REVISTA CIÊNCIAS EM SAÚDE
HEALTH SCIENCES JOURNAL e-ISSN 2236-3785

ORIGINAL ARTICLE

Effect of a fruit and vegetable drink on muscle recovery after resistance exercise

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Received 17 Jun 2022, accepted 27 Nov 2022, published 22 Dec 2022.

KEYWORDS

Muscle soreness
Muscular strength
Phenolic compounds
Regeneration
Resistance training

ABSTRACT

Objective: To evaluate the effect of fruit and vegetable drink supplementation on muscle recovery after resistance exercise.
Methods: 11 men performed two experimental conditions 12 days apart, in a randomized and double-blind manner: 1) Supplementation with Smoothie - drink based on pineapple, mint, sage, ginger, and pomegranate; and 2) Placebo - drink based on artificial pineapple juice. Participants ingested 400 mL of Smoothie or Placebo drinks daily for 9 days, starting one week before performing the exercise (10 sets of 10 unilateral maximum repetitions in leg press 45º). The perceived subjective recovery (PSR), thickness (MT) and soreness (MS) in the anterior thigh muscles, and maximum isometric strength (MIS) were measured before, 24, 48, 72, and 96 h after exercise.
Results: There was a reduction in MIS and PSR and an increase in MS 24 h after exercise ($p < 0.05$). In both situations, MIS returned to baseline values at 72 h ($p > 0.05$), while PSR and MS returned to baseline values 96 h after exercise. There was no change in MT ($p > 0.05$).
Conclusion: Supplementation with pineapple, mint, sage, ginger, and pomegranate drinks did not accelerate muscle recovery over 96 h after the 45º leg press exercise.

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https://doi.org/10.21876/rcshci.v12i4.1325

How to cite this article: Pinheiro MHA, Fonseca LP, Oliveira JCG, Castro GC, Santos-Rezende VH, Gouveia MS, et al. Effect of a fruit and vegetable drink on muscle recovery after resistance exercise. Rev Cienc Saude. 2022;12(4):57-65. https://doi.org/10.21876/rcshci.v12i4.1325

PALAVRAS-CHAVE

Compostos fenólicos
Dor muscular
Força muscular
Regeneração
Treinamento de força

RESUMO

Objetivo: Avaliar o efeito da suplementação com bebida à base de frutas e hortaliças na recuperação muscular após exercício resistido.
Métodos: 11 homens realizaram duas condições experimentais com 12 dias de intervalo, de forma randomizada e duplo cega: 1) Suplementação com *Smoothie* - bebida à base de abacaxi, hortelã, sálvia, gengibre e romã; e 2) Placebo - bebida à base de suco artificial de abacaxi. Os participantes ingeriram diariamente 400 mL da bebida *Smoothie* ou Placebo durante 9 dias, iniciando uma semana antes da realização do exercício (10 séries de 10 repetições máximas unilaterais no *leg press* 45 º). A percepção subjetiva da recuperação (PSR), espessura (EM) e dor (DM) nos músculos anteriores da coxa, e força máxima isométrica (FMI) foram medidas antes, 24, 48, 72 e 96 h após o exercício.
Resultados: Houve redução na FMI e na PSR, e aumento da DM 24 h após o exercício ($p < 0,05$). Em ambas as situações a FMI retornou aos valores basais em 72 h ($p > 0,05$), enquanto a PSR e a DM retornaram aos valores basais 96 h após o exercício. Não houve alteração na EM ($p > 0,05$).
Conclusão: A suplementação com bebida à base de abacaxi, hortelã, sálvia, gengibre e romã não acelerou a recuperação muscular ao longo de 96 h após o exercício de *leg press* 45º.

INTRODUCTION

A physically active person or an athlete may experience decreased performance shortly after physical training sessions or competitions. This effect can be transitory, lasting minutes or hours due to fatigue[1]. However, exercising can result in structural alterations in the muscle followed by an inflammatory response called exercise-induced muscle damage[1]. Consequently, there is a long-term reduction in muscle strength and range of motion, as well as swelling and late-onset muscle soreness (MS)[1,2]. The magnitude of change in these parameters is variable; so complete recovery can occur within 48 h. However, depending on the level of damage generated, it can take up to more than 7 days for complete muscle recovery. In this sense, several strategies have been used to accelerate muscle recovery after exercise, such as compression garments, massages, cryotherapy, supplements, and medications (i.e., anti-inflammatories), among others[3].

