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Pakistani Weightlifters and Power Production: Role of Protein Chelated Iron (Iron Bisglycinate / Ferrochel)

Muhammad Abdul Jabar Adnan[1], Muhammad Zafar Iqbal Butt[2], Alamgir Khan[3]

[1]Lecturer, Department of Sport Sciences and Physical Education, University of the Punjab, Lahore, Pakistan
[2]Professor, Department of Sport Sciences and Physical Education, University of the Punjab, Lahore, Pakistan
[3]Assistant Professor, Department of Sport Sciences and Physical Education, University of the Punjab, Lahore, Pakistan
Correspondence: abduljabar_4@yahoo.com[1]

ABSTRACT

Aims of the Study: Iron is of utmost importance in the human body due to its essential functions. The objectives of the current research are to test the effect of Ferrochel on the change in the level of Blood hemoglobin level (g/dL) and the change in the best weightlifting capacity of a Professional level Weightlifter of Pakistan.

Research Methodology: Experimental Research pattern was adopted for this research in which a pre-test post-test research design was used by segregating the total sample (n=40) into an experimental group (n=20) and control group (n=20) and treated with Ferrochel (orally) and placebo to both groups respectively for a period of two months alongside a game-specific generalized training program for weightlifters.

Results: Results showed a markable increase in the average best weightlifting capacity (29.94 Kgs) as well as the average blood hemoglobin level (4.71g/dL) of Weightlifters of the experimental group and non-noticeable change in for average best weightlifting capacity (2.96 Kgs) and average blood hemoglobin level (0.58 g/dL).

Conclusion: Research concluded that there is a positive effect of Ferrochel supplementation on Strength and Power development weightlifters by increasing blood hemoglobin level as it causes an increase in serum ferritin level and better muscle recovery.

Keywords: Protein, Iron Bisglycinate, Sports, Weightlifting, Power.

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Introduction

Iron plays a crucial role in the human body and is considered an essential mineral. It plays an important role in oxygen transport, energy production by forming ATPs, strength and power production, proper brain functioning, immune system support, DNA synthesis, and body temperature regulation (Tardy et al., 2020). Iron bisglycinate chelate (Ferrochel) is a form of iron supplement that combines iron with the amino acid glycine. This chelated form of iron offers several advantages over other forms of iron supplements (Fischer et al., 2023). While iron is important for overall health and strength, including muscle strength, the specific role of iron bisglycinate chelate in human body strength can be understood

as it has enhanced absorption as compared to other iron supplements, reduced side effects, better oxygen transport and energy production, faster recovery better exercise performance (Adnan et al., 2023). It is important to note that while iron is essential for health, both iron deficiency and excess can have adverse effects on the body. Maintaining a balanced intake of iron through a healthy diet and monitoring iron levels with the help of healthcare professionals is crucial for optimal health (Snetselaar et al., 2021). Weightlifting is a physically demanding activity that places significant stress on the muscles and can lead to increased iron requirements (Kohl et al., 2019). Iron is essential for muscle function, oxygen transport, energy production, and recovery, making it important for weightlifters to maintain adequate iron levels (Lee et al., 2017). Iron bisglycinate supplementation can be beneficial in supporting weightlifting performance and overall health by developing muscle strength, power and endurance, reducing fatigue, better muscle recovery and repair and supporting the immune system (Wilhelmsson, 2020).

