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An analysis of hemoglobin levels and body fat percentage on leg power in volleyball athletes

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ABSTRACT

This study aimed to determine the possible relationship between fat percentage and hemoglobin levels on leg power levels. It employed an analytical observational design using a cross-sectional approach. The sampling technique applied was purposive sampling, with the sample studied involving 24 male volleyball athletes aged under 22 years. Hemoglobin was assessed using the cyanmethemoglobin method. Body fat percentage was measured using Bioelectrical Impedance Analysis with the Omron Karada Scan HBF-358, while leg power was evaluated using the vertical jump test. The results indicated a strong negative relationship between the percentage of body fat and leg power (p=0.002; r=-.610), and a strong positive relationship between hemoglobin levels and leg power (p=0.001; r=0.613). The study demonstrated that a higher body fat percentage is associated with high power levels. In contrast, elevated hemoglobin concentrations are also positively related to power, indicating that both oxygen-carrying capacity and body composition may influence muscular performance.

KEYWORDS

Hemoglobin; Body Fat; Leg Power; Volleyball; Athletes

1. INTRODUCTION

Sport is an interesting field of study, and many people involved in it are paying close attention to efforts aimed at improving various aspects, especially fitness and athletic performance, including in volleyball (Luzzeri & Chow, 2020; Waardenburg et al., 2019). Volleyball is a sport that is quite popular in various countries, including Indonesia, and has become an international sport (Coutinho et al., 2016).

The components of physical conditions needed for volleyball involve strength, power, endurance, and flexibility. However, strength and power are the most essential components (López-Alonzo et al., 2016; Permana et al., 2022). An analysis of movement time in international men's volleyball games shows that during a rally that lasts 12 seconds on average, the setting and attacking players make at least one jumping movement. In contrast, the front-court players make four or three block jumps (Hastuti, 2018). Each set of jumping movements varies according to the type of position when playing. Power is significant for every volleyball player to have to become a player at the highest level (Ziv & Lidor, 2010), saying that having a good jump will benefit both the player and the team.

Apart from that, explosive power is an element of physical condition that has an essential role in volleyball (Benelguemar et al., 2020; Gantois et al., 2017), both as a supporting element in a particular movement and the main element in efforts to achieve perfect movement technique. Power is also vital for sports that require acceleration, such as sprinting, athletics, or sports whose movements are dominated by jumping, such as volleyball. Explosive power, in this case, the explosive power of the legs, is the ability of the leg muscles to move explosively in a short time. Volleyball requires explosive power, for example, when blocking the ball, smashing, and other jumping movements.

Power ability is influenced by several factors, including hemoglobin levels and body composition (Huovinen et al., 2015; Mairbäurl, 2013). Hemoglobin is one of the important factors that influences athletes' explosive power (Bachero-Mena et al., 2017; Škovierová et al., 2016). Hemoglobin is a protein in red blood cells that contains iron and has a role in transporting oxygen from the lungs to all body tissues (Glenn & Armstrong, 2019; Saha et al., 2014). Oxygen in the body is needed as fuel for energy formation (Katsounaros et al., 2014). Laborious activities carried out by athletes can have an impact on increasing the metabolic needs of muscle cells, where more acid is produced, so hemoglobin formation in athletes must also be adequate (Posey et al., 2021). Athletes need much oxygen to burn carbohydrates, which produce energy, especially during competition (Manolachi, 2020; Thomas et al., 2016). Hemoglobin (Hb) is needed to transport oxygen to muscles (Pittman, 2013). Apart from hemoglobin, body composition is one of the factors that can influence an athlete's explosive power ability. Someone who has a high percentage of fat tends to have low power (Bridge et al., 2014; Coutinho et al., 2016), low balance, and strength. Apart from that, body composition can also support an athlete's performance. If body composition is optimal, an athlete has more potential to achieve maximum success (Spyrou et al., 2020).