The effect of phenolic supplementation on muscle recovery after exercise has been evaluated because of its anti-inflammatory and antioxidant properties[4]. Physical exercise can generate inflammatory and oxidative responses that exacerbate muscle damage[2]. Therefore, the hypothesis is that the anti-inflammatory properties of phenolics would reduce the inflammatory process caused by the secondary muscle damage[4,5]. Studies have shown that daily supplementation of 650 to 1,300 mg of phenolics for 8 to 9 days accelerates the recovery of MS[6,7]. When supplementation was lower than 600 mg daily, even for 14 or 45 days, muscle recovery was not affected[8,9].

Alternatively, 14 days of daily supplementation with 1,800 mg of phenolics did not accelerate muscle recovery[10]. Another study did not observe the effect of supplementation with 1,000 mg of phenolics daily for 13 days on muscle recovery (e.g., strength, range of motion, muscle swelling)[11]. In these studies, phenolic supplementation was carried out in different ways, such as 1) fresh fruit-based beverages[6,12], fruit dry in powder[9] or fruit extract[7,13]; 2) energy bars with added isolated phytochemicals[11]; and 3) isolated phytochemical capsules[10] or combined with other substances[8]. Additionally, the main base of the beverages evaluated in the abovementioned studies were pomegranate[7,13], grape[9], blueberry[12], and cherry[6]. Therefore, the effect of phenolic supplementation on muscle recovery seems to be affected by several factors, such as 1) type and concentration of phytochemical compounds; 2) dose and time of intervention; 2) metabolism and biological activities of phytochemicals; 4) presence of other bioactive compounds; and 5) influence of factors inherent to the food matrix[4].

Investigating the effect of fruit and plant supplementation with anti-inflammatory or antioxidant properties, which has not been evaluated so far, could provide relevant information for nutritionists, strength and conditioning trainers, physical activity practitioners, and athletes. Pineapple, mint, sage, pomegranate, and ginger are considered functional foods native to Brazil that contain specific components that cause physiological changes considered beneficial to health[14]. Pineapple contains a large amount of bromelain, an enzyme that has anti-inflammatory action[15]. Ginger, mint, and sage contain phenolics and polyphenols, whose beneficial effect on health have been related to their anti-inflammatory activity[16-18]. Therefore, these are fruits and plants that, combined in a drink, may have metabolism and biological activities of phytochemicals different from the compounds already investigated by other studies[6-13].

Therefore, this study evaluated whether supplementation with a fruit and vegetable drink accelerates muscle recovery after a resistance exercise session. For the reasons described, it was hypothesized that the fruit and plant-based drink would accelerate the recovery of MS, delayed-onset MS, and recovery perception. It was also hypothesized that the drink would minimize muscle swelling.

METHODS

Sample

Eleven men (19.8 ± 1.9 years; 66.84 ± 7.67 kg; 174.9 ± 5.8 cm) participated in this study. Volunteers were physically active college students engaged in moderate physical activity (running, cycling, playing sports, etc.) on average 3 days a week. Volunteers were recruited through advertising pamphlets spread across the institution's campus. All volunteers who answered "no" to all questions in the risk questionnaire for physical activity – PAR-Q 20, had not been performing strength training for 6 months before the study, had not a history of musculoskeletal injury, and had not been using supplements or any food restriction program for 6 months were considered to participate. All data security and confidentiality precautions were taken, in addition to following the recommendations of CNS Resolution 466/12, which rules clinical research in Brazil. Volunteers signed an informed consent form, and the study was approved by the Research Ethics Committee of the Federal Institute of Southeast of Minas Gerais (CAAE: 15459819.0.0000.5588).

