Journal of The Korean Society of Integrative Medicine, 2023, 11(4), 61~71
https://doi.org/10.15268/ksim.2023.11.4.061
ISSN 2288-1174(Print)
ISSN 2383-9651(Online)

Effects of Pre- and Post-workout Energy Bar Supplementation on Blood Lactate and Fitness in Young Adults with CrossFit Training: A randomized crossover study

Byung-Gul Lim, MS[1,4] · Xinxing Li, MS[1,3] · Wook Song, Ph.D[2,3,5†]

[1]Health and Exercise Science Laboratory, Department of Physical Education, Seoul National University, Ph.D-Student
[2]Health and Exercise Science Laboratory, Dept. of Physical Education, Seoul National University, Professor
[3]Institute of Sport Science, Seoul National University, Adjunct Researcher
[4]Research Institute, Dr.Exsol.Inc, Director of Research
[5†]Research Institute, Dr.Exsol.Inc, Chief Executive Officer

Abstract

Purpose : Energy bars are increasingly popular among active individuals, yet their timing and nutrient combinations' impact on exercise adaptation remains unclear. This study aims to address this knowledge gap by investigating whether the combination of pre- and post-workout supplementation can synergistically enhance fitness and alleviate fatigue in trained CrossFit participants. Investigate if combining pre- and post-workout supplements can enhance fitness and blood lactate management in trained CrossFit participants, potentially improving exercise performance for this group.

Methods : In a randomized crossover study, 20 trained CrossFit individuals (11 males, 9 females) completed thrice-weekly 60-minute CrossFit sessions for 3 weeks, with a one-week washout period. Participants were randomly assigned to either a chocolate bar group (CH, 45 g, 225 ㎉) or an energy bar group (ES, 48 g, 238 ㎉, with protein, caffeine, taurine, and BCAAs). For one week, participants consumed two bars of their assigned supplement five minutes before and after workouts. After a washout period, they switched supplements. Blood lactate levels and a visual analog scale (VAS) were assessed before, immediately after, and 30 minutes post-workout. Fitness tests (hand grip, broad jump, sit-ups) were conducted at baseline and 30 minutes post-final workout. Data were analyzed using two-way repeated measures ANOVA ($p<.05$), 95 % confidence intervals, and magnitude inferences.

Results : Hand grip strength ($t=-5.60$, $p=.000$), broad jump ($t=-3.43$, $p=.003$) and sit up ($t=-3.94$, $p=.001$) were significantly increased in the ES group. Compared to CH group, there was a significant time and group interactions for blood lactate level ($F=5.51$, $p=.008$) and VAS($F=31.67$, $p=.000$) in the ES group.

Conclusion : Pre- and post-workout energy bar supplementation may have a beneficial effect on blood lactate clearance and fitness in trained CrossFit individual. The combination of proprietary supplements taken may provide benefits for removing the blood lactate during high-intensity functional exercise.

Key Words : blood lactate, crossfit, exercise, high-intensity, supplement

†Corresponding author : Wook Song, songw3@snu.ac.kr

Received : September 7, 2023 | Revised : October 15, 2023 | Accepted : November 3, 2023

Ⅰ. Introduction

The field of sports nutrition and its impact on athletic performance and body image are rapidly evolving (Campbell & Spano, 2011). The global trade in dietary supplements reached $140.3 billion in 2020, and its annual growth rate is estimated to be 8 % in the coming decade (Fortune Business Insights, 2022). Dietary supplement intake to enhance performance is becoming increasingly diverse.

Various surveys have consistently shown a high prevalence of dietary supplement use in the general population, with 85 % of the participants reporting their use of dietary supplements (Garthe & Maughan, 2018; Mazzilli et al., 2021). This trend extends to high-intensity exercise enthusiasts such as CrossFit practitioners (dos Santos Quaresma et al., 2021).

CrossFit is a physically demanding strength and conditioning method that aims to maximize the power output (Smith et al., 2013). Previous studies have correlated CrossFit performance with aerobic capacity, upper and lower body strength, and power (Butcher et al., 2015; Crawford et al., 2018; Jagim et al., 2017). However, evidence regarding the utilization of dietary supplementation in enhancing CrossFit performance is limited (Rountree et al., 2017).