This study aims to determine the relationship between hemoglobin levels and body fat percentage on leg power in volleyball athletes. Practically, these findings have significant implications for coaches, athletes, and sports scientists. Coaches can use the results of this study to design training and nutrition programs that target increased leg muscle strength through the management of body composition and hematological status. Athletes can utilize this information to monitor physiological health and adjust lifestyles to support optimal performance. Meanwhile, sports scientists can use the relationship between hemoglobin, body fat, and muscle strength as a basis for developing performance prediction models and evidence-based training interventions (Williams et al., 2023). Furthermore, this research also expects that the results can have good implications for volleyball athletes as well as educating athletes.

2. METHODS

2.1. Design and Participants

This study was an analytical observational research carried out using a cross-sectional approach that emphasizes the measurement or observation of data at one time. The approach was applied to the dependent and independent variables, with all subjects who participated in the data collection or measurement (Friesen et al., 2021).

This study involved 24 samples taken using the purposive sampling technique, with the inclusion provisions: male volleyball athletes in the age group under 22 years, not injured, and willing to be employed as research samples. Exclusion criteria included athletes with recent or chronic illnesses, those currently under medication affecting metabolism or hematological parameters, individuals with irregular training history (less than six months of consistent training), inadequate nutritional status, dehydration, or any condition that could influence physiological measurements such as hemoglobin levels, body fat percentage, or muscular strength.

2.2. Procedure and Measurements

Participants were instructed not to engage in strenuous physical activity or intense exercise for 24–48 hours before blood collection and to avoid excessive fluid intake to prevent dehydration. They were also asked to refrain from consuming alcohol or smoking for 12 hours prior to blood collection. All samples were collected at a consistent time in the morning, between 7:00 and 10:00 AM, to minimize circadian variations. Before blood collection, subjects sat quietly for 10–15 minutes to allow blood flow to stabilize. The variables studied in this research were hemoglobin levels, percent body fat, and leg power capabilities of volleyball athletes: Hemoglobin levels were measured using the cyanmethemoglobin method.

2.2.1. Hemoglobin

Hemoglobin levels were measured using the cyanmethemoglobin method. The cyanmethemoglobin method is most often used because it can practically measure all types of hemoglobin except sulfhemoglobin (Srivastava et al., 2014). The advantage of this method is that the color standards used are relatively stable over a long time. Hemoglobin in the normal category for males is in the range of 13-18 gd/l (Domenica Cappellini & Motta, 2015; Turner et al., 2022; Who & Chan, 2011).

2.2.2. Fat percentage

Measuring body fat percentage in this study used the Omron Karada Scan HBF 358 measuring instrument. This tool is another alternative for measuring fat percentage. Meanwhile, the measurement method used by this tool is Bioelectrical Impedance Analysis (BIA) (Mialich et al., 2014). This tool has an accuracy of 0.1 kg for measuring body weight 0-100 kg and an accuracy of 0.2 kg for measuring body weight 100-135 kg. Meanwhile, for measuring fat percentage, the measurement results are classified as 0/(low), +/(normal), ++/(high), and have a 12-level display. The assessment norms used in this research were adapted from (Gallagher et al., 2000).

2.2.3. Leg power

The volleyball athlete’s leg power was measured using the vertical jump test. The purpose of this test was to determine the power ability of the legs to use vertical jumps optimally in the shortest possible time. The vertical jump test procedure in this research is:

a) Hang a diving board upright on the wall.

b) Athletes warm up/stretch before doing the test.

c) The athlete stands sideways, and the right/left foot is close to the wall.

d) The right/left hand is given chalk straightened up as high as possible and touched to the upright diving board. The highest touchmark is the height achieved.

e) The athlete jumps as high as possible with the help of a swing of both arms.

f) When jumping, touch the chalky fingers of your hand on the measuring board.

g) Compare the height reached with the result achieved when jumping.

h) Athletes are given two opportunities to carry out this test, and the best result is taken.

i) Then, the assessment norms used in this research were adapted from (Patterson & Peterson, 2004).

2.3. Statistical Analysis

The data were analyzed using the Pearson Product-Moment Correlation technique with a significance level of < 0.05. Prior to this analysis, prerequisite tests were conducted, including a normality test using the Shapiro-Wilk method and a linearity test using the ANOVA (F-test), both with a significance level > 0.05. All analyses were performed using SPSS version 27.