Experimental design

To evaluate the effect of the consumption of fruit-based beverages on muscle recovery, a crossover design was used, in which volunteers performed two double-blind situations, randomly separated by 12 days of washout. The researcher who applied all the tests and the person responsible for analyzing the data were unaware of the drink administered. A professional who did not participate in the study sealed the envelopes using the sequentially numbered opaque sealed envelope method. The subjects consumed 400 mL of smoothie (Smoothie) or drink based on artificial pineapple juice (Placebo) daily, divided into 2 doses of 200 mL twice a day (at noon and 6 pm) for 9 days. For each situation, the volunteers visited the laboratory 5 times. On the first visit, corresponding to the eighth day of supplementation, the volunteers performed the resistance exercise protocol on the 45° leg press unilaterally, with different legs used in each condition to minimize the effects of repeated bout effect[21].

Parameters related to muscle recovery were measured before (pre), 24, 48, 72, and in the 96 h following the resistance exercise protocol, always in the same order: subjective perception of recovery, swelling of the anterior thigh muscles, MIS, and soreness in the anterior thigh muscles. To avoid the influence of the circadian cycle, the subjects were asked to visit the laboratory at the same time of day. They were also instructed not to take medication, nutritional supplements, alcohol and not to perform any vigorous or unaccustomed exercise for 72 h before the first visit and during the study period. Figure 1 shows the experimental design adopted in this study. The procedures related to the instruction of the volunteers, performance of the 45° leg press exercise, and measurement of parameters related to muscle recovery were performed at the Kinanthropometry and Human Performance Laboratory of the Federal Institute of Southeast of Minas Gerais - Campus Rio Pomba. The procedures related to the preparation and physical-chemical analysis of the beverages were carried out at the Institute's Food Science and Technology Department.

Pineapple, mint, sage, ginger and pomegranate Smoothie and Placebo drink

The smoothie drink provided to the volunteers was based on pineapple pulp and mint, sage, and ginger extracts. The formulation contained 68% pineapple, 22% mint, 5% sage, 2.5% ginger, 2.5% sugar, and 500 mg of pomegranate. The smoothie drink was stored in a freezer at 2°C for 14 days. Table 1 shows the physical-chemical parameters and bioactive compounds of the smoothie drink over 14 days of storage at an average temperature of 2 °C. The pH and acidity of the drink were evaluated according to Zebon et al.[22], using 10 mL of the beverages. The soluble solids, °Brix, were analyzed by refractometry in an ABBE-type refractometer. The total phenolic compounds of the Smoothie diluted in methanol at a 1:10 ratio were determined using the Folin - Ciocalteau reagent[23], with the results expressed in mg of gallic acid equivalents per 100 mL of sample (mg EAG/100 mL). The TEAC assay evaluated Smoothie Aliquots for their antioxidant capacity with the cationic radical ABTS•+ - [2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid)], according to the methodology of Re et al.[24], with modifications.

The Placebo drink was prepared daily based on 2.5% artificial pineapple powder, containing 1.95% carbohydrates and 0.01% sodium. According to a previous study, the soft drink used has a pH of 2.63, acidity of 0.03%, and a °Brix of 3.17[25]. Furthermore, no antioxidant and phenolic capacities were identified in powdered soft drinks[25].

Table 1 — Physical-chemical properties and bioactive compounds of the Smoothie drink.

Properties	Times (days)		
	0	7	14
pH	3.91	3.84	3.93
Acidity (% citric acid)	0.73	0.77	0.78
Soluble solids (°Brix)	6.83	7.33	7.88
Phenolic (mg EAG/100 mL)	400.8	326.9	324.4
Antioxidant capacity (μM Trolox /g)	5138.2	5278.9	5924.2

10 repetition maximum (RM) test and retest

To determine the intensity of the resistance exercise, 10 RM were performed on the 45° leg press[1]. Subjects were asked to keep their contralateral leg resting on a bench and arms crossed over the chest throughout the test. The foot's position on the 45° leg press plate was recorded to ensure the exact positioning in all tests. The range of motion adopted was from a complete knee extension (0°) to a 90° flexion angle. The load was increased using weight plates from 2 kg. On the test day, the participants performed a 5-min preparatory activity on an stationary bike (Bicicleta Suprema Fit - Rottax, Professional Vertical Spyder 500 model, Jabaquara, São Paulo, Brazil) with moderate intensity. Two minutes later, the volunteers performed 10 repetitions with 40% of their MIS. The 10 RM load was determined in 5 attempts, with 5 min of recovery between attempts. Each repetition lasted 4 s, controlled by an electronic metronome with a cadence of 60 bpm, 1 s for the concentric action, and 3 s for the eccentric action.