Studies in the field of sports nutrition have primarily focused on the effects of single-ingredient supplements such as proteins, branched-chain amino acids, caffeine, taurine, and dark chocolate (Blomstrand et al., 2006; Matsumoto et al., 2007; Pasiakos et al., 2014; Patel et al., 2015; Stein et al., 2019; Thirupathi et al., 2020; Yoon et al., 2015). However, limited studies have explored the combined effects of multiple nutrients, and the timing and method of supplement intake (Outlaw et al., 2014; Ribeiro et al., 2021).

Fatigue and can be precursors of decreased performance during high-intensity exercise. Various nutritional strategies, including bar supplements containing carbohydrates, proteins, and chocolate have gained popularity among CrossFit practitioners (dos Santos Quaresma et al., 2021).

Protein supplements are widely used because of their potential benefits in increasing muscle mass, improving exercise recovery, and enhancing performance (Morton et al., 2018; Pasiakos et al., 2014). Caffeine supplementation has been shown to enhance endurance and performance, especially in prolonged and exhausting exercises, such as CrossFit (Jacobs, 2014). The oral intake of taurine supplements can improve endurance performance and aid in fatigue recovery (Waldron et al., 2018). In addition, dark chocolate consumption has been associated with reduced oxygen consumption and potential exercise-enhancing effects (Patel et al., 2015).

While previous studies have explored the effects of caffeine supplementation before CrossFit training and did not find significant performance changes (Stein et al., 2020), there is a notable gap in the research regarding the combined effects of pre- and post-exercise supplementation on fitness and fatigue. Understanding the potential synergistic effects of these two types of supplements is crucial for optimizing athletic performance.

Considering the limited literature on this topic, in this study we aimed to investigate the effect of pre- and post-exercise supplementation on changes in fitness parameters and blood lactate levels among trained CrossFit individuals. By examining the combined effects of these supplements, we aimed to contribute to the current understanding of their potential benefits in optimizing exercise performance in this population.

Ⅱ. Methods

1. Participants

We determined the sample size for this study using G*power software, guided by an approximate effect size

obtained from a preliminary study (Faul et al., 2007; Forbes et al., 2017). The decision to include 20 participants in the study was informed by previous research. Previous study supported our choice of a sample size of 20 individuals, given the similarities in the study design and objectives, ensuring that our study had sufficient statistical power to detect meaningful effects.

Total 20 trained CrossFit individuals (11 males and 9 females) performed CrossFit workouts (squats, cleans, and jerks) with pre- and post-workout supplementation, and all subjects had been participating in at least three CrossFit classes per week for one year. CrossFit-trained males and females from the CrossFit Gym in Seoul, Korea volunteered. All participants were identified as eligible and provided written informed consent to participate in the study.

2. Experimental Design

The participants completed workouts three times per week, 60 min/day for three weeks with 1-week washout period. The participants were randomly assigned to one of two groups: the chocolate bar group (CH) and the energy bar group (ES) and received two pieces of chocolate or energy bars 5 min before and immediately after the workout for 1 week. Following a washout period of no supplements, they received an alternative supplement (either chocolate bar or energy bar) for another 1 week.

The participants were assigned to each groups using the simple randomization method (Suresh, 2011). In this approach, a list of participants was created, random numbers were generated, and participants were allocated to either the CH or ES based on the randomness of the numbers, ensuring an equal and unbiased distribution. Blinding procedures were in place to maintain the integrity of the randomization process and reduce bias.

The fatigue index passed the blood lactate level, and visual analog scale (VAS) scores were assessed before, immediately after, and 30 min after the workout. Fitness tests (muscle strength, endurance, hand grip, sit-up, power, and standing broad jump) were conducted at baseline and

