values of average power in left knee extensor at 240°/sec (%BW)

	PG	LBG	HBG	Total
Left extensor	295.31±41.81	331.46±61.77*	349.38±42.78**	325.38±53.42

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight;* *$p<.05$ and **$p<.01$ *compared to PG*

Table 79. The result of repeated-measures ANOVA for relative values of average power in left knee extensor at 240°/sec among all groups

	SS	df	MS	*F*	*p*
Between Subject	19728.154	2	9864.077	7.852	.002
Error	30149.179	24	1256.216		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of average power in left knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 78>. <Table 79> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of average power in left knee extensor.

As indicated by the results of repeated measures ANOVA in <Table 79>, there was a significant difference between groups (F=7.852, p=.002). We found that LBG (p=.048) and HBG (p=.004) was significantly lower than that observed in the PG.

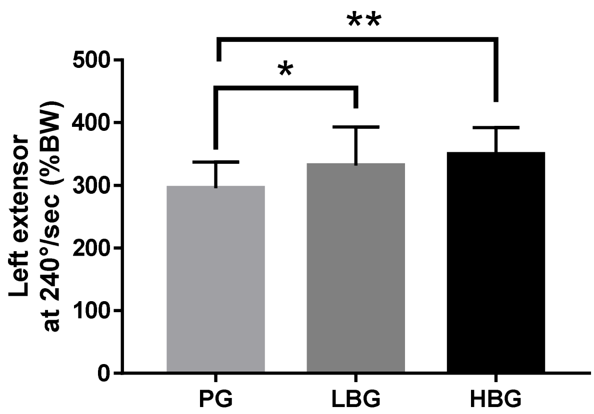


Figure 48. Comparison of relative values of average power in left knee extensor at 240°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* %BW, *percent body weight*; $^{*}p<.05$ and $^{**}p<.01$ compared to PG

⑰ Endurance ratio for right knee flexor

<Table 80>, <Table 81>, and <Figure 49> indicate the results of endurance ratio for right knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 80. Descriptive statistics of endurance ratio for right knee flexor at 240°/sec (%)

	PG	LBG	HBG	Total
Endurance ratio for right flexor	80.68±5.15	82.57±7.25	78.55±6.07	80.60±6.27

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 81. The result of repeated-measures ANOVA for endurance ratio for right knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	105.337	2	52.668	2.556	.099
Error	494.602	24	20.608		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of endurance ratio for right knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 80>. <Table 81> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the endurance ratio for right knee flexor.

As a result of repeated measures ANOVA in <Table 81>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the endurance ratio for right knee flexor (F=2.556, p=.099).

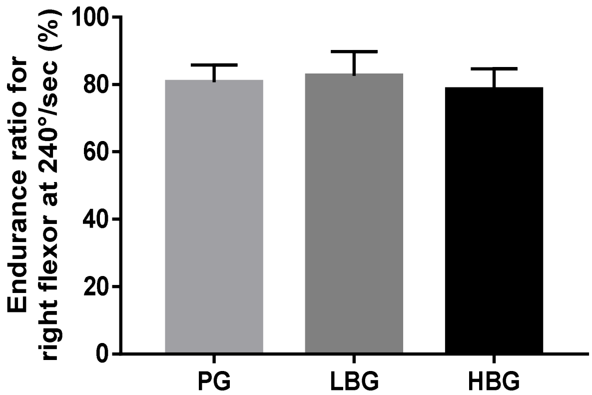


Figure 49. Comparison of endurance ratio for right knee flexor at 240°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group*

⑱ Endurance ratio for right knee extensor

<Table 82>, <Table 83>, and <Figure 50> indicate the results of endurance ratio for right knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in right knee following beetroot juice supplementation.

Table 82. Descriptive statistics of endurance ratio for right knee extensor at 240°/sec (%)

	PG	LBG	HBG	Total
Endurance ratio for right extensor	78.52±4.44	79.20±4.64	78.30±4.97	78.67±4.58

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 83. The result of repeated-measures ANOVA for endurance ratio for right knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	5.853	2	2.927	.228	.752
Error	243.704	24	10.154		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of endurance ratio for right knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 82>. <Table 83> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the endurance ratio for right knee extensor.

As a result of repeated measures ANOVA in <Table 83>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the endurance ratio for right knee extensor (F=.228, p=.752).

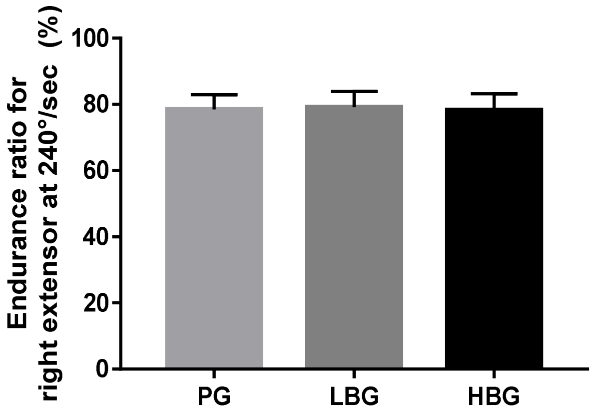


Figure 50. Comparison of endurance ratio for right knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

⑲ Endurance ratio for left knee flexor

<Table 84>, <Table 85>, and <Figure 51> indicate the results of endurance ratio for left knee flexor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 84. Descriptive statistics of endurance ratio for left knee flexor at 240°/sec (%)

	PG	LBG	HBG	Total
Endurance ratio for left flexor	83.82±5.59	83.04±6.45	81.24±8.38	82.70±6.81

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

Table 85. The result of repeated-measures ANOVA for endurance ratio for left knee flexor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	45.479	2	22.739	1.538	.235
Error	354.886	24	14.787		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of endurance ratio for left knee flexor at 240°/sec according to the beetroot juice supplementation are presented in <Table 84>. <Table 85> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the endurance ratio for left knee flexor.

As a result of repeated measures ANOVA in <Table 85>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the endurance ratio for left knee flexor (F=1.538, p=.235).

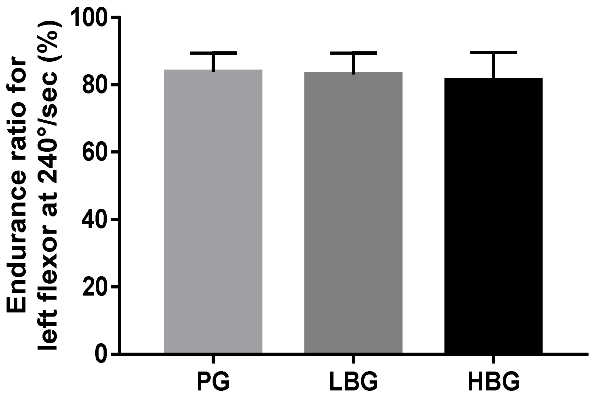


Figure 51. Comparison of endurance ratio for left knee flexor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

⑳ Endurance ratio for left knee extensor

<Table 86>, <Table 87>, and <Figure 52> indicate the results of endurance ratio for left knee extensor at 240°/sec to analyze the difference in isokinetic muscular endurance in left knee following beetroot juice supplementation.