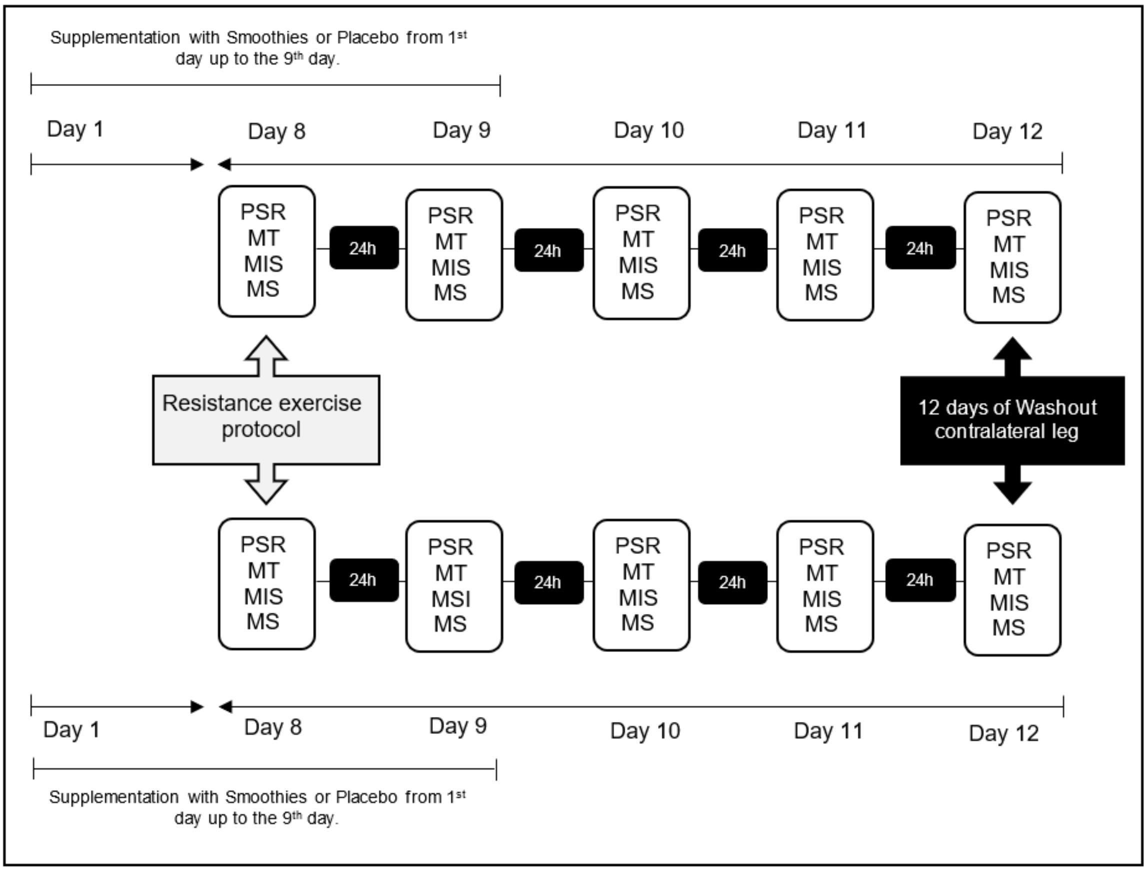

Figure 1 — Study experimental design. PSR: perceived subjective recovery; MT: muscle thickness; MIS: maximal isometric strength; MS: Muscle soreness.

Resistance exercise protocol

Initially, a preparatory activity of 5 min was performed on a stationary bicycle (Bicicleta Suprema Fit - Rottax, Professional Vertical Spyder 500 model, Jabaquara - São Paulo, Brazil), with moderate intensity. Then, 10 sets of 10 MR were performed on the 45° leg press unilaterally[1]. Subjects were asked to keep their contralateral leg resting on a bench and arms crossed over the chest throughout the test. In the 2nd, 5th and 7th sets, the load was reduced by 10% to avoid a significant drop in the number of repetitions. The participants were instructed to perform each repetition with a duration of 4 s: 1 s for the concentric action and 3 s for the eccentric action, controlled by a metronome with a cadence of 60 bpm. The interval between the sets was 2 min. The feet position and range of motion were the same as those described in the 10 RM test.