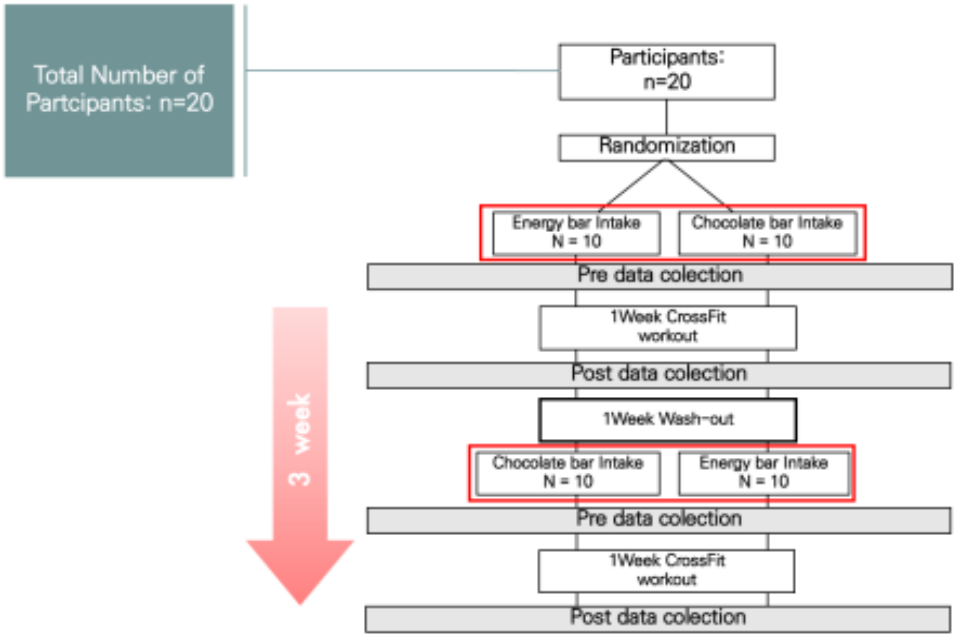

Fig 1. Experimental design

30 min after the last workout (Fig 1).

3. Supplementation

Both the chocolate bar and the energy bar were presented in identical packaging, and the participants were unable to differentiate between the products based on their external appearance.

Participants were provided with either a 45 g chocolate bar or a 48 g Energy Bar as supplements. These doses and formulations are within reasonable intake levels (Caperton et al., 2014; Tanskanen et al., 2012). The chocolate bar consisted of 25 g of carbohydrates, 4 g of protein, 50 ㎎ of sodium, 11 g of fat, and provided a total of 225 ㎉ (kilocalories). The energy bar contained 16 g of carbohydrates, 16 g of protein, vitamins B (96 ㎎), E (12 ㎎), and C (100 ㎎), branched-chain amino acids (BCAA) at 1852 ㎎, caffeine at 8 ㎎, taurine at 100 ㎎, and provided a total of 238 ㎉. These supplements were provided by Lotte Korea Inc. (Lotte Confectionery Co., Ltd.).

The participants received and consumed two pieces of their assigned supplement, either the chocolate bar or the energy bar, 5 min before and immediately after each workout session for 1 week. After a washout period without supplements, participants switched to alternate supplements for another 1 week.

4. CrossFit intervention

During the 3 weeks of the study, CrossFit was performed three times per week (60 min), with full body resistance and aerobic interval training, and moderate to high (60~90 % of HR Max).

Each session in the study included three main CrossFit workouts: "Fran," "Cindy," and "Grace" (Glassman, 2011). "Fran" is a three-round workout with a repetition scheme of 21-15-9, involving thrusters and pull-ups. The goal is to complete the exercises as fast as possible without scheduled rests. "Cindy" is an AMRAP (as many rounds as possible) workout lasting 20 minutes, consisting of 5 pull-ups, 10 push-ups, and 15 air squats in each round. "Grace" is a high-intensity workout where athletes complete 30 clean and jerks with a prescribed weight as quickly as possible (Fernández, 2015). These workouts are commonly used to assess fitness and performance in CrossFit training.

Each workout was performed in the gym, supervised by a certified CrossFit® degree 2-certified instructor. All participants completed the same physical activity routines to ensure they performed the same prescribed workouts during the study.

5. Measurements

We obtained measurements from the participants, including their VAS scores and blood lactate levels to assess fatigue. These measurements were taken before, immediately after, and 30 mins after the workout. We also assessed muscle strength using hand grip tests, endurance using a 1-minute sit-up test, and power using a broad test.

For physical function, we evaluated several aspects:

1) body composition

Height, weight, skeletal muscle mass, and body mass index were measured in all participants using a body composition analyzer (Inbody 270, Biospace, Republic of Korea) and bioelectrical impedance analysis (BIA) (Czartoryski et al., 2020).

2) handgrip test

Grip strength measurement is a representative and simple method for assessing upper limb muscle strength. While standing in place using a grip dynamometer (digital dynamometer, Takei Scientific Instruments Co., Japan) and lowering both arms naturally down the lower extremity side of the body, the body should not be excessively bent or the knees should be bent. Measurements were taken twice, alternating between the left and right sides, and the average value was recorded (Amaral et al., 2012).

3) 1-min sit-up

The participants performed sit-ups starting from a lying position with their backs on a mat, knees bent at 90 °, fingers intertwined with the occipital bone, and elbows open. Both shoulder blades were required to touch the ground prior to the next repetition. Their feet were securely held by a partner. Situations were performed as quickly as possible within a 60-second period (Arifin et al., 2020).