Table 86. Descriptive statistics of endurance ratio for left knee extensor at 240°/sec (%)

	PG	LBG	HBG	Total
Endurance ratio for left extensor	80.95±6.85	81.76±5.59	79.40±4.61	80.70±5.69

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

.

Table 87. The result of repeated-measures ANOVA for endurance ratio for left knee extensor at 240°/sec

	SS	df	MS	*F*	*p*
Between Subject	37.560	2	18.780	.914	.415
Error	493.360	24	20.557		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

The mean and standard deviation values of endurance ratio for left knee extensor at 240°/sec according to the beetroot juice supplementation are presented in <Table 86>. <Table 87> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the endurance ratio for left knee extensor.

As a result of repeated measures ANOVA in <Table 87>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the endurance ratio for left knee extensor (F=.914, p=.415).

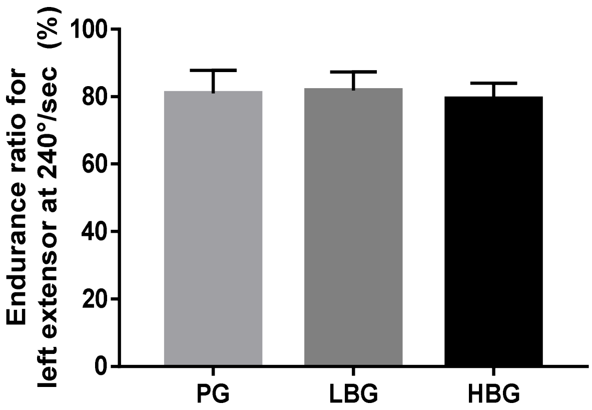


Figure 52. Comparison of endurance ratio for left knee extensor at 240°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group*

(3). Difference in isokinetic muscle strength in trunk according to beetroot juice supplementation

① Absolute values of peak torque in trunk flexor

<Table 88>, <Table 89>, and <Figure 53> indicate the results of absolute values of peak torque in trunk flexor at 30°/sec to analyze the difference in isokinetic muscular strength in trunk following beetroot juice supplementation.

Table 88. Descriptive statistics of absolute values of peak torque in trunk flexor at 30°/sec (N·m)

	PG	LBG	HBG	Total
Flexor	232.38±40.12	234.92±43.70	241.15±43.71	236.15±41.58

Mean±Standard Deviation; PG, placebo group; LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 89. The result of repeated-measures ANOVA for absolute values of peak torque in trunk flexor at 30°/sec

	SS	df	MS	*F*	*p*
Between Subject	529.385	2	264.692	.913	.415
Error	6960.615	24	290.026		

Mean±standard deviation; PG, placebo group; LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in trunk flexor at 30°/sec according to the beetroot juice supplementation are presented in <Table 88>. <Table 89> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in trunk flexor.

As a result of repeated measures ANOVA in <Table 89>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in trunk flexor (F=.913, p=.415).

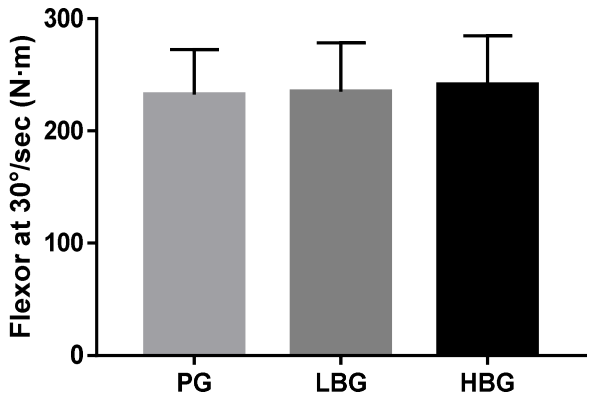


Figure 53. Comparison of absolute values of peak torque in trunk flexor at 30°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

② Relative values of peak torque in trunk flexor

<Table 90>, <Table 91>, and <Figure 54> indicate the results of relative values of peak torque in trunk flexor at 30°/sec to analyze the difference in isokinetic muscle strength in trunk following beetroot juice supplementation.

Table 90. Descriptive statistics of relative values of peak torque in trunk flexor at 30°/sec (%BW)

	PG	LBG	HBG	Total
Flexor	309.69±45.69	311.54±38.90	313.38±40.38	311.54±40.98

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 91. The result of repeated-measures ANOVA for relative values of peak torque in trunk flexor at 30°/sec

	SS	df	MS	*F*	*p*
Between Subject	88.615	2	44.308	.146	.865
Error	7267.385	24	302.808		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of peak torque in trunk flexor at 30°/sec according to the beetroot juice supplementation are presented in <Table 90>. <Table 91> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in trunk flexor.

As a result of repeated measures ANOVA in <Table 91>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in trunk flexor (F=.146, p=.865).

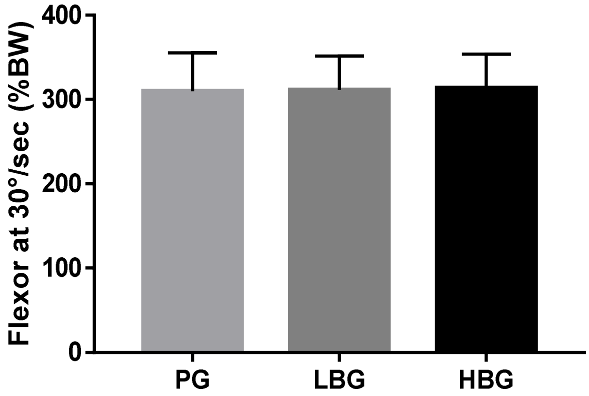


Figure 54. Comparison of relative values of peak torque in trunk flexor at 30°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* %BW*, percent body weight*

③ Absolute values of peak torque in trunk extensor

<Table 92>, <Table 93>, and <Figure 55> indicate the results of absolute values of peak torque in trunk extensor at 30°/sec to analyze the difference in isokinetic muscular strength in trunk following beetroot juice supplementation.

Table 92. Descriptive statistics of absolute values of peak power in trunk extensor at 30°/sec (N·m)

	PG	LBG	HBG	Total
Extensor	289.23±51.29	307.08±58.40	301.31±39.20	299.21±49.50

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

Table 93. The result of repeated-measures ANOVA for absolute values of peak power in trunk extensor at 30°/sec

	SS	df	MS	*F*	*p*
Between Subject	2156.359	2	1078.179	3.086	.064
Error	8384.974	24	349.374		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* N·m, *newton meter*

The mean and standard deviation values of absolute values of peak torque in trunk extensor at 30°/sec according to the beetroot juice supplementation are presented in <Table 92>. <Table 93> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the absolute values of peak torque in trunk extensor.

As a result of repeated measures ANOVA in <Table 93>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the absolute values of peak torque in trunk extensor (F=3.086, p=.064).

