CORRELATION OF CREATINE KINASE LEVELS TO MUSCLE MASS AND PROTEIN IN KONI DKI JAKARTA PELATDA ATHLETES

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Abstract. Training with high intensity and high training volume impacts muscle damage and increased creatine kinase levels. Muscle damage occurs due to mechanical and metabolic stress within the muscle activated during the exercise stimulus. Measurement of serum Creatine Kinase (CK) activity can be used to examine muscle damage indirectly. The author carried out data collection analysis of creatine kinase (CK) enzyme levels in blood samples and body composition measurement tests using the Bioelectrical Impedance Analysis (BIA) tool. Sampling was carried out using a purposive sampling technique. Out of 101 DKI Jakarta athletes in the sports of judo, kickboxing, muaythai, diving, table tennis, swimming, rock climbing and taekwondo, 81 athletes met the criteria. The data were analyzed using the Spearman's Correlation test. The results of the study showed that there was a significant relationship (p=0.001) and a moderate positive correlation (r=0.543) between creatine kinase levels and muscle mass. This research also shows a significant (p=0.001) and positive (r=0.566) relationship between creatine kinase levels and protein mass. This study shows that athletes with high muscle mass and protein mass produce high levels of creatine kinase but with levels that are normal for the athlete category. Further research needs to be carried out to examine the long-term effects of training carried out by athletes.

Keywords: Biochemical Analysis, Body Composition, Exercise, Muscle Damage.

1. INTRODUCTION

Athletes are involved in various competitive sports matches individually or in teams, with high physical performance and special training methods. An athlete must train or do physical activities with the aim of improving performance in order to improve the athlete's excellence and achievements [1]. Athlete will do heavy training to achieve his goals. The general principle of training is the provision of progressive, specific, and reversible overload [2][2]. The provision of training loads can have a negative impact when the load given is

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excessive but cannot be adapted properly. High-intensity training loads can cause fatigue and allow for overtraining [3].

Training and competition in various types of sports with different intensities can cause Exercise-induced muscle damage (EIMD). EIMD is the impact of intense to moderate physical activity, causing a temporary decrease in muscle function, increased serum creatine kinase (CK) and lactate dehydrogenase (LDH) concentrations, increased myoglobin, and delayed onset muscle soreness (DOMS) [4]. The disturbances resulting from training can lead to acute muscle fatigue, which may result in impairments in posture and balance, thereby heightening the risk of injury among athletes (Jo Verschueren 2020). Contractile protein degradation associated with decreased muscle strength occurs about one week to one month after eccentric exercise. Therefore, in the context of intense exercise, unusual exercise, or eccentric bias, recovery strategies that can reduce negative effects such as EIMD and DOMS are an important focus to minimize unwanted impacts [4].

Muscle damage occurs due to mechanical and metabolic stress within the muscle that is activated during the training stimulus. Mechanical stress, which arises from muscle elongation due to pressure, is considered to be a more dominant factor in causing muscle protein damage. Metabolic stress is believed to be caused by metabolic deficiencies in activated muscles, which can increase muscle susceptibility to mechanical loads during exercise [5]. Measurement of serum Creatine kinase (CK) activity can be used for indirect examination of muscle damage [6]. Increased blood creatine kinase (CK) levels detected after exercise indicate surface membrane damage and disruption of sarcomere architecture, possibly caused by oxidative stress. Muscle contraction requires increased intracellular calcium, and excess calcium can activate proteases such as calpain-1 that destroy sarcomeric proteins [7].