Subjective perception of recovery

The participants' state of recovery was assessed using the perceived subjective recovery (PSR) scale[26]. The individuals were asked to answer the following question: "How do you feel about your recovery now?"[26]. This scale is composed of values ranging from 6 "nothing recovered" to 20 "completely recovered".

Muscle thickness

Muscle thickness (MT) of the anterior thigh was measured using an ultrasound device (Contec, model CMS600P2 B-Ultrasound Diagnostic System, Qinhuangdao, China). Before performing the ultrasound, the individuals remained at rest for 10 min on a stretcher in the supine position with their legs relaxed. To provide better contact and imaging, a water-based transmission gel was used. Additionally, a pressure dynamometer was coupled to the probe to standardize the force applied to 5 N over the analyzed region. The measurement of the thickness of the anterior thigh muscles was performed at 60% of the distance between the greater trochanter and the lateral epicondyle and 3 cm medially from the midline of the anterior part of the thigh[1]. Once the evaluator was satisfied with the quality of the image, it was frozen on the monitor. The images were digitalized and later analyzed in Image - J software (National Institute of Health, USA, version 1.37), and MT was defined as the distance from the adipose tissue muscle interface to the bone muscle interface[1].

Maximum isometric strength in the 45° leg press

MIS was measured in the 45° leg press machine[1] with the knee in a position of 60^0 of flexion (0^0 to complete extension) guaranteed through a goniometer and with the foot positioned at shoulder width. MIS was measured using a load cell (EMG System, traction/compression model, version SAS1000V4, São José dos Campos, São Paulo, Brazil) with a measuring capacity of 500 kg, connected to the leg press device and a Signal Acquisition System device (EMG System, model SAS1000V4, São José dos Campos, Brazil). Data were collected using software (EMGLab V1.1-2010, EMG System, São José dos Campos, Brazil) during the entire test. The volunteers had two attempts to reach the MIS and were instructed to execute the contraction as fast and intensely as possible, sustaining it for 3 s[1]. A 60 s interval was given between attempts[1]. Foot position was recorded for replication. Furthermore, all tests were conducted by the same evaluator, and verbal encouragement was given to the volunteers during the tests. The attempt at greater isometric strength was recorded.

Muscle soreness

Delayed MS was determined using a 100 mm visual analog scale with "no pain" representing 0 mm and "very painful" representing 100 mm[28]. Volunteers reported MS in the anterior thigh muscles after the MIS test.

Statistical analysis

Data were expressed as mean ± standard deviation. Data were analyzed using a two-way analysis of variance (condition [Smoothie and Placebo] x time [pre, 24–96 h]) with repeated measures and Holm - Sidak post hoc. A significance level of 5% was adopted. Statistical analysis was performed using the SigmaPlot statistical program (version 11.0, SystatSoftware, Inc., Germany).

RESULTS

Effect of resistance exercise on muscle recovery parameters

After performing the resistance exercise, there was an alteration in the following muscle recovery parameters: MIS ($F = 3.17$; $p < 0.02$; Figure 2), PSR ($F = 15.7$; $p < 0.001$; Figure 3), and MS ($F = 3.12$; $p= 0.02$; Figure 4). MIS decreased 24 h after exercise ($p < 0.05$) and returned to baseline values after 72 h (Figure 2). PSR reduced 24 h after exercise ($p < 0.05$) and returned to baseline values after 96 h (Figure 3). There was an increase in MS 24 h after exercise ($p < 0.05$), which returned to baseline values 96 h after exercise (Figure 4). There was no change in MT after performing resistance exercise ($F = 1.16$; $p= 0.34$; Figure 5).

Effect of the Smoothie drink on muscle recovery

There was no interaction between condition x time factors for MIS ($F= 0.55$; $p= 0.69$; Figure 2), PSR ($F = 2.41$; $p = 0.07$; Figure 3), MS ($F = 1.41$; $p = 0.25$; Figure 4) and MT ($F = 0.28$; $p = 0.88$; Figure 5). Besides, there was no effect of the condition factor for MIS ($F = 2.24$; $p = 0.16$), MT ($F = 1.61$; $p = 0.23$), PSR ($F = 0.001$; $p = 0.97$), and MS ($F = 2.97$; $p = 0.11$). These results suggest that the *Smoothie drink* did not affect the recovery of the variables mentioned over the 96 h after resistance exercise.