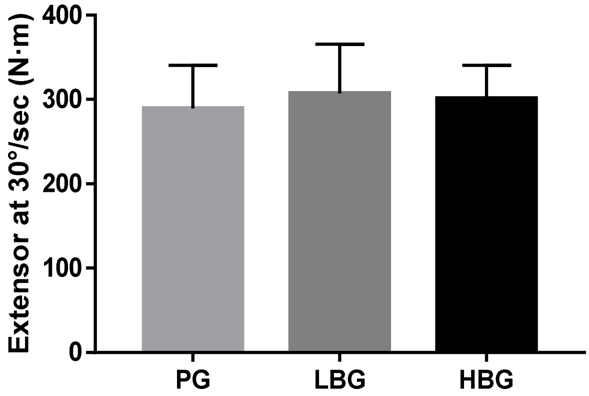


Figure 55. Comparison of absolute values of peak power in trunk extensor at 30°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* N·m*, newton meter*

④ Relative values of peak torque in trunk extensor

<Table 94>, <Table 95>, and <Figure 56> indicate the results of relative values of peak torque in trunk extensor at 30°/sec to analyze the difference in isokinetic muscular strength in trunk following beetroot juice supplementation.

Table 94. Descriptive statistics of relative values of peak torque in trunk extensor at 30°/sec (%BW)

	PG	LBG	HBG	Total
Extensor	385.00±59.95	409.00±74.69	402.31±51.62	398.77±61.99

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Table 95. The result of repeated-measures ANOVA for relative values of peak torque in trunk extensor at 30°/sec

	SS	df	MS	*F*	*p*
Between Subject	3988.154	2	1994.077	2.867	.076
Error	16694.513	24	695.605		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

The mean and standard deviation values of relative values of peak torque in trunk extensor at 30°/sec according to the beetroot juice supplementation are presented in <Table 94>. <Table 95> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the relative values of peak torque in trunk extensor.

As a result of repeated measures ANOVA in <Table 95>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the relative values of peak torque in trunk extensor ($F=2.867$, $p=.076$).

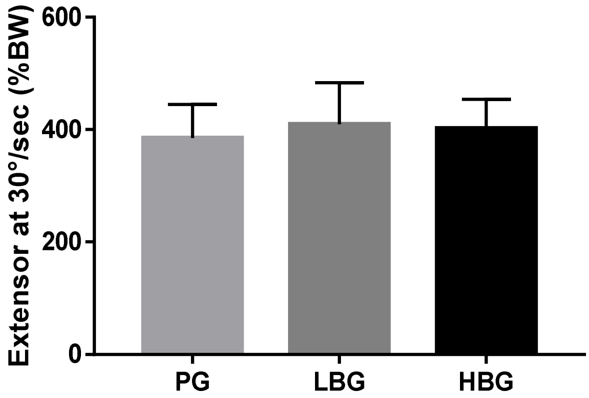


Figure 56. Comparison of relative values of peak torque in trunk extensor at 30°/sec. PG*, placebo group;* LBG*, low-volume beetroot supplement group;* HBG*, high-volume beetroot supplement group;* %BW*, percent body weight*

⑤ F:E ratio of trunk

<Table 96>, <Table 97>, and <Figure 57> indicate the results of F:E ratio ofr trunk at 30°/sec to analyze the difference in F:E ratio of trunk following beetroot juice supplementation.

Table 96. Descriptive statistics of F:E ratio of trunk at 30°/sec (%)

	PG	LBG	HBG	Total
F:E ratio for trunk	81.00±10.33	78.08±14.25	78.54±10.10	79.21±11.48

Mean±Standard Deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* F:E, *flexion:extension*

Table 97. The result of repeated-measures ANOVA for F:E ratio of trunk at 30°/sec

	SS	df	MS	*F*	*p*
Between Subject	64.205	2	32.103	.902	.419
Error	853.795	24	35.575		

Mean±standard deviation; PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* F:E, *flexor:extensor*

The mean and standard deviation values of F:E ratio of trunk at 30°/sec according to the beetroot juice supplementation are presented in <Table 96>. <Table 97> shows the results of repeated measures ANOVA used to analyze differences between groups after measuring the F:E ratio of trunk.

As a result of repeated measures ANOVA in <Table 97>, there was no significant difference between groups, indicating that beetroot juice supplementation had no effect on the F:E ratio of trunk (F=.902, p=.419).

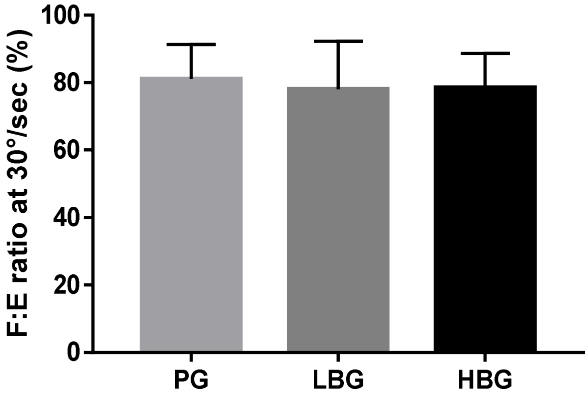


Figure 57. Comparison of F:E ratio of trunk at 30°/sec. PG, *placebo group;* LBG, *low-volume beetroot supplement group;* HBG, *high-volume beetroot supplement group;* %BW, *percent body weight*

Ⅴ. Discussion

Modern sports are divided into aerobic and anaerobic exercise according to the energy system used. Aerobic exercise generates energy through the krebs cycle and oxidative phosphorylation process, and is characterized by a relatively low-intensity exercise for a long time. In contrast, anaerobic exercise generates energy through the ATP-PC system, glycolysis, and lactate shuttle, and involves performing high-intensity exercise for a short time. Sports that mainly perform anaerobic exercise are classified as power sports. Since power players use strong force within a short time, physical factors, such as speed, maximum strength, and power, are emphasized. However, as the performance of modern athletes gradually improves, power endurance, the ability to sustain speed, maximum strength, and agility, is also emphasized in power athletes(Suna & Kumartasli, 2017). Therefore, power athletes need to improve both aerobic and anaerobic fitness factors.

Various training methods, periodization programs, and nutritional intake methods are being actively studied to improve factors related to the aerobic and anaerobic performance of power athletes. Among them, nutrition intake is an increasingly interesting factor in sports, because it is closely related to the removal of fatigue substances after exercise, muscle growth, and improvement of physical strength. Long-term eating habits, balanced nutrition, vitamin and mineral intake, the timing of intake, and ergogenic supplement intake can affect the performance of athletes, many researchers are currently investigating these participants (Guest et al., 2019). Nitrate intake among various nutrients helps to establish blood vessels by increasing NO and nitrite in the blood. Increased blood flow and neurotransmission reportedly induce a steady supply of energy sources and positive changes in aerobic and anaerobic performance (Coggan et al., 2015; Larsen et al., 2011; Lundberg et al., 2008). Therefore, in this study, aerobic and anaerobic performance factors and isokinetic muscle function were measured, compared, and analyzed after nitrate intake via beetroot juice.