High-intensity and high-volume training results in greater muscle damage and increased creatine kinase levels [8]. The training carried out by athletes Pelatda at the DKI Jakarta certainly uses many types of training, both low and high intensity. Several categories of sports such as measured, martial arts, and stop and go, usually have training programs with high intensity and volume so that they are prone to muscle damage. The training program carried out can be related to the degree of damage to the skeletal muscle cell structure at the sarcolemma and Z-disk levels, which can cause an increase in the creatine kinase enzyme in athletes [9]. The level of increase in creatine kinase is used to help detect the condition of an athlete's body that is experiencing tissue damage. It is natural for creatine kinase levels to increase temporarily due to heavy exercise, but the levels should not increase to the point that they can damage skeletal muscle, heart, or brain [10]. The increase in creatine kinase levels in athletes is higher than the creatine kinase levels of the general population, so it is necessary to use standards specifically for athletes in determining normal values to see signs of muscle damage that occurs [11]. During training, it is necessary to evaluate the results of adaptation from training by measuring the muscle damage that occurs and muscle mass and protein in the body. Therefore, an examination is needed to see the relationship between creatine kinase and muscle mass and protein in athletes at the KONI DKI Jakarta Pelatda. This study aims to determine the correlation between creatine kinase levels with muscle mass and protein in athletes of the KONI DKI Jakarta Pelatda.

2. METHOD

Participants

The population of this study was KONI DKI Jakarta athletes in eight (8) sports, namely judo, kick boxing, muaythai, diving, table tennis, swimming, rock climbing, and taekwondo totaling 101 people. The sampling technique was purposive sampling. Samples were taken from superior sports at KONI DKI Jakarta that met the criteria. The sampling criteria are as follows; (1) Pelatda KONI DKI Jakarta athletes, (2) include in high intensity training sports: heavy training sports and use a lot of explosive power (3) between 18 - 35 years old, (4) have no history of illness, and proven by a health certificate from a sports specialist doctor, (5) are willing to participate in the study. Research samples who drop out if they suffer from illness during the research process or fail to continue the research.

The data collection technique in this study used a body composition measurement test and serum creatine kinase levels in respondents who were the subjects of the study. The number of samples that met the criteria and participated in the study was 81 athletes consisting of 45 male and 36 female.

Procedure

The method in this study was quantitative research using a cross-sectional study design. A cross-sectional study is an observational study that analyzes data from a population at a certain point in time. This study looked at the correlation between blood creatine kinase levels and muscle mass and protein mass in KONI DKI Jakarta Province Athletes. This research was conducted at KONI DKI Jakarta from March to April 2023. This study used primary data as follows.

Table 1. Materials and Research Methods

Variable	Data Types	Data	Collection Method	Reference
Individual Characteristics	Primary	• Age • Gender • Sport category • History of illness	• Interview	(Oosthuyse & Bosch, 2017)
Anthropometrics measurement	Primary	• Muscle Mass • Protein Mass	• Measurement using BIA (Bioelectrical Impedance Analysis) Mediana i30 • Measurement with stature meter	(Campa et al., 2021).
Biochemical measurement	Primary	• Serum creatine kinase levels	• Analysis of serum creatine kinase (CK) in human blood serum using an automated photometric system.	(Ovchinnikov et al., 2022).

Body composition measurements were carried out using Bioelectrical Impedance Analysis (BIA). The BIA principle is measuring the resistance (impedance) to harmless alternating electric current when passing through the body's water components, usually between the upper and lower extremities [12]. Electric current will be passed through electrodes on the hands and feet. The current that flows will be inhibited by tissue, such as fat and cell membranes. The body's resistance to current will be used to estimate body composition [13]. Then enter athlete data such as name, age, gender, height into the body composition measurement tool software. Furthermore, athletes prepare themselves for the examination by removing footwear, accessories, metal objects, and wearing minimal clothing to then measure body composition. After that, the tool will produce the results of body composition measurements.