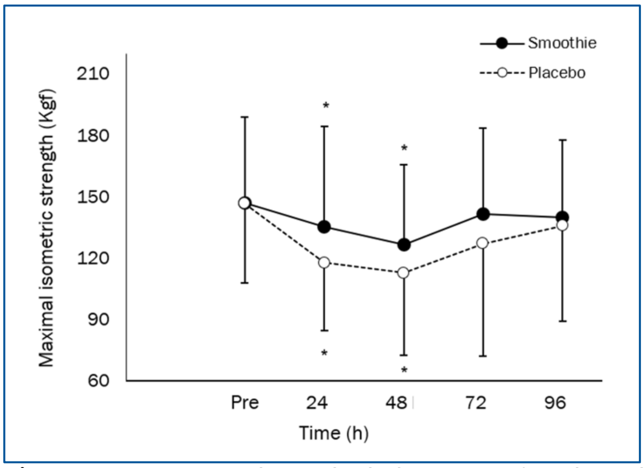

Figure 2 — Mean and standard deviation of unilateral maximum isometric strength in the 45° leg press before (pre), 24–96 h after exercise. (*) $p < 0.05$, lower than pre-exercise.

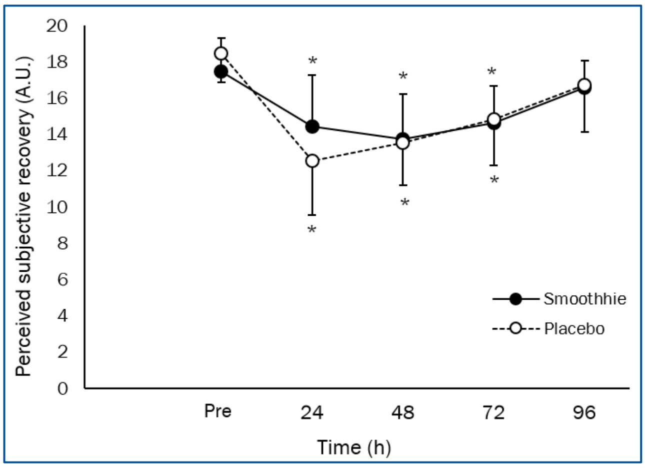

Figure 3 — Mean and standard deviation of perceived subjective recovery before (pre) and 24-96 h after the 45° leg press exercise. (*) $p < 0.05$, lower than pre-exercise.

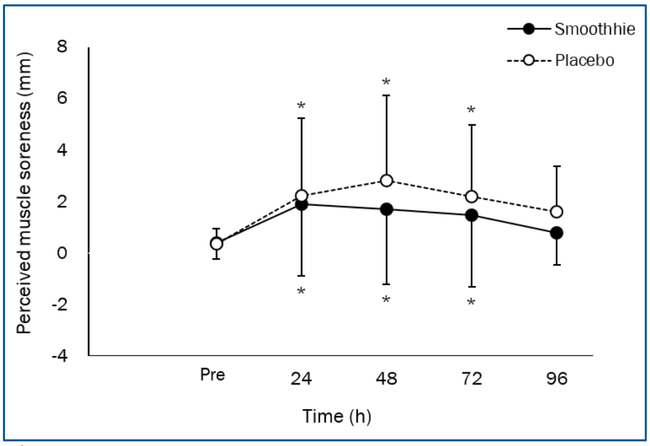

Figure 4 — Mean and standard deviation of perceived muscle soreness before (pre) and 24-96 h after the 45°leg press exercise. (*) $p < 0.05$, greater than pre-exercise.