Aerobic capacity refers to the ability to sustain submaximal exercise and is important for long-distance athletes and various types of exercise. The harvard step test is a reliable measurement tool used to measure cardiorespiratory endurance to determine aerobic capacity. As a result of analyzing aerobic capacity according to beetroot juice intake in this study, there were no significant differences between groups. According to a previous study that analyzed the relationship between beetroot juice intake and aerobic exercise performance, a single intake of 70ml beet juice did not show a significant difference compared to the placebo group in the 5km running test. It was reported that beetroot juice intake did not improve aerobic exercise performance (Hurst et al., 2020). In addition, Cermak et al. (2012) reported that ingestion of 140ml beetroot juice had no effect on the aerobic performance of cyclists. Meanwhile, in a study by Hemmatinafar et al. (2021), soccer players were asked to consume 140ml beetroot juice per day for six days, followed by a Yo-Yo test. The Yo-Yo test performance significantly increased in the group taking beetroot juice compared to the placebo group. A literature review on beetroot juice and cardiorespiratory endurance also suggested that chronic beetroot juice intake could improve aerobic exercise performance compared to acute beetroot juice intake (Domínguez et al., 2017). Combining the results of previous studies and this study, we conclude that acute ingestion of beet juice does not affect aerobic exercise performance regardless of the dose. However, some studies suggest the possibility that chronic supplementation of beetroot juice can improve aerobic capacity.

SAQ ability refers to speed, agility, and reaction time. In modern sports, speed, agility, and reaction time are representative physical fitness factors that affect the performance of athletes. In this study, a 20 m sprint test was conducted to measure speed. We found that the low-volume and high-volume beetroot juice groups displayed significantly improved speed compared to the placebo group. A previous study reported that the 20m sprint performance was improved after ingestion of a low-volume (70ml) beetroot juice, while a study measuring a short distance sprint after ingestion of a high-volume (140ml) beetroot juice also reported that running performance improved (Lansley et al., 2011; Sandbakk et al., 2015). According to a previous study analyzing the underlying mechanism, nitrate intake increases blood NO concentration, and NO directly increases acetylcholine action in the muscle, thereby exerting strong muscle contractility (Petrov et al., 2013). Another study reported that the increase in NO through beetroot juice intake was due to activation of the NO-CGMP mechanism to induce neuromuscular activity (Rimer et al., 2016). Combining the results of this study and previous studies to date, it is thought that beetroot juice supplementation of 70ml or more is effective as an ergogenic supplement to improve sprint ability.

Among SAQ abilities, agility refers to the ability to change direction, and is one of the most important physical fitness factors for athletes. In this study, the side step test was used to measure agility, and there was no significant difference between groups. A previous study verified the effect of beetroot juice on agility using the Illinois test after administering 250ml of nitrate to soccer players. No significant difference was observed between the groups, which agrees with the results obtained from the present study (Karampelas et al., 2021). Based on our presents and results from previous studies, we conclude that beet juice intake had no significant effect on agility. However, further research is currently underway to determine the relationship between beetroot juice and agility, and future research should be conducted on these participants.

Reaction time refers to the speed of responding to stimuli, such as sound and light, and is mainly measured through the whole-body reaction time test. In this study, we observed no difference in whole-body reaction time between groups. According to a previous study on beetroot juice supplementation and reaction time, team sports players were asked to consume 140 ml of beet juice for seven days, and the reaction time was measured on the seventh day. Research has found that consumption of beetroot juice was effective in improving reaction time (Tompson et al., 2015). According to a previous study that revealed the neurological mechanism related to this, it was reported that nitrate supplementation had a positive effect on cognitive function by increasing hippocampal blood flow (Aamand et al., 2013). However, the present study showed contradictory results to these previous studies. This is thought to be because, unlike previous studies, this study only allowed beetroot juice to be consumed once. Additional research is needed to determine the reaction time after long-term beetroot juice supplementation.

Anaerobic power is the ability to exert power in a short time. The Wingate test using a bicycle ergometer is used to measure anaerobic power. We determined anaerobic power by conducting the Wingate test after beetroot juice supplementation. We observed no significant difference between the maximum power and the average power. According to a previous study, the Wingate test was conducted for 30 s after administering 70ml of beetroot juice to athletes and results indicated that the maximum power and average power were improved (Domínguez, 2017; Kramer et al. al., 2016; Rimer et al., 2016). However, Conger et al. (2021) found that anaerobic power was not affected in power athletes after the consumption of 8 mmol beet juice. The results obtained from the present study do not agree with results from previous studies; however, there are some consistent results. Therefore, the relationship between beetroot juice supplementation and anaerobic power is still controversial, and it is necessary to investigate these participants further.

Blood lactate is a fatigue substance released into the blood after high-intensity exercise, and the degree of fatigue and recovery ability can be predicted by measuring the blood lactate concentration over time. In this study, blood lactate concentrations were measured and compared 3 min, 5 min, and 15 min after the Wingate test. We observed no significant difference in blood lactate concentration and removal rate of blood lactate within the study period. Cuenca et al. (2018) reported that Wingate performance was improved, but no difference in fatigue substances was found after supplementing with 70ml beetroot juice. Reynolds et al. (2020) reported that beet juice did not relieve blood lactate concentration after studying repeating sprints post-supplementation with 70ml beetroot juice. The results of many previous studies and the results of this study reported that beetroot juice supplementation did not affect on blood lactate concentration. However, some studies have reported that beet juice consumption can improve blood lactate concentration. Therefore, the relationship between beetroot juice and blood lactate concentration is still controversial (Domínguez et al., 2017).

The isokinetic muscle function test can precisely measure the function of a specific muscle, and it is used as a reliable test in modern scientific sports. Isokinetic muscle functions refer to the maximum force exerted at a constant angular velocity (Adams, 1998; Haff and Triplett, 2015), and the peak torque obtained here is calculated by the distance and magnitude of the force (distance × force) (Kemp & Anderson, 1988). When the peak torque is divided by the body weight (peak torque/body weight × 100), a relative value can be calculated, which can be a useful index for relative evaluation of the participants maximum exercise capacity (Perrin, 1993). In this study, isokinetic muscle function tests of the knee and trunk were performed at angular rates of 60°/sec and 30°/sec to measure the maximum muscle strength of the knee and trunk. We observed no significant difference between the groups for both variables. In a previous study that measured isokinetic muscle strength of the knee at 60°/sec after asking wrestlers to consume 140ml beetroot juice, it was reported that there was no significant difference between the beetroot juice group and the placebo group (Tatlici, 2021). In addition, a previous study investigated the effect of beetroot juice on maximum muscle strength after the consumption of beetroot juice for six days and reported no observed difference, which agrees with the results obtained from the present study (Jonvik et al., 2021). Therefore, physiological changes via beetroot juice supplementation did not improve maximal strength. Maximal strength is the ability to exert maximum force and is affected by the mobilization rate of motor units (Del Vecchio et al., 2019). It is thought that the physiological benefits of beetroot juice supplementation, such as vasodilation and increased blood flow, did not affect maximal strength. However, evidence comparing beetroot juice and maximal strength is lacking, and additional research regarding maximal strength, speed, power, and endurance is required.