Creatine kinase (CK) analysis is carried out to determine the levels of this enzyme quantitatively in human serum in vitro using an automatic photometric system. Optimized UV testing according to IFCC (International Federation of Clinical Chemistry) and DGKC (German Society of Clinical Chemistry) standards. The test steps are as follows: (1) Prepare reagents 1 and 2. The reagents are stable until the expiration date stated on the kit if stored at a temperature of 2 – 8°C and Avoid contamination and protected from light. Test Procedure: Basic settings for Bio Majesty® JCA-BM6010/C by adding a wavelength of 340/410 nm. Temperature setting of 37°C with kinetic measurement. Then added 3.0 µL sample/calibrator, 80 µL R1, and 20 µL R2. Measure the absorbance during the kinetic and linear calibration periods using a calculator.

Data collection and analysis

The data obtained were summarized and processed using Microsoft Office Excel 2019 and SPSS version 27 for Windows. Data processing began with several stages, namely coding, entry (data input), cleaning (data rechecking), and data analysis. Coding is done by providing certain codes as guidelines for the next stage. Then the data will be entered into Microsoft Office Excel and presented in the form of a table. Rechecking is done after all data is entered and the next stage is data analysis.

Individual characteristic data used are age, gender and sport. Body composition data are muscle mass and protein mass. Biochemical data are serum creatine kinase levels. Data were analyzed with several tests. The first test was carried out to see whether the distribution of data in the sample was normally distributed or not. The correlation test carried out was the Pearson Correlation test if the quantitative data (interval or ratio) was normally distributed. Meanwhile, if the data was not normally distributed, the Spearman correlation test was used.

H0: There is no correlation between creatine kinase levels and muscle mass and protein in DKI Jakarta athletes

H1: There is a correlation between creatine kinase levels and muscle mass and protein in DKI Jakarta athletes

The significance value used in this study is 0.05. This provides an explanation that H0 is rejected and H1 is accepted when the p value <0.05, which means there is a correlation between creatine kinase levels and muscle mass and protein in DKI Jakarta athletes.

3. RESULTS AND DISCUSSION

3.1 Result

Pelatda athletes who were the subjects in this study consisted of 8 sports, namely judo, kick boxing, muaythai, diving, table tennis, swimming, rock climbing, and taekwondo, totaling 81 people consisting of 55.6% (45 people) male athletes and 44.4% (36 people) female athletes. The largest proportion of athletes came from diving as many as 15 athletes with the smallest number of athletes being muaythai as many as 5 athletes. The average age of the subjects was 22.61 ± 3.58 years.

Table 2. Sociodemographic Data Of Athletes Per Sport

No	Sport Category	Number of Athletes n (%)	Gender		Age (Mean ± SD)
			Male (n)	Female (n)	
1	Judo	8 (10)	6	2	22.30 ± 5.34
2	Kick Boxing	12 (15)	7	5	24.83 ± 3.32
3	Muaythai	5 (6)	4	1	22.80 ± 1.09
4	Diving	15 (19)	7	8	22.20 ± 3.90
5	Table Tennis	11 (14)	6	5	24.27 ± 3.10
6	Swimming	11 (14)	5	6	21.45 ± 3.32
7	Rock Climbing	7 (9)	3	4	21.14 ± 3.89
8	Taekwondo	12 (15)	7	5	21.41 ± 2.02
	Total	81 (100)	45	36	22.61 ± 3.58

Body composition describes and measures the various elements in the human body. Body composition can be measured based on five levels of complexity, considering body mass as the sum of different atoms, molecules, cells, tissues, or body segments. Body composition can be a determinant of athlete health and performance [1]. Body composition has a significant influence on athlete performance, including muscle mass, fat mass, protein mass, mineral mass, and body fluids [14].