4) broadjump test

Each subject stood on the starting line with legs parallel and feet shoulder-width apart. The participants were instructed to bend their knees (the depth of flexion was self-selected) and bring their arms behind the body. Subsequently, using a powerful drive, they extend their legs, move their arms forward, and jump as far as possible. The distance jumped was measured in centimeters. Measurements were performed twice, and the average of these values was recorded (Krishnan et al., 2017).

To test for fatigue, we evaluated the following aspects:

1) blood lactate levels

Lactate Pro 2 (AKRAY Europe B.V. Prof J. H. Bavincklaan 51,183 AT, Amstelveen, The Netherlands) is a handheld point-of-care analyzer that operates by enzymatic amperometric detection. Blood lactate reacts with the reagent on the test strip, producing a small electrical current that is proportional to its concentration of blood lactate. The meter measured the current and calculated blood lactate levels. It requires .3 μ l of a whole-blood sample and 15 s to measure the lactate value. LP2 has a measurement range of .5-25.0 ㎜㏖/ℓ . If "Hi" or "Lo" appears on the display it means that the blood lactate level is above 25.0 ㎜㏖/ℓ or below .5 ㎜㏖/ℓ , respectively. Therefore, in this study only lactate values between .5 and 25 were included.

2) visual analog scale (VAS)

This method is valid and convenient, and participants require minimal reading skills, time, and effort (Lee et al., 1991). Participants were asked to score their fatigue using a 100 ㎜ VAS from 0 (absence of fatigue) to 100 (worst fatigue imaginable) (LaChapelle & Finlayson, 1998).

6. Statistical analysis

Data were entered into SPSS 26 (Armonk, NY, USA) for analysis. A paired t-test was used to compare the differences according to the intake two supplements. A two-way repeated-measures analysis of variance (ANOVA) test was used to examine interaction effects (time supplementation group) among supplementation groups (ES and CH) for hand grip, sit-up, standing broad jump. Statistical significance was indicated when $p<.05$. 95 % confidence intervals, and magnitude inferences.

Ⅲ. Results

1. General characteristics of the study subjects

Twenty participants were enrolled in the study and the general characteristics of the study participants are presented in Table 1.

Table 1. General characteristics of the study participants (n= 20)

Variables	Total
	Mean±SD
Age (years)	29.90±3.28
Body weight (㎏)	65.10±13.73
Body fat percentage (%)	22.50±6.54
Skeletal muscle mass (㎏)	29.60±8.12

2. Physical function

The pre and post-test results for hand grip, broad jump, sit up are shown in Table 2.

Table 2. Changes in physical function from the pre to the post-test across the two groups (n= 20)

Variables	Group	Pre-test Mean±SD	Post-test Mean±SD	Source	F	*p*
Hand Grip (kg)	CH (n=20)	36.73±13.01	36.73±13.05	G	.12	.031
	ES (n=20)	37.06±12.91	38.61±13.01	T	.01	.345
				G×T	4.41	.047
Broad Jump (m)	CH (n=20)	2.26±.40	2.26±.39	G	.07	.647
	ES (n=20)	2.29±.39	2.34±.38	T	.09	.567
				G×T	.39	.732
Sit up (reps/min)	CH (n=20)	33.00±10.38	33.90±11.12	G	2.73	.107
	ES (n=20)	32.20±9.52	36.90±10.85	T	.45	.309
				G×T	3.36	.024

CH; chocolate bar group, ES; energy bar group

In the analysis of hand grip strength, there were no significant differences observed between the CH and ES groups over time. However, statistically significant differences were detected between the groups and their interaction. Notably, the post-hand grip strength (38.61±13.01) was found to be significantly higher than the pre-hand grip strength (37.06±12.91). This improvement in hand grip strength suggests that the combination of CrossFit training and energy bar supplementation positively influenced upper limb muscle strength in the ES group.

Similarly, in the broad-jump performance, there was a statistically significant improvement in broad-jump performance after CrossFit training with energy bar supplementation. However, the statistical analyses revealed no significant impact of time, group, and their interaction on the broad-jump performance.

Lastly, in the sit-up performance, the results indicate that there was no significant difference between the two groups, and there was no significant change in sit-up performance over time within each group. However, a notable finding emerged from the analysis of the group by time Interaction, where a significant interaction effect was observed. This interaction effect suggests that the intervention, which includes crossfit training and energy bar supplementation, had varying and distinct effects on sit-up performance in the CH and ES.