3. RESULTS

Table 1 presents descriptive statistics for participants grouped by vertical jump performance, showing the mean ± standard deviation (SD) for several variables across categories from "Excellent" to "Very Poor."

Table 1. Descriptive statistics for vertical jump category (mean ± SD)

	Vertical Jump					
	Excellent	**Good**	**Average**	**Poor**	**Very Poor**	**Total**
N	5	0	11	8	0	24
Age	18.8±1.3	0	19.82±1.66	19.38±1.40	0	19.46±1.50
Height (cm)	180.4±9.01	0	177.91±6.84	178.87±9.47	0	178.75±7.92
Weight (kg)	74.52±8.22	0	73.95±6.47	75.05±9.23	0	74.43±7.49
Body Fat (%)	13.98±2.04	0	17.57±2.70	18.76±4.00	0	17.22±3.45
HB (gd/l)	16.32±0.59	0	15.63±0.60	13.48±0.89	0	15.05±1.35

The results indicate that participants with higher vertical jump performance ("Excellent") generally had greater height, slightly lower body fat percentage, and higher hemoglobin levels compared to those in the "Average" or "Poor" categories. Age and weight were relatively similar across groups, while no participants were classified as "Good" or "Very Poor." Table 2 shows the results of the correlation analysis between vertical jump performance and body fat percentage.

Table 2. Relationship between vertical jump performance and body fat percentage

		Vertical Jump	**Body Fat**
Vertical Jump	Pearson Correlation	1	-.610**
	Sig. (2-tailed)		0.002
	N	24	24
Body Fat	Pearson Correlation	-.610**	1
	Sig. (2-tailed)	0.002	
	N	24	24

Note. ***. Correlation is significant at the 0.01 level (2-tailed).*

Based on the results of the analysis in Table 2, there is a relationship between body fat and muscle power, which was evaluated using the vertical jump test, which is proven by the significance result of 0.002 with the Pearson coefficient value stated with correlation coefficient (r). The cross-tabulation process between the hemoglobin levels and the fat percentage on leg power ability was analyzed using the Pearson Product Correlation test with the following results, which can be seen in Table 2. Table 3 shows the results of the correlation analysis between vertical jump performance and hemoglobin level.

Table 3. Relationship between vertical jump and hemoglobin level

		Vertical Jump	**HB (gd/l)**
Vertical Jump	Pearson Correlation	1	.613**
	Sig. (2-tailed)		0.001
	N	24	24
HB (gd/l)	Pearson Correlation	.613**	1
	Sig. (2-tailed)	0.001	
	N	24	24

Based on the results of the analysis in Table 3, there is a relationship between hemoglobin levels and leg muscle power, which was evaluated using the vertical jump test. The test was proven by the results of a significance value of 0.001, with the Pearson Correlation coefficient value showing a value of .613 (positive direction/value). This result means that there is a positive correlation between leg power ability and hemoglobin levels in volleyball athletes. The Pearson correlation coefficient value is .613, in the range of 0.61-0.80, so the correlation between variables has a substantial degree of relationship. In short, there is a strong positive correlation between power ability and hemoglobin levels in volleyball athletes. If there is an increase in hemoglobin levels, there will also be an increase in the power abilities of volleyball athletes.

4. DISCUSSION

Based on the results of this research, if athletes have an increase in power ability, there will be a decrease in body fat percentage, and athletes with a lower body fat percentage will have an advantage in their leg muscle power ability (jumping). This is proven in research by Markovic & Jaric (2007), which compared women’s body fat with men’s body fat on jumping performance, where women have higher body fat than men, so men have an advantage in jumping higher because they have less body fat.

The results of this study are also in accordance with research from (Katralli & Goudar, 2012), which reported that the higher the fat percentage, the lower the performance during activities involving body movement. Excess body fat can affect performance by reducing the energy available to move each kilogram of body weight, but having a lack of fat can also impair physical performance, including jumping power (Ben Mansour et al., 2021). Therefore, it can be concluded that the body fat requirements for an athlete would be better to have body fat in the ideal or standard category. Although body fat has a substantial effect on leg muscle power performance in volleyball athletes, body fat is not the only or main factor responsible for the performance that researchers observed. Other factors that can contribute to this effect include hormones, length of exercise, mineral levels, and muscle volume.