Table 3. Distribution of BMI data during COVID-19 Delta and Omicron variants

No	Sport Categories	Amount n (%)	Muscle Mass, Kg (Mean ± SD)	Protein Mass, Kg (Mean ± SD)	Creatine Kinase Levels, U/L (Mean ± SD)
1	Judo	8 (10)	45.88 ± 9.6	9.63 ± 2.03	200.37 ± 115.83
2	Kick Boxing	12 (15)	43.42 ± 6.56	9.08 ± 1.38	154.16 ± 42.53
3	Muaythai	5 (6)	46.56 ± 8.64	9.76 ± 1.84	155.80 ± 62.35
4	Diving	15 (19)	49.50 ± 11.99	10.37 ± 2.57	197.66 ± 92.17
5	Table Tennis	11 (14)	42.68 ± 8.67	8.96 ± 1.88	169.45 ± 80.28
6	Swimming	11 (14)	49.09 ± 12.6	10.41 ± 1.87	257.90 ± 135.36
7	Rock Climbing	7 (9)	42.24 ± 6.93	8.74 ± 1.49	197.57 ± 134.89
8	Taekwondo	12 (15)	49.01 ± 8.99	10.30 ± 1.97	238.08 ± 115.96
	Amount	81 (100)	46.38 ± 9.77	9.73 ± 1.98	199.23 ± 103.24

Based on the results of the examination of the body composition of the muaythai, diving, swimming, and taekwondo sports, they have higher muscle mass than the average (46.38 ± 9.77 kg) of the overall measurement results of the sports. The diving sport has the largest average muscle mass, namely 49.50 ± 11.99 kg with the largest protein mass, namely 10.37 ± 2.57 kg. The creatine kinase levels that are higher than the average are Judo (200.37 ± 115.83 U/L), Swimming (257.90 ± 135.36 U/L) and Taekwondo (238.08 ± 115.96 U/L).

Table 4. Test Of Differences In Muscle Mass, Protein Mass And Creatine Kinase Levels Based On Gender

No	Variable	Male	Female	p-Value
1	Muscle Mass, Kg (Mean ± SD)	52.53 ± 6.96	38.68 ± 47.61	<0.001[a]
2	Protein Mass, Kg (Mean ± SD)	11.04 ± 1.45	8.09 ± 1.18	<0.001[a]
3	Creatine Kinase Levels, U/L (Mean ± SD)	243.71 ± 109.31	143.63 ± 60.15	<0.001[a]

[a] Mann-Whitney

Based on the results of the examination of body composition by gender, it was found that the muscle mass and protein mass of male athletes were higher (52.53 ± 6.96 kg and 11.04 ± 1.45 kg) compared to female athletes. In addition, creatine kinase levels in male athletes

(243.71 ± 109.31 U/L) also had higher results compared to female athletes (143.63 ± 60.15 U/L). Based on the results of the Mann-Whitney difference test, it was found that the variables of muscle mass, protein mass and creatine kinase levels in male athletes were statistically significantly different compared to female athletes (p-value <0.05).

Table 5. Correlation Test of Creatine Kinase Levels to Muscle Mass and Protein

	Muscle Mass	Protein Mass
Creatine Kinase Levels	r = 0.543 *p-value* = <0.001[b]	r = 0.566 *p-value* = <0.001[b]

[b] Spearman Correlation

The results of the Spearman correlation test showed a significant relationship (p = 0.001) and moderate positive correlation (r = 0.543) between creatine kinase levels and muscle mass. This study also showed a significant relationship (p = 0.001) and positive (r = 0.566) between creatine kinase levels and protein mass.

3.2 Discussion

A total of 81 athletes of Pelatda KONI DKI Jakarta had their body composition measured and their serum creatine kinase (CK) levels analyzed. Pelatda athletes who were the subjects of the study consisted of 55.6% (45 people) male athletes and 44.4% (36 people) female athletes. The age of the athletes sampled in this study was 18-35 years with an average age of 22.61 ± 3.58 years. Pelatda athletes studied consisted of 8 sports, namely judo, kick boxing, muaythai, diving, table tennis, swimming, rock climbing, and taekwondo. These sports are included in high-intensity sports. Diving, swimming, and taekwondo athletes have the highest muscle mass, protein mass, and creatine kinase levels compared to other sports in this study. Sports such as kickboxing, table tennis and rock climbing have the lowest muscle mass, protein mass, and creatine kinase levels. In addition to body composition, training performed by athletes from various sports also influences increasing creatine kinase in athletes. Differences in the type and intensity of training performed will affect the increase in creatine kinase levels in athletes. Research by Karaman et al., (2021) showed a significant difference in creatine kinase levels between wrestling and taekwondo. Where the sport of wrestling has higher creatine kinase levels due to higher training intensity.