Table 3. Changes in fatigue pre-test and post-test, 30min after test across the two groups (n= 20)

Variables	Group	Pre-test Mean±SD	Post-test Mean±SD	30min after Mean±SD	Source	F	*p*
VAS	CH (n=20)	27.50±10.07	70.75±9.22	41.25±9.71	G	.88	.354
	ES (n=20)	30.00±12.14	69.00±8.52	33.25±12.59	T	298.41	.000
					G×T	5.51	.008
Lactate	CH (n=20)	3.96±1.93	14.09±4.91	7.96±2.51	G	.45	.506
	ES (n=20)	4.54±2.79	14.14±3.84	5.56±3.03	T	184.21	.000
					G×T	31.67	.000

G; group, T; time, G×T; interaction, VAS; visual analog scale

3. Fatigue

The pre and post-test, 30 min after test results for VAS and lactate are shown in Table 3.

After 3 weeks of CrossFit training and supplementation, fatigue was assessed using the VAS for perceived fatigue and blood lactate levels. The VAS scores revealed a significant interaction between the group and time (F=5.51, p=.008). This interaction effect indicated that the changes in perceived fatigue (VAS scores) over time differed between the ES and CH groups. Additionally, changes in the VAS scores by time point were statistically significant (p=.000). This suggests that there were significant differences in perceived fatigue levels before, immediately after, and 30 min after the workout within both the ES and CH groups.

Similarly, for blood lactate levels, two-way ANOVA showed a significant interaction between group and time (F=31.67, p=.000). This interaction effect suggests that changes in blood lactate levels over time differed between the energy bar (ES) group and the chocolate bar (CH) groups. Moreover, changes in blood lactate levels at different time points were highly significant (p=.000). This indicates that there were significant differences in blood lactate levels before, immediately after, and 30 min after the workout within both the ES and CH groups.

These results provide compelling evidence that the combination of CrossFit training and energy bar supplementation has a distinct impact on fatigue-related outcomes during CrossFit training. The significant interaction effects between group and time for both perceived fatigue (VAS scores) and blood lactate levels suggest that energy bar supplementation uniquely influenced the changes in fatigue levels and lactate response compared to chocolate bar supplementation during CrossFit workouts.

Ⅳ. Discussion

In the present study, we investigated the effects of pre- and post-workout energy bar supplementation on the fitness and blood lactate levels in trained CrossFit individuals. The results indicated that combining pre- and post-workout energy bar supplementation, which included proprietary ingredients such as taurine, caffeine, and branched-chain amino acids (BCAA), led to significant improvements in fitness performance and blood lactate clearance.

Previous studies have highlighted the role of taurine in reducing oxidative stress and inflammatory responses induced by exercise (Thirupathi et al., 2020). Short-term taurine supplementation has also been associated with enhanced physiological performance during high-intensity work. In addition, caffeine has been shown to enhance endurance and improve CrossFit performance (Jacobs, 2014). These findings are consistent with our results, suggesting that the inclusion of taurine and caffeine in the energy bars may have contributed to the observed improvements in fitness and blood lactate clearance.

The hand grip test is a reliable measure of upper limb muscle strength and endurance (Zhang et al., 2022). In comparison to previous research, the observed increase in hand grip strength in response to training with supplementation is in line with findings from studies that highlight the benefits of HIIT on muscular strength and endurance (Zhang et al., 2022). This is particularly relevant for individuals engaging in functional fitness, such as CrossFit.

The 1-minute sit-up test assesses core strength and endurance. The observed improvements in this test, along with pre- and post-exercise supplementation, align with prior research demonstrating the positive effects of HIIT on core strength (Kurtz et al., 2021). It is worth noting that core strength is integral for various CrossFit movements and functional exercises, making these results highly relevant to the training demands of CrossFit participants.

However, the overall lack of significant changes in the broad jump test within the groups, over time, or in interaction suggests that additional factors or variations may play a role. While previous research may have

demonstrated improvements in the leg strength under different conditions or training modalities (Jendricke et al., 2019), the unique context and specific combination of HIIT training and supplementation in this study have yielded distinct outcomes. These results emphasize the complexity of physical performance and the potential influence of various factors beyond the scope of this study.

Furthermore, protein consumption has been linked to a positive net protein balance during high-intensity exercises such as CrossFit workouts (Hulmi et al., 2010). Because our energy bar supplement contained protein along with other ingredients, it is plausible that the combination of BCAA, taurine, caffeine, and protein effectively affected muscle contraction and lactate clearance, leading to improved fitness outcomes.