Given the body’s response to exercise, it is known that exercise changes hematological parameters. As seen from the hemoglobin profile, existing research shows that the stimulation provided by exercise can increase total hemoglobin mass, which is characterized by an increase in the amount of O2 that can be transported by the blood (Mairbäurl, 2013). In addition, hemoglobin contributes to the buffering capacity of the blood and the release of ATP (Adenosine triphosphate) and NO (Nitric oxide) from red blood cells. It also contributes to vasodilation and increased blood flow to working muscles (Mairbäurl, 2013). Hematological changes in athletes are generally related to aerobic exercise and aerobic performance. Increased Hb concentration has been reported to be positively associated with aerobic capacity (El-Sayed et al., 2000; Otto et al., 2013). However, research regarding the relationship between hemoglobin concentration levels and increased power is scarce because the majority is more related to aerobic power or aerobic capacity.

Apart from analyzing body fat percentage, this research also analyzed the relationship between hemoglobin levels and the leg power abilities of male volleyball athletes. Based on the results of this study, there is a strong positive correlation between power ability and hemoglobin levels in male volleyball athletes. We assume that if there is an increase in hemoglobin levels, there will also be an increase in the power performance of volleyball athletes.

Exercise can change hematological parameters (Wardyn et al., 2008). Furthermore, training with goals can influence physical performance (Bompa & Buzzichelli, 2019). Thus, changes in hematological parameters can also be related to changes in physical performance. In this research, high HB levels are known to be associated with high power levels. Meanwhile, low hemoglobin levels are associated with relatively low power levels. However, a direct explanation regarding the increase in power due to high Hb levels still needs to be studied further, considering that the power component is an advanced physical component and is influenced by many components. The components that make up power can be mentioned but are not only limited to, namely, the components of strength and speed (Bompa & Buzzichelli, 2019).

Increased power can be explained by the relationship between Hb levels and several components that make up power. When viewed from its relationship to muscle strength, several studies show that the level of hematological parameters shows an influence on strength, such as grip strength. Even though it is known to influence muscle strength, the role of hemoglobin levels is only as a support (Shimizu et al., 2018). Higher Hb levels are often associated with higher levels of grip strength. However, currently, studies regarding Hb in relation to muscle strength in athletes are scarce. Meanwhile, decreased muscle strength and physical performance are known to be associated with low Hb levels in elderly anemia sufferers (Fukushima et al., 2019). The possible reason for this is that the oxygen supplied to the muscles is limited, which interferes with physical performance (Tsai et al., 2019).

In the speed component, hemoglobin levels can affect sprint ability. An increase in Hb concentration and a decrease in hematocrit levels, or in other words, an increase in mean corpuscular hemoglobin, influence sprinting ability. High mean corpuscular hemoglobin can improve athletes' sprint performance (Bachero-Mena et al., 2017), which means that hemoglobin levels can also affect speed performance. However, it has yet to be discovered with certainty the relationship between Hb levels and speed in various sports. Furthermore, because speed is also strongly influenced by aerobic and anaerobic component factors, the relationship between Hb and speed can be biased to see that Hb has a strong relationship with the aerobic capacity component (Cai et al., 2019; El-Sayed et al., 2000; Otto et al., 2013). When looking at the long-term response to exercise, several studies show that there are changes or adaptations in hematological parameters (Gómez Martín et al., 2020). Regarding hemoglobin levels, athletes who have trained with chronic high-intensity exercise show lower hemoglobin levels compared to ordinary individuals. This condition is influenced by an increase in blood plasma so that hemoglobin levels decrease. However, this decrease in hemoglobin levels is not actually a decrease in hemoglobin but rather a decrease in hemoglobin levels due to blood hemodilution. This condition is known as sports anemia (Damian et al., 2021). When compared with ordinary individuals, athletes' hemoglobin levels actually remain higher but appear lower due to the increase in blood plasma, which increases faster than the increase in Hb (Schumacher et al., 2002). When viewed from the body's short-term or acute response to exercise, several studies show that an increase in Hb levels often appears to increase as a result of the acute response to exercise. This increase is generally seen in the competition preparation phase since the training given in this phase is aimed at improving aerobic ability (Bekris et al., 2015).