Literature Review

Iron is of utmost importance in the human body due to its essential functions. Iron is a vital component of hemoglobin, the protein responsible for carrying oxygen from the lungs to all body tissues (Abbaspour et al., 2014). This ensures that oxygen is delivered to cells, allowing for proper energy production and metabolism. Iron is necessary for the electron transport chain, a series of reactions that generate adenosine triphosphate (ATP), the primary energy source in cells (Nolfi-Donegan et al., 2020). Iron helps facilitate the transfer of electrons, allowing for efficient energy production. Iron is involved in the synthesis of DNA, which carries genetic information and is essential for cell growth and division (Zhang, 2014). Iron is required to produce enzymes involved in DNA synthesis. Iron is essential for optimal muscle function (Buratti et al., 2015). It is required to produce myoglobin, a protein that stores oxygen in muscle cells. This allows muscles to receive the necessary oxygen supply during physical activity, contributing to endurance and performance (Joyner & Coyle, 2008). The relationship between hemoglobin level and body strength and power is indirect and multifaceted. While hemoglobin plays a crucial role in oxygen transport and energy production. A hemoglobin level can affect aerobic capacity, which refers to the body's ability to use oxygen efficiently during prolonged exercise (Armstrong & Welsman, 2007). Higher hemoglobin levels may support greater aerobic capacity, enabling individuals to sustain higher intensity and longer duration workouts, which can indirectly contribute to strength and power gains (Burke, 2021). Hemoglobin carries oxygen from the lungs to the body's tissues, including muscles. Sufficient oxygen availability is vital for energy production during physical activity. Higher hemoglobin levels can potentially enhance oxygen delivery, leading to improved endurance and reduced fatigue during exercise (Santisteban et al., 2022). While hemoglobin is important for oxygen transport, other factors like muscle mass, neuromuscular coordination, and muscle fiber types significantly influence strength and power (Mendonca et al., 2017). These factors determine muscles' force production capabilities and energy utilization efficiency, which are crucial for strength and power performance. Strength and power gains primarily result from specific training regimens that target muscular strength, hypertrophy, and neuromuscular adaptations (Baroni et al., 2015). While hemoglobin level can impact the delivery of oxygen to working muscles, it is the combination of training-induced physiological changes in muscles, such as increased muscle fiber size, neural adaptations, and improved coordination, that directly influence strength and power gains (Calbet et al., 2006). It is important to recognize that individual variations exist, and hemoglobin levels alone do not predict an individual's strength or power capabilities. Factors like genetics, training history, nutrition, overall health, and other physiological variables contribute to an individual's strength and power potential (Fragala et al., 2019). In summary, hemoglobin level is one of many factors that can, directly and indirectly, influence strength and power performance. While adequate oxygen delivery is essential for energy production during exercise, factors like muscle mass, neuromuscular coordination, and training adaptations have a more direct impact on strength and power gains. A comprehensive approach that considers multiple factors and optimizes training, nutrition, and overall health is crucial for improving strength and power.

Iron is involved in energy production and metabolism. Without sufficient iron, the body's energy production may be compromised, leading to fatigue, weakness, and reduced physical performance (Tardy et al., 2020). Iron deficiency can impact exercise capacity and performance. Inadequate iron levels can reduce oxygen-carrying capacity, impairing the delivery of oxygen to muscles during physical activity (Tsai et al., 2019). This can result in decreased endurance, reduced exercise tolerance, and early fatigue. Iron deficiency during muscle development can have significant implications for overall muscle growth, strength, and performance. Iron is involved in the synthesis of collagen, which plays a role in muscle structure and repair. Iron deficiency can disrupt the production of collagen, negatively impacting muscle protein synthesis and hampering muscle growth and repair (Schreurs et al., 2020). Iron deficiency can delay the recovery process following intense exercise or muscle damage. Adequate iron levels are necessary for efficient tissue repair and adaptation (di Corcia et al., 2022). Insufficient iron can impair the recovery of damaged muscle fibers, delay the repair process, and limit the overall muscle development and adaptation to exercise stimuli. Iron is essential for the synthesis and regulation of certain anabolic hormones, including testosterone and insulin-like growth factor 1 (IGF-1) (Castilla-Cortázar et al., 2020). Iron deficiency can disrupt the normal functioning of these hormones, which are important for muscle growth, development, and repair.