Other studies further supported our findings. Kumstát et al. (2019) revealed that beta-alanine supplementation improved anaerobic power and reduced perceived fatigue in CrossFit athletes, highlighting the significance of specific supplements for enhancing performance during high-intensity training. Similarly, Kramer (2015) demonstrated that creatine monohydrate supplementation led to increased muscle strength and mass in CrossFit trainees, emphasizing the potential benefits of supplementation with specific nutrients to improve exercise outcomes.

Our study's findings align with those of previous research, indicating that caffeine can effectively increase anaerobic power and training volume, whereas taurine contributes to enhanced energy production and general resistance to fatigue. The combination of these components in the energy bar appears to have synergistic effects, benefiting trained CrossFit individuals in terms of performance and recovery.

In contrast, while some studies have shown that acute caffeine supplementation does not yield significant improvements in CrossFit performance (Stein et al., 2020), it is essential to consider that the effects of single supplements, such as caffeine, may vary based on factors such as individual differences, exercise context, and dosage. Because our study involved pre- and post-workout energy bar supplementation with a combination of taurine, caffeine, BCAA, and proteins, the results may differ from those of studies involving one-time caffeine intake. The proprietary ingredients in the energy bar may have contributed to the observed improvements in the fitness and blood lactate clearance of our trained CrossFit participants.

The significant interaction effects between group and time for VAS and blood lactate levels suggested that the combination of CrossFit training and energy bar supplementation influenced fatigue-related outcomes differently than in the control group. The proprietary ingredients of the energy bar appear to have synergistic effects, leading to improved fitness performance and blood lactate clearance during and after CrossFit workouts.

Although our results are promising, we acknowledge the limitations of our study. One limitation was the challenge of controlling the participants' daily food intake. Although we recommended following specific daily food intake instructions, we could not control for factors such as excessive eating or drinking that may have influenced the outcomes. Future studies should consider implementing stricter dietary control measures to isolate the effects of supplementation better.

To extend our findings further, future investigations should explore training and nutritional interventions for a greater duration. Studying the effects of daily food intake in conjunction with CrossFit training performance could provide valuable insights into the overall effects of supplementation and diet on athletic performance.

Overall, our study demonstrated that pre- and post-workout energy bar supplementation, containing a combination of proprietary ingredients such as taurine, caffeine, BCAA, and protein, can positively affect fitness and blood lactate levels in trained CrossFit individuals. These results reinforce the potential benefits of specific supplement combinations for enhancing exercise performance and warrant further exploration in the realm of sports nutrition and high-intensity training.

Ⅴ. Conclusion

In conclusion, our short-term results suggest that pre- and post-workout energy bar supplementation may have beneficial effects on blood lactate clearance and fitness in trained CrossFit individuals. The combination of proprietary supplements (taurine, caffeine, protein, BCAA, and carbohydrates) may be beneficial for removing blood lactate during high-intensity functional exercise.

References

Amaral JF, Mancini M, Novo Júnior JM(2012). Comparison of three hand dynamometers in relation to the accuracy and precision of the measurements. Braz J Phys Ther, 16(3), 216-224. https://doi.org/10.1590/s1413-35552012000300007.

Arifin S, Retnawati H, Putranta H(2020). Indonesian air force physical tester reliability in assessing one-minute push-up, pull-up, and sit-up tests. Sport Mont, 18(2), 89-93.

Blomstrand E, Eliasson J, Karlsson HK, et al(2006). Branched-chain amino acids activate key enzymes in protein synthesis after physical exercise. J Nutr, 136(1), 269S-273S. https://doi.org/10.1093/jn/136.1.269S.

Butcher SJ, Neyedly TJ, Horvey KJ, et al(2015). Do physiological measures predict selected CrossFit(®) benchmark performance?. Open Access J Sports Med, 241-247. https://doi.org/10.2147/OAJSM.S88265.

Campbell BI, Spano MA(2011). NSCA's guide to sport and exercise nutrition. 1st ed, Champaign IL, Human Kinetics, pp.99-121.

Caperton C, Block S, Viera M, et al(2014). Double-blind, placebo-controlled study assessing the effect of chocolate consumption in subjects with a history of acne vulgaris. J Clin Aesthet Dermatol, 7(5), 19-23.

Crawford DA, Drake NB, Carper MJ, et al(2018). Are changes in physical work capacity induced by high-intensity functional training related to changes in associated physiologic measures?. Sports (Basel), 6(2), Printed Online. https://doi.org/10.3390/sports6020026.