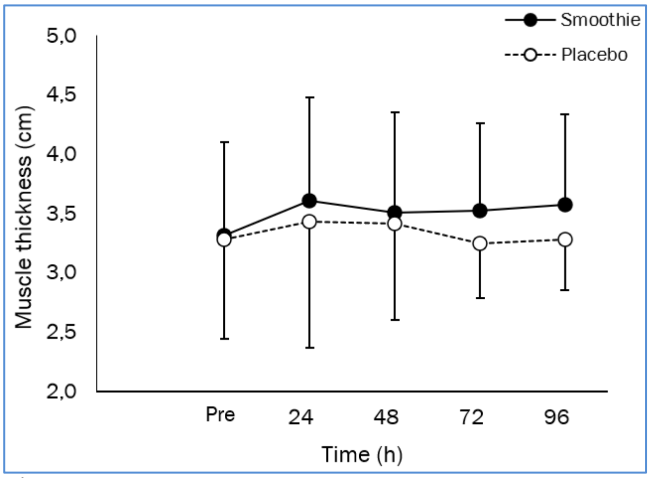

Figure 5 — Mean and standard deviation of muscle thickness of the anterior thigh before (pre) and 24-96 h after the 45° leg press exercise.

DISCUSSION

This study evaluated the effect of a smoothie based on pineapple, mint, sage, ginger, and pomegranate in recovery after a resistance exercise session in untrained young men. It was initially hypothesized that supplementation with smoothies would accelerate muscle recovery. However, there was no difference in MIS, PSR, MS, and MT over the 96 h between the *Smoothie* and Placebo drinks, which does not confirm the initial hypothesis.

The resistance exercise protocol adopted in this study resulted in an MIS reduction of 8% in the Smoothie and 19% in the Placebo conditions 24 h after training. MIS returned to baseline 72 h after training in both situations. This pattern of muscle recovery characterizes moderate exercise-induced muscle damage, commonly accompanied by changes in the myofibrillar structure (e.g., myofibrillar ruptures) along with an acute inflammatory response (leukocyte accumulation)[28]. Furthermore, the increase in the perception of MS observed after the exercise protocol suggests that an inflammatory response has occurred[29]. Due to its anti-inflammatory property, it has been suggested that phenolic supplementation could reduce the inflammatory process triggered by resistance exercise and, thus, accelerate muscle recovery[5]. In the present study, the subjects drank 400 mL of *Smoothie* daily, corresponding to approximately 1,200 mg of phenolics (Table 1). However, the results suggest that the 9 days of Smoothie supplementation did not accelerate muscle recovery.

The current study may be the first to evaluate the effect of ingestion of a fruit and vegetable drink (i.e., pineapple, pomegranate, mint, sage, ginger) on recovery from muscle damage, which makes direct comparison with previous studies impossible. Other studies have shown a positive effect on muscle recovery after supplementation with fruit-based drinks rich in phenolics: cherry[6], pomegranate[7,13,30], or blueberry[12]. The studies used supplementation of 650 to 1,300 mg of phenolic, with a duration of 8 to 15 days, except for McLeay et al.[12], who administered a drink containing 168 mg of phenolics 10 and 5 h before and 0, 12, and 36 h after exercise. Another recent study reported that nine days of supplementation with 480 mL daily of mixed fruit juice (apple, plum, blueberry, raspberry, and blackberry) containing about 160 mg of phenolic accelerated the recovery of maximal strength and muscle soreness, and decreased the creatine kinase (CK) concentrations throughout 96 h after downhill running[31]. The positive results were mainly attributed to the antioxidant and anti-inflammatory properties of the phytochemicals present in the supplement. Both cherry and blueberry are fruits arranged in berries, rich in anthocyanins, and considered to have high antioxidant and anti-inflammatory potential[32].

However, other studies did not find an effect of supplementation with fruit-based beverages, rich in phenolics, on muscle recovery[9-11,33-35]. Supplementation with vegetable and fruit concentrate, including anthocyanin-rich berries, did not affect indirect markers of muscle damage (e.g., muscle strength, swelling, soreness, etc.), although it attenuated oxidative stress[33]. The levels of phenolics present in the drink were not reported. Another study that evaluated 45 days of supplementation with a grape-based drink containing 176 mg of phenolics did not observe an effect on the recovery of strength, range of motion, swelling, and MS[9]. According to a recent study[34], supplementation over 9 days with cherry juice (600 mg phenolic) or pomegranate juice (1,700 mg phenolic) did not affect the recovery of maximum strength, range of motion, muscle soreness, or CK levels. Other studies that examined the 14-day effect of consuming supplements with phenolic concentrations similar to or higher than the current study also did not find a positive effect on muscle recovery[10,11]. Kerksick et al.[10] evaluated daily supplementation with 1,800 mg of epigallocatechin gallate (98% polyphenols). In comparison, O'Fallon et al.[11] examined supplementation with 1,000 mg of phenolics daily (quercetin via an energy bar) plus 20 mg of vitamin C and 14 mg of vitamin E. Controversial effects of supplementing fruit drinks, rich in phenolics, have also been reported[35].