Based on the results obtained in this study, the researchers believe that the level of leg power can be influenced by fat percentage and hematological parameters. Lower fat percentages are known to be associated with higher levels of leg power. Meanwhile, high hematological parameters, in this case hemoglobin, are related to high power levels. Thus, the researchers advise coaches to monitor or pay more attention to changes in fat percentage or hematological parameters if they want to develop an athlete's power performance further.

5. LIMITATIONS

This study still has several limitations, namely, the athletes examined were only male athletes, so further research needs to be done on female athletes, or comparisons can be made between male and female athletes. Then, analysis regarding hematological relationships must actually be carried out comprehensively and not limited to HB concentration alone, for example, levels of hematocrit (Hct), blood plasma, red blood cells (RBC), white blood cells (WBC), mean cellular volume (MCV), mean cellular hemoglobin (MCH), and mean cellular hemoglobin concentration (MCHC). Through an integral understanding of hematological parameters, a good understanding of the relationship between hematological parameters and power levels can be achieved. Leg muscle strength is a key determinant of volleyball performance, particularly the ability to jump for spikes and blocks. The positive relationship between hemoglobin levels and leg muscle strength suggests that adequate oxygen supply plays a role in supporting energy metabolism during explosive muscle contractions (McArdle, Katch, and Katch 2014). Meanwhile, the negative relationship between body fat percentage and leg muscle strength suggests that increased body fat can hinder the efficiency of power production. Therefore, a balance between optimal hemoglobin levels and a controlled body fat percentage is key to improving leg muscle strength and overall volleyball performance.

Our research is observational and was conducted at random times, so we cannot explain whether high Hb levels really affect power levels. In this case, the athletes studied in this study were in the competition preparation phase. There is a demand to compare the relationship between hematological parameter levels between athletes in the preparation phase for competition, competition, and after competition. In addition, comparative research between novice and elite athletes needs to be carried out to determine acute and chronic responses related to the level of hematological parameters.

6. CONCLUSIONS

In accordance with the results of the research and discussion above, changes in the proportion of fat and hematological parameters might affect physical performance, especially energy. In this case, the proportion of fat was found to have a strong negative relationship with an increase in leg power. Meanwhile, the hematological parameters had a strong positive relationship with the increase of leg power. Seeing the relationship obtained, we recommend that trainers or interested staff further monitor and monitor changes in fat and hematological levels because this has good potential in further levels of power development.