Muscular endurance refers to the ability to continue the same movement. In this study, muscular endurance was determined by measuring isokinetic muscle function at an angular velocity of 240°/sec. We found that low-volume and high-volume beetroot juice intake had significantly higher total work and average power of left and right extensors compared to the placebo group. According to a previous study that measured muscle endurance at an angular velocity of 240°/sec, 70 ml of beetroot juice supplementation 3 h before measurement showed significantly higher muscle endurance in the right extensor muscle, consistent with the results of this study. These results show that increased bioavailability of NO due to the increased concentration of NO in the blood after supplementation with beetroot juice increases blood flow in skeletal muscle (Ferguson et al., 2013; Jones, 2014). In particular, it is thought that nitrate intake increased the content of $Ca2^{+}$-handling proteins, dihydropyridine receptors (DHPR), and calsequestrin (CASQ) in type II muscle fibers and improved the contractility of skeletal muscle (Hernández et al., 2012). Wylie et al. (2013) reported that the intake of 8.4 mmol of nitrate improved exercise performance, and that there was no additional performance benefit even if a high dose of nitrate (16.8 mmol) was ingested. Therefore, more than 70ml of beetroot juice supplementation is thought to be effective as an ergogenic supplement that can improve muscular endurance.

VI. Conclusion

The purpose of this study was to investigate the effects of beetroot juice supplementation on the aerobic and anaerobic performance factors and isokinetic muscle functions in 13 power athletes.

As a result of this study, the following conclusions were drawn.

First, there was no difference in aerobic exercise performance after beetroot juice supplementation.

Second, there was a significant difference between low-volume and high-volume beetroot juice supplementation in the 20m sprint compared to the placebo group.

Third, there was no significant difference in agility after beetroot juice supplementation.

Fourth. there was no significant difference in reaction time after beetroot juice supplementation.

Fifth, there was no significant difference in anaerobic power after beetroot juice supplementation.

Sixth, there was no significant difference in blood lactate concentration after beetroot juice supplementation.

Seventh, there was no significant difference in the isokinetic muscle function test in the trunk at 30°/sec after beetroot juice supplementation.

Eighth, there was no significant difference in the isokinetic muscle function test in the knee at 60°/sec after beetroot juice supplementation.

Ninth, as a result of isokinetic muscle function test in the knee at 240°/sec after supplementation with low-volume and high-volume beetroot juice revealed, significant differences in total work and average power of the right extensor muscles.

Taken together, oral intake of beetroot juice did not affect aerobic exercise performance, agility, reaction time, anaerobic power, fatigue, and isokinetic knee and trunk muscular strength, but had a positive effect on speed and isokinetic muscular endurance. Therefore, our finding suggested scientific evidence that beetroot juice intake before the performance might be used as an ergogenic supplement to improve performance-related physical fitness (speed and muscle endurance) in power athletes.

However, there was no statistically significant difference in aerobic exercise performance and anaerobic power. Therefore further studies are needed by additionally adjusting the dose and intake period.

References

Aamand, R., Dalsgaard, T., Ho, Y. C. L., Møller, A., Roepstorff, A., & Lund, T. E. (2013). A NO way to BOLD?: dietary nitrate alters the hemodynamic response to visual stimulation. Neuroimage, 83, 397-407.

Andrade, F. H., Reid, M. B., Allen, D. G., & Westerblad, H. (1998). Effect of nitric oxide on single skeletal muscle fibres from the mouse. The Journal of physiology, 509(2), 577-586.

Arazi, H., & Eghbali, E. (2021). Possible Effects of Beetroot Supplementation on Physical Performance Through Metabolic, Neuroendocrine, and Antioxidant Mechanisms: A Narrative Review of the Literature. Frontiers in Nutrition, 8.

Aucouturier, J., Boissière, J., Pawlak-Chaouch, M., Cuvelier, G., & Gamelin, F. X. (2015). Effect of dietary nitrate supplementation on tolerance to supramaximal intensity intermittent exercise. Nitric Oxide, 49, 16-25.

Bailey, S. J., Winyard, P., Vanhatalo, A., Blackwell, J. R., DiMenna, F. J., Wilkerson, D. P., ... & Jones, A. M. (2009). Dietary nitrate supplementation reduces the O2 cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. Journal of applied physiology.

Bentley, D. J., Ackerman, J., Clifford, T., & Slattery, K. S. (2015). Acute and chronic effects of antioxidant supplementation on exercise performance. Antioxidants in Sport Nutrition, 1st ed.; CRC Press: Boca Raton FL, USA, 141.

Bloomer, R. J., Farney, T. M., Trepanowski, J. F., McCarthy, C. G., Canale, R. E., & Schilling, B. K. (2010). Comparison of pre-workout nitric oxide stimulating dietary supplements on skeletal muscle oxygen saturation, blood nitrate/nitrite, lipid peroxidation, and upper body exercise performance in resistance trained men. Journal of the international society of sports nutrition, 7(1), 1-15.

Bogdanis, G. C., Nevill, M. E., Lakomy, H. K., Graham, C. M., & Louis, G. (1996). Effects of active recovery on power output during repeated maximal sprint cycling. European journal of applied physiology and occupational physiology, 74(5), 461-469.

Bondonno, C. P., Blekkenhorst, L. C., Prince, R. L., Ivey, K. L., Lewis, J. R., Devine, A., ... & Hodgson, J. M. (2017). Association of vegetable nitrate intake with carotid atherosclerosis and ischemic cerebrovascular disease in older women. Stroke, 48(7), 1724-1729.

Borg, G. (1998). Borg's perceived exertion and pain scales. Human kinetics.

Boulay, M. R., Lortie, G., Simoneau, J. A., Hamel, P., Leblanc, C., & Bouchard, C. (1985). Specificity of aerobic and anaerobic work capacities and powers. International journal of sports medicine, 6(6), 325-328.

Carlström, M., Lundberg, J. O., & Weitzberg, E. (2018). Mechanisms underlying blood pressure reduction by dietary inorganic nitrate. Acta Physiologica, 224(1), e13080.

Carter, P., Gray, L. J., Troughton, J., Khunti, K., & Davies, M. J. (2010). Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. Bmj, 341.

Castello, P. R., David, P. S., McClure, T., Crook, Z., & Poyton, R. O. (2006). Mitochondrial cytochrome oxidase produces nitric oxide under hypoxic conditions: implications for oxygen sensing and hypoxic signaling in eukaryotes. Cell metabolism, 3(4), 277-287.

Cermak, N. M., 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, 22(6), 470-478.