Different types of exercise have varying impact on creatine kinase (CK) levels and muscle adaptations. Endurance training primarily focuses on high repetitions with lower weights, typically resulting in a moderate increase in CK levels due to less severe muscle damage that is more evenly distributed across muscle fibers [16]. In contrast, strength training, particularly at high intensities, is more likely to result in significant elevation in CK levels. This is primarily due to the damage caused by strong eccentric contractions. The adaptations resulting from strength training include increases in muscle size and strength, with more pronounced gains in muscle mass compared to endurance training [17].

Skeletal muscle functions as the main motor for body movement and has a key role in athletic performance. Skeletal muscle, or striated muscle, is the most metabolically active body tissue. This is because muscles require energy to contract, and this metabolic activity can contribute to higher calorie burning. Muscle protein can continuously undergo synthesis and degradation processes. After physical exercise, changes occur in the synthesis and degradation of muscle protein. This process is important for muscle recovery and structural changes that support the body's adaptation to physical loads [18].

High-intensity exercise involves intense muscle contractions that will cause minor damage to muscle fibers. This damage is a normal part of the muscle adaptation process to exercise. The body will repair and strengthen damaged muscle fibers. Strength training can trigger muscle tissue damage. When muscles are damaged, myoglobin (MB) and creatine kinase (CK) will leave the muscle and enter the bloodstream. The activity of creatine kinase is one of the indicators of muscle damage, exhibiting considerable variability among individuals. Research has shown that blood concentrations of creatine kinase (CK) and myoglobin (Mb) can rise markedly following intense exercise, highlighting considerable differences in how individuals respond to muscle damage [19].

Factors that affect cell membrane integrity include estrogen, dystrophin, and genotype. In general, female tend to have lower creatine kinase activity than male, which is due to the protective effect of estrogen on cell membranes. Estrogen helps limit muscle fiber damage by modulating the inflammatory response and stabilizing muscle membranes during physical stress. This protective effect leads to less CK (creatine kinase) release into the bloodstream, a common marker used to assess muscle damage. Research also indicates that phases of the menstrual cycle with higher estrogen levels may further enhance this protective role [20], [21].

Dystrophin also plays an important role in maintaining membrane integrity. People with dystrophin deficiency can show very high creatine kinase activity, even up to 25 to 200 times higher than normal. In addition, individuals with the DD allele have lower creatine kinase activity. The D allele of the ACE (Angiotensin-Converting Enzyme) gene appears to have a protective effect against muscle damage, particularly in response to eccentric contractions, which are known to cause muscle injury. Studies have shown that individuals with the DD genotype exhibit lower creatine kinase (CK) levels in the blood after performing eccentric contractions compared to those with the II allele. This lower CK level suggests that individuals with the DD genotype may experience less muscle damage or a reduced inflammatory response to the mechanical stress caused by high-intensity exercise [22].

Creatine kinase levels in male and female differ significantly (p-value = 0.001). This is in line with muscle mass and protein mass which are significantly different between male and female (p-value = 0.001) also differ between male and female. A study stated that the level of creatine kinase in the blood during resting conditions in male is higher than in female [23]. This is in line with the results obtained in the study. The hormone estrogen not only plays a role in the female reproductive system, but also acts as a natural protector of body cells from damage. Estrogen acts as an antioxidant that protects cells from damage caused by free radicals. Estrogen also acts as a stabilizer of cell membranes because estrogen has a structure similar to cholesterol which allows it to intercalate in membrane phospholipids. Estrogen plays a key role in maintaining cell membrane stability, which helps reduce muscle damage, particularly after intense or eccentric exercise. This is why female athletes typically show lower markers of muscle damage, such as creatine kinase, compared to males engaging in similar activities [20].