7. REFERENCES

1. Bachero-Mena, B., Pareja-Blanco, F., & González-Badillo, J. J. (2017). Enhanced strength and sprint levels, and changes in blood parameters during a complete athletics season in 800 m high-level athletes. *Frontiers in Physiology, 8,* 1-10. https://doi.org/10.3389/fphys.2017.00637
2. Bekris, E., Gioldasis, A., Gissis, I., Anagnostakos, K., & Eleftherios, M. (2015). From preparation to competitive period in soccer: Hematological changes. *Sport Science Review*, *24*(1–2), 103–114.
3. Ben Mansour, G., Kacem, A., Ishak, M., Grélot, L., & Ftaiti, F. (2021). The effect of body composition on strength and power in male and female students. *BMC Sports Science, Medicine and Rehabilitation*, *13*(1), 1–11. https://doi.org/10.1186/s13102-021-00376-z
4. Benelguemar, H., Bouabdellah, S., & Mouıssı, F. (2020). The kinematical analysis of blocking skill in volleyball and their relationships with the explosive force of lower limbs. International Journal of Sport Exercise and Training Sciences, 6(2), 73-79. https://doi.org/10.18826/useeabd.731462
5. Bompa, T. O., & Buzzichelli, C. (2019). *Periodization: theory and methodology of training*. Human kinetics.
6. Bridge, C. A., Ferreira da Silva Santos, J., Chaabène, H., Pieter, W., & Franchini, E. (2014). Physical and physiological profiles of taekwondo athletes. *Sports Medicine*, *44*(6), 713–733. https://doi.org/10.1007/s40279-014-0159-9
7. Cai, G., Qiu, J., Chen, S., Pan, Q., Shen, X., & Kang, J. (2019). Hematological, Hormonal and Fitness Indices in Youth Swimmers: Gender-Related Comparisons. *Journal of Human Kinetics*, *70*, 69–80. https://doi.org/10.2478/hukin-2019-0027
8. Coutinho, L. A., Porto, C. P., & Pierucci, A. P. (2016). Critical evaluation of food intake and energy balance in young modern pentathlon athletes: a cross-sectional study. *Journal of the International Society of Sports Nutrition*, *13*(1), 1-8. https://doi.org/10.1186/s12970-016-0127-x
9. Coutinho, P., Mesquita, I., Davids, K., Fonseca, A. M., & Côté, J. (2016). How structured and unstructured sport activities aid the development of expertise in volleyball players. *Psychology of Sport and Exercise*, *25*, 51–59. https://doi.org/10.1016/j.psychsport.2016.04.004
10. Damian, M.-T., Vulturar, R., Login, C. C., Damian, L., Chis, A., & Bojan, A. (2021). Anemia in sports: a narrative review. *Life*, *11*(9), 1-12.
11. Domenica Cappellini, M., & Motta, I. (2015). Anemia in Clinical Practice-Definition and Classification: Does Hemoglobin Change With Aging? *Seminars in Hematology*, *52*(4), 261–269. https://doi.org/10.1053/j.seminhematol.2015.07.006
12. El-Sayed, M. S., Sale, C., Jones, P. G., & Chester, M. (2000). Blood hemostasis in exercise and training. *Medicine and Science in Sports and Exercise*, *32*(5), 918–925.