Clifford, P. S., & Hellsten, Y. (2004). Vasodilatory mechanisms in contracting skeletal muscle. Journal of applied physiology, 97(1), 393-403.

Clifford, T., Howatson, G., West, D. J., & Stevenson, E. J. (2015). The potential benefits of red beetroot supplementation in health and disease. Nutrients, 7(4), 2801-2822.

Coggan, A. R., Leibowitz, J. L., Kadkhodayan, A., Thomas, D. P., Ramamurthy, S., Spearie, C. A., ... & Peterson, L. R. (2015). Effect of acute dietary nitrate intake on maximal knee extensor speed and power in healthy men and women. Nitric Oxide, 48, 16-21.

Conger, S. A., Zamzow, C. M., & Darnell, M. E. (2021). Acute Beet Juice Supplementation Does Not Improve 30-or 60-second Maximal Intensity Performance in Anaerobically Trained Athletes. International Journal of Exercise Science, 14(2), 60.

Corbett, J., Neal, R. A., Lunt, H. C., & Tipton, M. J. (2014). Adaptation to heat and exercise performance under cooler conditions: a new hot topic. Sports Medicine, 44(10), 1323-1331.

Cuenca, E., Jodra, P., Pérez-López, A., González-Rodríguez, L. G., Fernandes da Silva, S., Veiga-Herreros, P., & Domínguez, R. (2018). Effects of beetroot juice supplementation on performance and fatigue in a 30-s all-out sprint exercise: a randomized, double-blind cross-over study. Nutrients, 10(9), 1222.

Del Vecchio, A., Casolo, A., Negro, F., Scorcelletti, M., Bazzucchi, I., Enoka, R., ... & Farina, D. (2019). The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. The Journal of physiology, 597(7), 1873-1887.

Domínguez, R., Cuenca, E., Maté-Muñoz, J. L., García-Fernández, P., Serra-Paya, N., Estevan, M. C. L., ... & Garnacho-Castaño, M. V. (2017). Effects of beetroot juice supplementation on cardiorespiratory endurance in athletes. A systematic review. Nutrients, 9(1), 43.

Domínguez, R., Garnacho-Castaño, M. V., & Maté-Muñoz, J. L. (2016). Efectos del entrenamiento contra resistencias o resistance training en diversas patologías. Nutrición Hospitalaria, 33(3), 719-733.

Domínguez, R., Garnacho-Castaño, M. V., Cuenca, E., García-Fernández, P., Muñoz-González, A., De Jesús, F., ... & Maté-Muñoz, J. L. (2017). Effects of beetroot juice supplementation on a 30-s high-intensity inertial cycle ergometer test. Nutrients, 9(12), 1360.

Domínguez, R., Maté-Muñoz, J. L., Cuenca, E., García-Fernández, P., Mata-Ordoñez, F., Lozano-Estevan, M. C., ... & Garnacho-Castaño, M. V. (2018). Effects of beetroot juice supplementation on intermittent high-intensity exercise efforts. Journal of the International Society of Sports Nutrition, 15(1), 1-12.

Enoka, R. M., & Duchateau, J. (2008). Muscle fatigue: what, why and how it influences muscle function. The Journal of physiology, 586(1), 11-23.

Eston, R., & Evans, H. J. L. (2009). The validity of submaximal ratings of perceived exertion to predict one repetition maximum. Journal of sports science & medicine, 8(4), 567.

Ferguson, S. K., Hirai, D. M., Copp, S. W., Holdsworth, C. T., Allen, J. D., Jones, A. M., ... & Poole, D. C. (2013). Impact of dietary nitrate supplementation via beetroot juice on exercising muscle vascular control in rats. The Journal of physiology, 591(2), 547-557.

Fullagar, H. H., Skorski, S., Duffield, R., Hammes, D., Coutts, A. J., & Meyer, T. (2015). Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. Sports medicine, 45(2), 161-186.

Galanti, G., Stefani, L., Scacciati, I., Mascherini, G., Buti, G., & Maffulli, N. (2015). Eating and nutrition habits in young competitive athletes: a comparison between soccer players and cyclists. Translational Medicine@ UniSa, 11, 44.

Gastin, P. B. (2001). Energy system interaction and relative contribution during maximal exercise. Sports medicine, 31(10), 725-741.

Gliszczyńska-Świgło, A., Szymusiak, H., & Malinowska, P. (2006). Betanin, the main pigment of red beet: Molecular origin of its exceptionally high free radical-scavenging activity. Food additives and contaminants, 23(11), 1079-1087.

Goedecke, J. H., Gibson, A. S. C., Grobler, L., Collins, M., Noakes, T. D., & Lambert, E. V. (2000). Determinants of the variability in respiratory exchange ratio at rest and during exercise in trained athletes. American Journal of Physiology-Endocrinology And Metabolism, 279(6), E1325-E1334.

Guest, N. S., Horne, J., Vanderhout, S. M., & El-Sohemy, A. (2019). Sport nutrigenomics: Personalized nutrition for athletic performance. Frontiers in nutrition, 6, 8.

Haff, G. G., & Triplett, N. T. (Eds.). (2015). Essentials of strength training and conditioning 4th edition. Human kinetics.

Hambrecht, R., Adams, V., Erbs, S., Linke, A., Krankel, N., Shu, Y., ... & Schuler, G. (2003). Regular physical activity improves endothelial function in patients with coronary artery disease by increasing phosphorylation of endothelial nitric oxide synthase. Circulation, 107(25), 3152-3158.

Haseler, L. J., Hogan, M. C., & Richardson, R. S. (1999). Skeletal muscle phosphocreatine recovery in exercise-trained humans is dependent on O2availability. Journal of applied physiology, 86(6), 2013-2018.

Hemmatinafar, M., Mosallanezhad, Z., Abdollahei, M. H., Yazdani, H., Samsami Pour, A., Kooroshfard, N., & Hanani, M. (2021). Beetroot Juice Supplementation Improves Fatigue, Aerobic, Anaerobic Performance and Nitrite concentration In College Soccer Players. Razi Journal of Medical Sciences, 28(2), 81-92.

Hernández, A., Schiffer, T. A., Ivarsson, N., Cheng, A. J., Bruton, J. D., Lundberg, J. O., ... & Westerblad, H. (2012). Dietary nitrate increases tetanic [Ca2+] i and contractile force in mouse fast twitch muscle. The Journal of physiology, 590(15), 3575-3583.

Higashi, Y., & Yoshizumi, M. (2004). Exercise and endothelial function: role of endothelium-derived nitric oxide and oxidative stress in healthy participants and hypertensive patients. Pharmacology & therapeutics, 102(1), 87-96.

Hobbs, D. A., Kaffa, N., George, T. W., Methven, L., & Lovegrove, J. A. (2012). Blood pressure-lowering effects of beetroot juice and novel beetroot-enriched bread products in normotensive male participantss. British Journal of Nutrition, 108(11), 2066-2074.

Hrabak, A., Bajor, T., Temesi, Á., & Mészáros, G. (1996). The inhibitory effect of nitrite, a stable product of nitric oxide (NO) formation, on arginase. FEBS letters, 390(2), 203-206.