The difference between the studies may be due, for example, to the type of phenolic compound present in the drink. Of the six studies that showed a positive effect of supplementation, three administered beverages whose phenolic compound was hydrolyzed tannins[7,13,30] or anthocyanin, a class of flavonoids[31]. In the other two studies, the beverages contained anthocyanin and phenolic acids[6,12]. In those who did not observe the effect of supplementation, two had the presence of catechin (flavonoid class)[10,11], one had phenolic acid[33], and the other had flavonoids (catechin and anthocyanin) and stilbenes[9]. Finally, in another drink, there were both hydrolyzed tannins and flavonoids (i.e., anthocyanin)[34]. The smoothie evaluated in the present study contained several phenolic compounds, such as 1) flavonoids (e.g., flavones, flavonols) present in parsley, sage, and mint[16,18,36]; 2) phenyl alkenones (e.g., ginger)[37]; 3) phenolic acids (e.g., sage, mint, and pineapple[16-18]; 4) terpenes (e.g., mint)[18]; and 5) hydrolyzed tannins (e.g., pomegranate)[4,18].

The effect of the drink on the indirect markers of muscle damage may have been affected by the decrease in the biological activity of the bioactive compounds due to the intestinal and hepatic metabolism of the fruits and vegetables present in the drink[4,9,11], based on their interaction with other constituents of food, or because they may have been quantitatively insufficient in the target tissues to bring benefits in muscle recovery[4,9]. Therefore, the effectiveness of phenolic supplementation may be influenced by factors related to the food matrix and plant extracts, such as the nature, quantity, and metabolism of phytochemicals and their interactions[4,38,39]. In this sense, knowledge and control of the subjects' dietary patterns can help determine phenolic supplementation's effect on muscle recovery. However, only four studies recorded the dietary pattern of volunteers over the study period[9,12,34,35], and three studies adopted the use of supplements as an exclusion criterion[6,7,30]. Furthermore, of the six studies that found a positive effect of supplementation with a fruit drink rich in phenolics, two were not double-blind clinical trials[6,12]. Although the consumption of supplements was adopted as an exclusion criterion in the present study, the recording of the volunteers' dietary patterns before and during the study period was not evaluated because of the inconsistency of the information provided by the individuals, which constitutes a limitation. Thus, it was impossible to assess whether the amount of antioxidants ingested was in accordance with the recommendations.

Furthermore, the macronutrients present in the smoothie drink were not evaluated, nor was the time of the meal before the consumption of the drinks controlled. Such factors may have interfered with the absorption of the investigated compounds. In addition, blood parameters linked to anti-inflammatory and antioxidant capacity were also not evaluated, which limits the understanding of the effect of supplementation investigated in these systems. However, it is essential to highlight, as a strong point of the current study, that it was a double-blind, randomized clinical trial with an intra-subject and placebo-controlled design, which are considered essential to avoid confounding factors and biases[40]. Therefore, for a better understanding of the effects of phenolic-rich foods and beverages on muscle recovery after physical exercise, future clinical trials with the above characteristics should evaluate phytochemical compound type, concentration, metabolism, and biological activities. Future studies should also examine the effect of other bioactive compounds (e.g., vitamin C) and the influence of factors inherent to the food matrix.

CONCLUSION

The present study showed that 9 days with daily supplementation of 400 mL of drink based on pineapple, mint, sage, ginger, and pomegranate did not accelerate the recovery of maximum isometric strength, perception of recovery, and muscle soreness over 96 h after 45° leg press exercise.

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Conflicts of interest: No conflicts of interest declared concerning the publication of this article.

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Funding information: This study was partially funded by the National Council for Scientific and Technological Development (CNPq) and the Research Support Foundation of Minas Gerais (FAPEMIG).