Czartoryski P, Garcia J, Manimaleth R, et al(2020). Body composition assessment: a comparison of the DXA, Inbody 270, and Omron. Journal of Exercise and Nutrition, 3(1). Printed Online.

dos Santos Quaresma MV, Marques CG, Nakamoto FP(2021). Effects of diet interventions, dietary supplements, and performance-enhancing substances on the performance of CrossFit-trained individuals: a systematic review of clinical studies. Nutrition, 82, Printed Online. https://doi.org/10.1016/j.nut.2020.110994.

Faul F, Erdfelder E, Lang AG, et al(2007). G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods, 39(2), 175-191. https://doi.org/10.3758/bf03193146.

Fernández JF, Solana RS, Moya D, et al(2015). Acute physiological responses during Crossfit® workouts. Eur J Hum Mov, 35, 114-124.

Forbes SC, Sletten N, Durrer C, et al(2017). Creatine monohydrate supplementation does not augment fitness, performance, or body composition adaptations in response to four weeks of high-intensity interval training in young females. Int J Sport Nutr Exerc Metab, 27(3), 285-292. https://doi.org/10.1123/ijsnem.2016-0129.

Garthe I, Maughan RJ(2018). Athletes and supplements: prevalence and perspectives. Int J Sport Nutr Exerc Metab, 28(2), 126-138. https://doi.org/10.1123/ijsnem.2017-0429.

Hulmi JJ, Lockwood CM, Stout JR(2010). Effect of protein/essential amino acids and resistance training on skeletal muscle hypertrophy: a case for whey protein. Nutr Metab (Lond), 7(1), Printed Online. https://doi.org/10.1186/1743-7075-7-51.

Jacobs PL(2014). The acute effects of a commercial pre workout product, wodFuel®, on performance of a Crossfit exercise series, the Cindy. J Int Soc Sports Nutr, 11(1), 1-2. https://doi.org/10.1186/1550-2783-

11-S1-P21.

Jagim AR, Rader O, Jones MT, et al(2017). Physical demands of multimodal training competitions and their relationship to measures of performance. J Strength Cond Res, 31(5), 1212-1220. https://doi.org/10.1519/JSC.0000000000000992.

Jendricke P, Centner C, Zdzieblik D, et al(2019). Specific collagen peptides in combination with resistance training improve body composition and regional muscle strength in premenopausal women: a randomized controlled trial. Nutrients, 11(4), 892. https://doi.org/10.3390/nu11040892.

Kumstát M, Širc P, Struhár I, et al(2019). The effects of 32 weeks of beta-alanine supplementation on CrossFit-specific performance, body composition and dietary habits in CrossFit athletes. Faculty Sports Stud, 24, 47.

Kramer SJ(2015). The effects of six days of dietary nitrate supplementation on strength, power, and endurance in Crossfit athletes. Graduate school of Florida State University, Republic of United State of America, Doctoral dissertation.

Krishnan A, Sharma D, Bhatt M, et al(2017). Comparison between standing broad jump test and wingate test for assessing lower limb anaerobic power in elite sportsmen. Med J Armed Forces Indi, 73(2), 140-145. https://doi.org/10.1016/j.mjafi.2016.11.003.

Kurtz JA, VanDusseldorp TA, Doyle JA, et al(2021). Taurine in sports and exercise. J Int Soc Sports Nutr, 18(1), 39. https://doi.org/10.1186/s12970-021-00438-0.

LaChapelle DL, Finlayson MAJ(1998). An evaluation of subjective and objective measures of fatigue in patients with brain injury and healthy controls. Brain Inj, 12(8), 649-659. https://doi.org/10.1080/026990598122214.

Lee KA, Hicks G, Nino-Murcia G(1991). Validity and reliability of a scale to assess fatigue. Psychiatry Res, 36(3), 291-298. https://doi.org/10.1016/0165-1781(91)90027-M.

Matsumoto K, Mizuno M, Mizuno T, et al(2007). Branched-chain amino acids and arginine supplementation attenuates skeletal muscle proteolysis induced by moderate exercise in young individuals. Int J Sports Med, 28(6), 531-538. https://doi.org/10.1055/s-2007-964940.

Mazzilli M, Macaluso F, Zambelli S, et al(2021). The use of dietary supplements in fitness practitioners: a cross-sectional observation study. Int J Environ Res Public Health, 18(9), Printed Online. https://doi.org/10.3390/ijerph18095005.