Hultman, E., Greenhaff, P. L., Ren, J. M., & Söderlund, K. (1991). Energy metabolism and fatigue during intense muscle contraction. Biochemical Society Transactions, 19(2), 347-353.

Hurst, P., Saunders, S., & Coleman, D. (2020). No differences between beetroot juice and placebo on competitive 5-km running performance: A double-blind, placebo-controlled trial. International journal of sport nutrition and exercise metabolism, 1(aop), 1-6.

Jones, A. M. (2014). Dietary nitrate supplementation and exercise performance. Sports medicine, 44(1), 35-45.

Jonvik, K. L., Hoogervorst, D., Peelen, H. B., De Niet, M., Verdijk, L. B., Van Loon, L. J., & van Dijk, J. W. (2020). The impact of beetroot juice supplementation on muscular endurance, maximal strength and countermovement jump performance. European Journal of Sport Science, 1-8.

Kanner, J., Harel, S., & Granit, R. (2001). Betalains a new class of dietary cationized antioxidants. Journal of Agricultural and Food chemistry, 49(11), 5178-5185.

Kapadia, G. J., Azuine, M. A., Sridhar, R., Okuda, Y., Tsuruta, A., Ichiishi, E., ... & Tokuda, H. (2003). Chemoprevention of DMBA-induced UV-B promoted, NOR-1-induced TPA promoted skin carcinogenesis, and DEN-induced phenobarbital promoted liver tumors in mice by extract of beetroot. Pharmacological Research, 47(2), 141-148.

Kapil, V., Milsom, A. B., Okorie, M., Maleki-Toyserkani, S., Akram, F., Rehman, F., ... & Ahluwalia, A. (2010). Inorganic nitrate supplementation lowers blood pressure in humans: role for nitrite-derived NO. Hypertension, 56(2), 274-281.

Karampelas, D., Antonopoulos, K., Michailidis, Y., Mitrotasios, M., Mandroukas, A., & Metaxas, T. (2021). Comparison of Ergogenic Effects of Caffeine and Nitrate Supplementation on Speed, Power and Repeated Sprint Performance of Soccer Players. Physiologia, 1(1), 3-11.

Kramer, S. J., Baur, D. A., Spicer, M. T., Vukovich, M. D., & Ormsbee, M. J. (2016). The effect of six days of dietary nitrate supplementation on performance in trained CrossFit athletes. Journal of the International Society of Sports Nutrition, 13(1), 1-7.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjær, M., & Bangsbo, J. (2006). Muscle and blood metabolites during a soccer game: implications for sprint performance. Medicine and science in sports and exercise, 38(6), 1165-1174.

Krustrup, P., Söderlund, K., Relu, M. U., Ferguson, R. A., & Bangsbo, J. (2009). Heterogeneous recruitment of quadriceps muscle portions and fibre types during moderate intensity knee extensor exercise: effect of thigh occlusion. Scandinavian journal of medicine & science in sports, 19(4), 576-584.

Landmesser, U., & Drexler, H. (2007). Endothelial function and hypertension. Current opinion in cardiology, 22(4), 316-320.

Lansley, K. E., Winyard, P. G., Fulford, J., Vanhatalo, A., Bailey, S. J., Blackwell, J. R., ... & Jones, A. M. (2011). Dietary nitrate supplementation reduces the O2 cost of walking and running: a placebo-controlled study. Journal of applied physiology, 110(3), 591-600.

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, 13(2), 149-159.

Larsen, F. J., Weitzberg, E., Lundberg, J. O., & Ekblom, B. (2007). Effects of dietary nitrate on oxygen cost during exercise. Acta physiologica, 191(1), 59-66.

Larsen, F. J., Weitzberg, E., Lundberg, J. O., & Ekblom, B. (2010). Dietary nitrate reduces maximal oxygen consumption while maintaining work performance in maximal exercise. Free Radical Biology and Medicine, 48(2), 342-347.

Lidder, S., & Webb, A. J. (2013). Vascular effects of dietary nitrate (as found in green leafy vegetables and beetroot) via the nitrate nitrite nitric oxide pathway. British journal of clinical pharmacology, 75(3), 677-696.

Lundberg, J. O., Weitzberg, E., & Gladwin, M. T. (2008). The nitrate–nitrite–nitric oxide pathway in physiology and therapeutics. Nature reviews Drug discovery, 7(2), 156-167.

Machha, A., & Schechter, A. N. (2011). Dietary nitrite and nitrate: a review of potential mechanisms of cardiovascular benefits. European journal of nutrition, 50(5), 293-303.

Manchado, C., Cortell-Tormo, J. M., & Tortosa-Martínez, J. (2018). Effects of two different training periodization models on physical and physiological aspects of elite female team handball players. The Journal of Strength & Conditioning Research, 32(1), 280-287.

Mosher, S. L., Sparks, S. A., Williams, E. L., Bentley, D. J., & Mc Naughton, L. R. (2016). Ingestion of a nitric oxide enhancing supplement improves resistance exercise performance. The Journal of Strength & Conditioning Research, 30(12), 3520-3524.

Natera, A. O., Cardinale, M., & Keogh, J. W. (2020). The Effect of High Volume Power Training on Repeated High-Intensity Performance and the

Assessment of Repeat Power Ability: A Systematic Review. Sports Medicine, 50(7), 1317-1339.

Petrov, K. A., Malomouzh, A. I., Kovyazina, I. V., Krejci, E., Nikitashina, A. D., Proskurina, S. E., ... & Nikolsky, E. E. (2013). Regulation of acetylcholinesterase activity by nitric oxide in rat neuromuscular junction via N methyl d aspartate receptor activation. European Journal of Neuroscience, 37(2), 181-189.

Phillips, S. M. (2015). Nutritional supplements in support of resistance exercise to counter age-related sarcopenia. Advances in nutrition, 6(4), 452-460.

Pinna, M., Roberto, S., Milia, R., Marongiu, E., Olla, S., Loi, A., ... & Crisafulli, A. (2014). Effect of beetroot juice supplementation on aerobic response during swimming. Nutrients, 6(2), 605-615.

Plowman, S. A., & Smith, D. L. (2007). Anaerobic metabolism during exercise. Sports-Specific Rehabilitation, 23, 213-230.

Ranković, G., Mutavdžić, V., Toskić, D., Preljević, A., Kocić, M., Nedin-Ranković, G., & Damjanović, N. (2010). Aerobic capacity as an indicator in different kinds of sports. Bosnian journal of basic medical sciences, 10(1), 44.

Reynolds, C. M., Evans, M., Halpenny, C., Hughes, C., Jordan, S., Quinn, A., ... & Egan, B. (2020). Acute ingestion of beetroot juice does not improve short-duration repeated sprint running performance in male team sport athletes. Journal of Sports Sciences, 38(18), 2063-2070.