https://doi.org/10.1097/00005768-200005000-00007
13. Friesen, K. B., Anz, A. W., Dugas, J. R., Andrews, J. R., & Oliver, G. D. (2021). The Effects of Body Mass Index on Softball Pitchers' Hip and Shoulder Range of Motion. *Sports Medicine International Open*, *5*(1), 8–13. https://doi.org/10.1055/a-1244-1621
14. Fukushima, T., Nakano, J., Ishii, S., Natsuzako, A., Kawachi, H., Sakamoto, J., Miyazaki, Y., & Okita, M. (2019). Influence of hemoglobin level on muscle and physical functions, activities of daily living, and quality of life in patients with hematological malignancies. *Integrative Cancer Therapies*, *18(2), 1-10*.
15. Gallagher, D., Heymsfield, S. B., Heo, M., Jebb, S. A., Murgatroyd, P. R., & Sakamoto, Y. (2000). Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *The American Journal of Clinical Nutrition*, *72*(3), 694–701. https://doi.org/10.1093/ajcn/72.3.694
16. Gantois, P., Pinto, V., Castro, K. R. de, João, P. V, Dantas, P., & Cabral, B. G. A. T. (2017). Skeletal age and explosive strength in young volleyball players. *Revista Brasileira de Cineantropometria & Desempenho Humano*, *19*, 331–342.
17. Glenn, A., & Armstrong, C. E. (2019). Physiology of red and white blood cells. *Anaesthesia & Intensive Care Medicine*, *20*(3), 170–174.
18. Gómez Martín, J. P., Clemente-Suárez, V. J., & Ramos-Campo, D. J. (2020). Hematological and running performance modification of trained athletes after reverse vs. block training periodization. *International Journal of Environmental Research and Public Health*, *17*(13), 1-11. https://doi.org/10.3390/ijerph17134825
19. Hastuti, H. (2018). The Effect of Freeletic Exercise on Leg Strength in the Freeletic Community of Makassar. *Nusantara Medical Science Journal*, *3*(1), 27–31.
20. Huovinen, H. T., Hulmi, J. J., Isolehto, J., Kyröläinen, H., Puurtinen, R., Karila, T., Mackala, K., & Mero, A. A. (2015). Body composition and power performance improved after weight reduction in male athletes without hampering hormonal balance. *Journal of Strength and Conditioning Research*, *29*(1), 29–36. https://doi.org/10.1519/JSC.0000000000000619
21. Katralli, J., & Goudar, S. S. (2012). Anthropometric Profile and Special Judo Fitness levels of Indian Judo Players. *Asian Journal of Sports Medicine*, *3*(2), 113–118. https://doi.org/10.5812/asjsm.34710
22. Katsounaros, I., Cherevko, S., Zeradjanin, A. R., & Mayrhofer, K. J. (2014). Oxygen electrochemistry as a cornerstone for sustainable energy conversion. *Angewandte Chemie*, *53*(1), 102–121. https://doi.org/10.1002/anie.201306588
23. López-Alonzo, S. J., Rivera-Sosa, J. M., Buenaventura Pardo-Remetería, J., & Muñoz-Daw, M. de J. (2016). Indicadores de condición física en escolares mexicanos con sobrepeso y obesidad. *Boletin Medico Del Hospital Infantil de Mexico*, *73*(4), 243–249. https://doi.org/10.1016/j.bmhimx.2016.06.003
24. Luzzeri, M., & Chow, G. M. (2020). Presence and search for meaning in sport: Initial construct validation. *Psychology of Sport and Exercise*, *51*, 1-16. https://doi.org/10.1016/j.psychsport.2020.101783
25. Mairbäurl, H. (2013). Red blood cells in sports: effects of exercise and training on oxygen supply by red blood cells. *Frontiers in Physiology*, *4*, 1-13. https://doi.org/10.3389/fphys.2013.00332
26. Manolachi, V. (2020). Carbohydrates Energy Reserves as a Factor of Recovery after Training and Competitive Efforts. *Revista Românească Pentru Educaţie Multidimensională*, *12*(1), 357–367.
27. Markovic, G., & Jaric, S. (2007). Is vertical jump height a body size-independent measure of muscle power? *Journal of Sports Sciences*, *25*(12), 1355–1363. https://doi.org/10.1080/02640410601021713
28. McArdle, W. D., Katch, F. I., & Katch, V. L. (2014). *Exercise physiology: Nutrition, energy, and human performance* (8th ed.). Lippincott Williams & Wilkins.