The results of the correlation test between creatine kinase and muscle mass showed a significant positive relationship, meaning that the higher the level of creatine kinase, the higher the muscle mass. Likewise with the results of the test on creatine kinase with protein mass which showed a significant positive relationship. This aligns with research by Chen et al., (2023), which found that lower CK levels are associated with reduced muscle mass, serving as a biomarker for muscle loss. This indicates that a decrease in muscle mass often results in lower serum CK levels, particularly in conditions related to muscle atrophy.

Creatine kinase levels are not directly related to protein mass, but protein mass is related to muscle mass in the body. High muscle mass or increased muscle mass is positively correlated with high protein mass. The process of increasing muscle mass involving exercise can cause an increase in creatine kinase. Additionally, consistently elevated CK levels, especially in cases of overtraining, may indicate overtraining syndrome (OTS) or severe muscle injury, both of which involve more extensive muscle tissue damage than usual [25].

The increase in CK activity can reach ~100% within 8 hours after strength training. CK activity will continue to increase to 300-6000 U/L with a peak level at 24-96 hours after exercise. Serum CK activity usually increases a few hours after strength training. The activity of creatine kinase during maximal resistance exercise training can rise above 3000 U·L−1 [26]. In the study, the average blood creatine kinase level of athletes was 199.23 ± 103.24 U/L. The normal range of CK at rest for male is 55-170 U/L and for female is 30-35 U/L. The study found that blood creatine kinase levels in male athletes (243.71 ± 109.31 U/L) and female athletes (143.63 ± 60.15 U/L). The results obtained showed that creatine kinase levels were included in the high category compared to normal values in the general population. However, these levels are common for athletes who actively do physical exercise to have creatine kinase levels ranging from 100-1000 U/L.

A study showed that the normal range of CK in athletes is 82-1083 U/L in male athletes and 47-513 U/L in female athletes [11]. These results show that the blood creatine kinase levels of athletes at the KONI DKI Jakarta training center are included in the normal category for athletes. Athletes have higher resting creatine kinase levels compared to the general population due to their greater muscle mass and greater intensity and frequency of exercise compared to the general population [27]. These high resting blood creatine kinase levels are caused by decreased clearance of the enzyme from the blood, permanent damage to muscle cell membranes due to chronic physical stress, higher fat-free mass in athletes compared to the general population, or a combination of all these factors [11].

The results of this study can have significant implications for athletic training programs. Regular monitoring of CK levels can provide a valuable reference for coaches to evaluate the extent of muscle strain experienced by athletes, helping them adjust training intensity to prevent overtraining and injuries. Additionally, CK measurements can serve as a benchmark for assessing the effectiveness of strength and hypertrophy training programs in athletes. Moreover, consistently tracking CK levels can guide the implementation of appropriate nutritional recovery strategies to support muscle regeneration and reduce CK levels post-training.

4. CONCLUSION

The research conducted showed that there was a significant and positive correlation between creatine kinase levels with muscle mass and protein mass. This means that athletes with high muscle mass and protein mass produce high creatine kinase levels but with normal levels for the athlete category. So in this study, athletes did not show excessive training without being able to adapt and muscle damage that occurred during training. Long-term CK research is needed to determine the relationship between creatine kinase levels and increased muscle mass and protein mass. There is a need for longitudinal studies that explore the impact of elevated creatine kinase levels with athletic performance. The studies may examine how increased creatine kinase levels correlate with injury risk.

REFERENCES

[1] F. Campa, S. Toselli, M. Mazzilli, L. A. Gobbo, and G. Coratella, "Assessment of body composition in athletes: A narrative review of available methods with special reference to quantitative and qualitative bioimpedance analysis," *Nutrients*, vol. 13, no. 5. 2021, doi: 10.3390/nu13051620.