Rimer, E. G., Peterson, L. R., Coggan, A. R., & Martin, J. C. (2016). Increase in maximal cycling power with acute dietary nitrate supplementation. International Journal of Sports Physiology and Performance, 11(6), 715-720.

Rosenblat, M. A., Perrotta, A. S., & Thomas, S. G. (2020). Effect of high-intensity interval training versus sprint interval training on time-trial performance: a systematic review and meta-analysis. Sports Medicine, 50(6), 1145-1161.

Sacheck, J. M., & Blumberg, J. B. (2001). Role of vitamin E and oxidative stress in exercise. Nutrition, 17(10), 809-814.

Sandbakk, S. B., Sandbakk, Ø., Peacock, O., James, P., Welde, B., Stokes, K., ... & Tjønna, A. E. (2015). Effects of acute supplementation of L-arginine and nitrate on endurance and sprint performance in elite athletes. Nitric Oxide, 48, 10-15.

Shiva, S., Huang, Z., Grubina, R., Sun, J., Ringwood, L. A., MacArthur, P. H., ... & Gladwin, M. T. (2007). Deoxymyoglobin is a nitrite reductase that generates nitric oxide and regulates mitochondrial respiration. Circulation research, 100(5), 654-661.

Stamler, J. S., & Meissner, G. (2001). Physiology of nitric oxide in skeletal muscle. Physiological reviews, 81(1), 209-237.

Stevens, T., Garcia, J. G., Shasby, D. M., Bhattacharya, J., & Malik, A. B. (2000). Mechanisms regulating endothelial cell barrier function. American Journal of Physiology-Lung Cellular and Molecular Physiology, 279(3), L419-L422.

Suna, G., & Kumartasli, M. (2017). Investigating Aerobic, Anaerobic Combine Technical Trainings' Effects on Performance in Tennis Players. Universal Journal of Educational Research, 5(1), 113-120.

Swanwick, E., & Matthews, M. (2018). Energy systems: A new look at aerobic metabolism in stressful exercise. MOJ Sport Medicine, 2(1), 15-22.

Syrotuik, D. G., & Bell, G. J. (2004). Acute creatine monohydrate supplementation: a descriptive physiological profile of responders vs. nonresponders. The Journal of Strength & Conditioning Research, 18(3), 610-617.

Tatlici, A. (2021). The effects of acute beetroot juice supplementation on lower and upper body isokinetic strength of the wrestlers. JOURNAL OF MENS HEALTH, 17(4), 249-254.

Thompson, C., Wylie, L. J., Fulford, J., Kelly, J., Black, M. I., McDonagh, S. T.,

... & Jones, A. M. (2015). Dietary nitrate improves sprint performance and cognitive function during prolonged intermittent exercise. European journal of applied physiology, 115(9), 1825-1834.

Tomlin, D. L., & Wenger, H. A. (2001). The relationship between aerobic fitness and recovery from high intensity intermittent exercise. Sports Medicine, 31(1), 1-11.

Vanhatalo A, Fulford J, Bailey SJ, Blackwell JR, Winyard PG, Jones AM. Dietary nitrate reduces muscle metabolic perturbation and improves exercise tolerance in hypoxia. J Physiol. 2011;589:5517–28.

Webb, A. J., Patel, N., Loukogeorgakis, S., Okorie, M., Aboud, Z., Misra, S., ... & Ahluwalia, A. (2008). Acute blood pressure lowering, vasoprotective, and antiplatelet properties of dietary nitrate via bioconversion to nitrite. Hypertension, 51(3), 784-790.

Wylie, L. J., Kelly, J., Bailey, S. J., Blackwell, J. R., Skiba, P. F., Winyard, P. G., ... & Jones, A. M. (2013). Beetroot juice and exercise: pharmacodynamic and dose-response relationships. Journal of applied physiology, 115(3), 325-336.

Zamani, H., de Joode, M. E. J. R., Hossein, I. J., Henckens, N. F. T., Guggeis, M. A., Berends, J. E., ... & van Breda, S. G. J. (2021). The benefits and risks of beetroot juice consumption: a systematic review. Critical reviews in food science and nutrition, 61(5), 788-804.

Zupan, M. F., Arata, A. W., Dawson, L. H., Wile, A. L., Payn, T. L., & Hannon, M. E. (2009). Wingate anaerobic test peak power and anaerobic capacity classifications for men and women intercollegiate athletes. The Journal of Strength & Conditioning Research, 23(9), 2598-2604.

Zweier, J. L., Wang, P., Samouilov, A., & Kuppusamy, P. (1995). Enzyme-independent formation of nitric oxide in biological tissues. Nature medicine, 1(8), 804-809.

국문초록

비트 주스 섭취가 파워종목 선수의 유·무산소성 경기력 요인 및 등속성 근기능에 미치는 영향

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본 연구의 목적은 비트 주스 섭취가 파워종목 선수의 유·무산소성 경기력 요인 및 등속성 근기능에 미치는 영향을 규명하는 것이다. 연구대상은 성인 파워종목 선수 13명을 대상으로 실시하였으며, 무작위 교차 혼합설계(Randomized cross-over design)에 따라 위약(PG), 저용량 비트 주스(LBG), 고용량 비트 주스(HBG)를 섭취하였다. 파워종목 선수들의 유산소성 경기력 요인을 측정하기 위해 하버드 스텝 테스트를 실시하였으며, 무산소성 경기력 요인을 측정하기 위해 20m 달리기, 사이드 스텝, 전신 반응 검사, 윈게이트 테스트, 혈중 젖산농도를 측정하였다. 또한 무릎과 허리의 등속성 근기능을 측정하기 위해 Humac Norm을 이용하여 무릎의 굴근과 신근, 허리의 굴근과 신근의 등속성 근기능을 검사하였다. 본 연구의 결과는 반복측정 분산분석(Repeated-measures ANOVA)을 통해 집단 간 차이를 분석하였으며,

대비검정(Contrasts)을 통해 사후분석을 실시하였다. 모든 분석의 통계적 유의수준(p)은 0.05로 설정하였다. 본 연구의 결과 하버드 스텝, 사이드 스텝, 전신 반응 검사, 무산소성 파워, 혈중 젖산 농도, 무릎과 허리의 등속성 근력은 집단 간 유의한 차이가 나타나지 않았다. 하지만 20m 달리기와 무릎의 등속성 근지구력을 측정한 결과 비트 주스를 섭취한 LBG와 HBG가 PG보다 유의하게 개선된 것으로 나타났다. 이러한 연구 결과를 종합하면 비트 주스 섭취는 유산소성 운동수행능력, 민첩성, 반응속도, 무산소성 파워, 피로, 무릎과 허리의 등속성 근력에는 영향을 미치지 않지만, 스피드와 등속성 근지구력에 긍정적인 효과를 미치는 것 확인하였다.

따라서 본 연구는 파워 종목 선수들에게 운동 전 비트 주스 섭취가 경기력 관련 체력(스피드, 근지구력)을 향상 시킬 수 있는 에르고제닉 보조제로 사용될 수 있음을 제시한다.