29. Medina, C., Monge, A., Romero, M., López-Ridaura, R., Barquera, S., Romieu, I., Denova-Gutiérrez, E., & Lajous, M. (2021). Reliability and validity of the Mexican teachers' physical activity questionnaire (MTPAQ) in a subsample of female Mexican teachers. *BMC Sports Science, Medicine & Rehabilitation*, *13*(1), 1-8. https://doi.org/10.1186/s13102-021-00371-4
30. Mialich, M. S., Sicchieri, J. M. F., & Junior, A. A. J. (2014). Analysis of body composition: a critical review of the use of bioelectrical impedance analysis. *International Journal of Clinical Nutrition*, *2*(1), 1–10.
31. Otto, J. M., Montgomery, H. E., & Richards, T. (2013). Haemoglobin concentration and mass as determinants of exercise performance and of surgical outcome. *Extreme Physiology & Medicine*, *2*(1), 1–8. https://doi.org/10.1186/2046-7648-2-33
32. Patterson, D. D., & Peterson, D. F. (2004). Vertical Jump and Leg Power Norms for Young Adults. *Measurement in Physical Education and Exercise Science*, *8*(1), 33–41. https://doi.org/10.1207/s15327841mpee0801_3
33. Permana, H., Sukamti, E. R., Suhadi, & Miftachurochmah, Y. (2022). The Impacts of Plyometric Circuit Training before and after Technical Training on Cardiorespiratory and Power Abilities of Junior Male Volleyball Athletes. *International Journal of Human Movement and Sports Sciences*, *10*(4), 823–831. https://doi.org/10.13189/saj.2022.100423
34. Pittman, R. N. (2013). Oxygen transport in the microcirculation and its regulation. *Microcirculation*, *20*(2), 117–137.
35. Posey, E. A., Bazer, F. W., & Wu, G. (2021). Amino Acids and Their Metabolites for Improving Human Exercising Performance. *Advances in Experimental Medicine and Biology*, *1332*, 151–166. https://doi.org/10.1007/978-3-030-74180-8_9
36. Saha, D., Patgaonkar, M., Shroff, A., Ayyar, K., Bashir, T., & Reddy, K. V. (2014). Hemoglobin expression in nonerythroid cells: novel or ubiquitous?. *International Journal of Inflammation*, *2014*, 1-8. https://doi.org/10.1155/2014/803237
37. Schumacher, Y. O., Schmid, A., Grathwohl, D., Bültermann, D., & Berg, A. (2002). Hematological indices and iron status in athletes of various sports and performances. *Medicine and Science in Sports and Exercise*, *34*(5), 869–875. https://doi.org/10.1097/00005768-200205000-00022
38. Shimizu, Y., Yamanashi, H., Noguchi, Y., Koyamatsu, J., Nagayoshi, M., Kiyoura, K., Fukui, S., Tamai, M., Kawashiri, S.-Y., & Arima, K. (2018). Association of hemoglobin concentration with handgrip strength in relation to hepatocyte growth factor levels among elderly Japanese men aged 60–69 years: a cross-sectional study. *Environmental Health and Preventive Medicine*, *23*(1), 1–9.
39. Škovierová, H., Vidomanová, E., Mahmood, S., Sopková, J., Drgová, A., Červeňová, T., Halašová, E., & Lehotský, J. (2016). The molecular and cellular effect of homocysteine metabolism imbalance on human health. *International Journal of Molecular Sciences*, *17*(10), 1-18. https://doi.org/10.3390/ijms17101733
40. Spyrou, K., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review. *Frontiers in Psychology*, *11*, 1-17. https://doi.org/10.3389/fpsyg.2020.569897
41. Srivastava, T., Negandhi, H., Neogi, S. B., Sharma, J., & Saxena, R. (2014). Methods for hemoglobin estimation: A review of" what works. *Journal of Hematology & Transfusion*, *2*(3), 1-7.
42. Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. *Journal of the Academy of Nutrition and Dietetics*, *116*(3), 501–528. https://doi.org/10.1016/j.jand.2015.12.006
43. Tsai, K. Z., Lai, S. W., Hsieh, C. J., Lin, C. S., Lin, Y. P., Tsai, S. C., Chung, P. S., Lin, Y. K.,

Lin, T. C., & Ho, C. L. (2019). Association between mild anemia and physical fitness in a military male cohort: The CHIEF study. *Scientific Reports*, *9*(1), 1-8. https://doi.org/10.1038/s41598-019-47625-3
44. Turner, J., Parsi, M., & Badireddy, M. (2022). Anemia. In *StatPearls*. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK526017
45. Waardenburg, M., Visschers, M., Deelen, I., & van Liempt, I. (2019). Sport in liminal spaces: The meaning of sport activities for refugees living in a reception centre. *International Review for the Sociology of Sport*, *54*(8), 938–956. https://doi.org/10.1177/1012690218768200
46. Wardyn, G. G., Rennard, S. I., Brusnahan, S. K., McGuire, T. R., Carlson, M. L., Smith, L. M., McGranaghan, S., & Sharp, J. G. (2008). Effects of exercise on hematological parameters, circulating side population cells, and cytokines. *Experimental Hematology*, *36*(2), 216–223.
47. Who, & Chan, M. (2011). Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. *Geneva, Switzerland: World Health Organization*, 1–6. https://doi.org/2011
48. Williams, A. M., Ford, P. R., & Drust, B. (2023). *Science and soccer: Developing elite performers*. Routledge.
49. Ziv, G., & Lidor, R. (2010). Vertical jump in female and male volleyball players: a review of observational and experimental studies. *Scandinavian Journal of Medicine & Science in Sports*, *20*(4), 556–567. https://doi.org/10.1111/j.1600-0838.2009.01083.x

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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