[2] R. Furrer, J. A. Hawley, and C. Handschin, "Themolecular athlete: Exercise physiology frommechanisms to medals,"

Physiological Reviews, vol. 103, no. 3. 2023, doi: 10.1152/physrev.00017.2022.

[3] C. Malm, J. Jakobsson, and A. Isaksson, "Physical activity and sports—real health benefits: A review with insight into the public health of sweden," *Sports*, vol. 7, no. 5. 2019, doi: 10.3390/sports7050127.

[4] Y. Jiaming and M. H. Rahimi, "Creatine supplementation effect on recovery following exercise-induced muscle damage: A systematic review and meta-analysis of randomized controlled trials," *Journal of Food Biochemistry*, vol. 45, no. 10. 2021, doi: 10.1111/jfbc.13916.

[5] I. Markus, K. Constantini, J. R. Hoffman, S. Bartolomei, and Y. Gepner, "Exercise-induced muscle damage: mechanism, assessment and nutritional factors to accelerate recovery," *European Journal of Applied Physiology*, vol. 121, no. 4. 2021, doi: 10.1007/s00421-020-04566-4.

[6] L. de A. Freire *et al.*, "Correlation between creatine kinase and match load in soccer: A case report," *J. Phys. Educ. Sport*, vol. 20, no. 3, 2020, doi: 10.7752/jpes.2020.03178.

[7] A. N. Ovchinnikov, A. Paoli, V. V. Seleznev, and A. V. Deryugina, "Measurement of Lipid Peroxidation Products and Creatine Kinase in Blood Plasma and Saliva of Athletes at Rest and following Exercise," *J. Clin. Med.*, vol. 11, no. 11, 2022, doi: 10.3390/jcm11113098.

[8] D. Csala, B. M. Kovacs, P. Bali, G. Reha, and G. Panics, "The influence of external load variables on creatine kinase change during preseason training period," *Physiol. Int.*, vol. 108, no. 3, 2021, doi: 10.1556/2060.2021.30019.

[9] B. Giechaskiel, "Weight Training and Creatine Kinase (CK) Levels: A Literature Review," *Int. J. Sci. Res.*, vol. 9, no. 1, 2020.

[10] F. C. Lam, T. M. Khan, H. Faidah, A. Haseeb, and A. H. Khan, "Effectiveness of whey protein supplements on the serum levels of amino acid, creatinine kinase and myoglobin of athletes: A systematic review and meta-analysis," *Syst. Rev.*, vol. 8, no. 1, 2019, doi: 10.1186/s13643-019-1039-z.

[11] N. Akmal, R. Farenia, and D. Prihatni, "PERBANDINGAN KADAR ENZIM KREATININ FOSFOKINASE DAN NYERI OTOT SEBELUM DAN SESUDAH LATIHAN BERENANG

SELAMA EMPAT MINGGU PADA PERENANG UNIT KEGIATAN MAHASISWA KLUB RENANG," *J. ILMU FAAL OLAHRAGA Indones.*, vol. 3, no. 1, 2021, doi: 10.51671/jifo.v3i1.91.

[12] J. Lyons-Reid, L. C. Ward, T. Kenealy, and W. Cutfield, "Bioelectrical impedance analysis—an easy tool for quantifying body composition in infancy?," *Nutrients*, vol. 12, no. 4. 2020, doi: 10.3390/nu12040920.

[13] M. H. S. T. Penggalih, M. C. N. Dewinta, D. Pratiwi, K. M. Solichah, and I. Niamilah, *Gizi Olahraga I: Sistem Energi Antropometri dan Asupan Makan Atlet*. UGM Press, 2019.

[14] M. Baranauskas, D. Kupčiūnaitė, and R. Stukas, "The association between physical activity and psychological well-being in a sample of medicine and health sciences students: a pilot study," *Sport. Moksl. / Sport Sci.*, vol. 101, no. 1, 2022, doi: 10.15823/sm.2022.101.4.