Morton RW, Murphy KT, McKellar SR, et al(2018). A systematic review, meta-analysis and meta-regression of the effect of protein supplementation on resistance training-induced gains in muscle mass and strength in healthy adults. Br J Sports Med, 52(6), 376-384. http://doi.org/10.1136/bjsports-2017-097608.

Outlaw JJ, Wilborn CD, Smith-Ryan AE, et al(2014). Effects of a pre-and post-workout protein-carbohydrate supplement in trained Crossfit individuals. Springerplus, 3(1), Printed Online. https://doi.org/10.1186/2193-1801-3-369.

Pasiakos SM, Lieberman HR, McLellan TM(2014). Effects of protein supplements on muscle damage, soreness and recovery of muscle function and physical performance: a systematic review. Sports Med, 44(5), 655-670. https://doi.org/10.1007/s40279-013-0137-7.

Patel RK, Brouner J, Spendiff O(2015). Dark chocolate supplementation reduces the oxygen cost of moderate intensity cycling. J Int Soc Sports Nutr, 12(1), Printed Online. https://doi.org/10.1186/s12970-015-0106-7.

Ribeiro F, Longobardi I, Perim P, et al(2021). Timing of creatine supplementation around exercise: a real concern?. Nutrients, 13(8), Printed Online. https://doi.org/10.3390/nu13082844.

Rountree JA, Krings BM, Peterson TJ, et al(2017). Efficacy of carbohydrate ingestion on crossfit exercise performance. Sports (Basel), 5(3), Printed Online. https://doi.org/10.3390/sports5030061.

Smith MM, Sommer AJ, Starkoff BE, et al(2013). Crossfit-based high-intensity power training improves maximal aerobic fitness and body composition. J Strength Cond Res, 27(11), 3159-3172. https://doi.org/10.1519/JSC.0b013e318289e59f.

Stein JA, Ramirez M, Heinrich KM(2019). The effects of acute caffeine supplementation on performance in trained CrossFit athletes. Sports (Basel), 7(4), Printed Online. https://doi.org/10.3390/sports7040095.

Stein JA, Ramirez M, Heinrich KM(2020). Acute caffeine supplementation does not improve performance in trained Crossfit® athletes. Sports(Basel), 8(4), Printed Online. https://doi.org/10.3390/sports8040054.

Suresh KP(2011). An overview of randomization techniques: an unbiased assessment of outcome in clinical research. J Hum Reprod Sci, 4(1), 8-11. https://doi.org/10.4103/0974-1208.82352.

Tanskanen MM, Westerterp KR, Uusitalo AL, et al(2012). Effects of easy-to-use protein-rich energy bar on energy balance, physical activity and performance during 8 days of sustained physical exertion. Plos One, 7(10), Printed Online. https://doi.org/10.1371/journal.pone.0047771.

Thirupathi A, Pinho RA, Baker JS, et al(2020). Taurine reverses oxidative damages and restores the muscle function in overuse of exercised muscle. Front Physiol, 11, Printed Online. https://doi.org/10.3389/fphys.2020.582449.

Waldron M, Patterson SD, Tallent J, et al(2018). The effects of an oral taurine dose and supplementation period on endurance exercise performance in humans: a meta-analysis. Sports Med, 48(5), 1247-1253. https://doi.org/10.1007/s40279-018-0896-2.

Yoon JA, Shin KO, Choi KS(2015). Studies on the function of taurine. Korean J Food Nutr, 28(5), 880-893. https://doi.org/10.9799/ksfan.2015.28.5.880.

Zhang JL, Poon CCW, Wong MS, et al(2022). Vitamin D supplementation improves handgrip strength in postmenopausal women: a systematic review and meta-analysis of randomized controlled trials. Front Endocrinol, 13, Printed Online. https://doi.org/10.3389/fendo.2022.863448.

Glassman G. The CrossFit level 1 training guide, 2011. Available at http://library.crossfit.com/free/pdf/CFJ_English_Level1_TrainingGuide.pdf?_ga=2.218222174.676950275.1697439570-1556144214.1696578764/ Accessed October 1, 2023.

Fortune Business Insights. Dietary supplements market size, share & covid 19 impact analysis, by type (vitamins, minerals, enzymes, fatty acids, proteins, and others), form (tablets, capsules, liquids, and powders), and regional forecasts, 2021-2028, 2022. Available at https://www.fortunebusinessinsights.com/dietary-supplements-market-102082/ Accessed December 27, 2022.