[15] M. E. Karaman, C. Arslan, and A. E. Kinaci, "The Effect of Single Bout of Competitive Training on Muscle Damage and Liver Enzymes in University Student Wrestling and Taekwondo Athletes," *J. Pharm. Res. Int.*, 2021, doi: 10.9734/jpri/2021/v33i1731304.

[16] S. Liu, Y. Niu, and L. Fu, "Metabolic Adaptations to Exercise Training," *Journal of Science in Sport and Exercise*, vol. 2, no. 1. 2020, doi: 10.1007/s42978-019-0018-3.

[17] L. Lu, L. Mao, Y. Feng, B. E. Ainsworth, Y. Liu, and N. Chen, "Effects of different exercise training modes on muscle strength and physical performance in older people with sarcopenia: a systematic review and meta-analysis," *BMC Geriatr.*, vol. 21, no. 1, 2021, doi: 10.1186/s12877-021-02642-8.

[18] M. Baranauskas, I. Kupčiūnaitė, and R. Stukas, "Dietary Intake of Protein and Essential Amino Acids for Sustainable Muscle Development in Elite Male Athletes," *Nutrients*, vol. 15, no. 18, 2023, doi: 10.3390/nu15184003.

[19] C. D. F. C. Leite *et al.*, "Exercise-Induced Muscle Damage after a High-Intensity Interval Exercise Session: Systematic Review," *International Journal of Environmental Research and Public Health*, vol. 20, no. 22. 2023, doi: 10.3390/ijerph20227082.

[20] N. Romero-parra *et al.*, "Influence of the menstrual cycle on blood markers of muscle damage and inflammation following

eccentric exercise," *Int. J. Environ. Res. Public Health*, vol. 17, no. 5, 2020, doi: 10.3390/ijerph17051618.

[21] A. Pellegrino, P. M. Tiidus, and R. Vandenboom, "Mechanisms of Estrogen Influence on Skeletal Muscle: Mass, Regeneration, and Mitochondrial Function," *Sports Medicine*, vol. 52, no. 12. 2022, doi: 10.1007/s40279-022-01733-9.

[22] H. Ahmad Yusof and A. M. Che Muhamed, "Angiotensin-converting enzyme (ACE) insertion/deletion gene polymorphism across ethnicity: a narrative review of performance gene," *Sport Sciences for Health*, vol. 17, no. 1. 2021, doi: 10.1007/s11332-020-00712-9.

[23] T. Oosthuyse and A. N. Bosch, "The effect of gender and menstrual phase on serum creatine kinase activity and muscle soreness following downhill running," *Antioxidants*, vol. 6, no. 1, 2017, doi: 10.3390/antiox6010016.

[24] Z. Chen *et al.*, "Associations of Serum CXCL12α and CK Levels with Skeletal Muscle Mass in Older Adults," *J. Clin. Med.*, vol. 12, no. 11, 2023, doi: 10.3390/jcm12113800.

[25] F. A. Cadegiani and C. E. Kater, "Novel causes and consequences of overtraining syndrome: The EROS-DISRUPTORS study," *BMC Sports Sci. Med. Rehabil.*, vol. 11, no. 1, 2019, doi: 10.1186/s13102-019-0132-x.

[26] N. Haller *et al.*, "Blood-Based Biomarkers for Managing Workload in Athletes: Considerations and Recommendations for Evidence-Based Use of Established Biomarkers," *Sports Medicine*, vol. 53, no. 7. 2023, doi: 10.1007/s40279-023-01836-x.

[27] B. Jurjiu *et al.*, "Should Creatine Kinase be tested at baseline in athletes?," *Heal. Sport. Rehabil. Med.*, vol. 22, no. 4, 2021, doi: 10.26659/pm3.2021.22.4.236.