Iron bisglycinate chelate (Ferrochel) is a form of iron supplement that is often used to address iron deficiency or as a dietary supplement to support overall health (Shubham et al., 2020). While iron is important for various bodily functions, including energy production and oxygen transport, the specific use of iron bisglycinate chelate for strength and power development is not well-established (Avery, 2021). Ferrochel is involved in energy production through its role in the electron transport chain. Adequate iron levels are important for optimal energy metabolism, which can indirectly support strength and power development during physical activity (ABREU, 2021). The ferrous bisglycinate chelate (Fe-Ron, 26 mg elemental iron) is profoundly steady and promptly bioavailable, with late examinations exhibiting decreased GI trouble in relationship with a 4-5 times more prominent retention rate as contrasted and ferrous sulfate within the sight of phytates (McGee & Diosady, 2018).

Weightlifting is a competitive sport that involves two main lifts: the snatch and the clean and jerk (Garhammer, 2020). It is also an Olympic sport, with weightlifters competing in various weight categories to showcase their strength, power, and technique (Storey & Smith, 2012). In the snatch, the lifter lifts the barbell from the ground to overhead in one continuous motion. The lifter must quickly and explosively lift the barbell overhead while dropping into a deep squat to catch the barbell with locked arms. The clean and jerk involve two distinct movements. First, the lifter performs the clean, lifting the barbell from the ground to the shoulders. Then, after a brief pause, the lifter performs the jerk, driving the barbell overhead while splitting the legs into a lunge position and then recovering to a standing position (Altepeter & Mike, 2017). Weightlifting is renowned for developing explosive strength and power (Izquierdo et al., 2004). The lifts require a tremendous amount of force production to lift heavy weights from the ground to overhead. Athletes engage multiple muscle groups, including the legs, back, shoulders, and core, to generate the necessary power for successful lifts (Allen et al., 2002). Weightlifters compete in specific weight categories to ensure fair competition. The categories range from lower weight classes (e.g., 55 kg for men and 45 kg for women) to higher weight classes (e.g., +109 kg for men and +87 kg for women) (Hilton & Lundberg, 2021). Athletes strive to lift the heaviest weight possible in their respective weight categories. Weightlifting is a recognized sport in Pakistan, and the country has produced notable weightlifters who have represented Pakistan at various international competitions (Marwat et al., 2014). The Pakistan Weightlifting Federation (PWLF) is the governing body responsible for overseeing weightlifting activities in the country. It is affiliated with the International Weightlifting Federation (IWF) and the Asian Weightlifting Federation (AWF). Pakistani weightlifters have represented the country in various international competitions, including the Olympic Games, Commonwealth Games, Asian Games, and South Asian Games. They compete in different weight categories and aim to achieve personal bests and national records.

This research is concerned with the objective to test the effects of Ferrochel on blood hemoglobin level (g/dL) as well as weightlifting capacity (Kgs) of weightlifters in their weightlifting events i.e. Snatch and Clean+Jerk which raised the research question that is there any effect of supplementation of Ferrochel on blood hemoglobin level (g/dL) as well as Weightlifting capacity in Snatch and Clean+Jerk as these two are the events of Weightlifting Sports. Researchers hypothesized that supplementation of Ferrochel (Fe-Ron) has a positive effect on the Blood Hemoglobin Level (g/dL) of Weightlifters as well as on Weightlifting capacity in Snatch and Clean+Jerk of Weightlifters at the professional level. This type of experimental research of pre-test post-test nature was performed for the first time on professional Weightlifters at the National / International level so has great significance regarding the practical utilization of Ferrochel on Weightlifters.

Methodology

Researchers selected 40 (n=40) professional weightlifters from different Weightlifting Clubs in Pakistan (using convenience sampling method) of having maturity in their Sports professional life i.e. 5-6 years of Weightlifting Experience and chronological age between 20 to 25 Years of having their body weight ranges from 73-96 Kgs (As mostly players avails in these bodyweight categories who have given consent for participation in research).

All players were placed under one roof in a standard environment and diet pattern and all possible variating agents were controlled to minimize the chance of error in conducting the study.

The blood hemoglobin level (g/dL) of all players was checked using Bio Vision Abcam® Haemoglobin Assay Kit (Colorimetric) (Kit. No. ab234046) through the colorimetric detection method (Wang et al., 2021).

At the first stage, the Weightlifting Capacity of all players was checked through their best performance in Snatch and Clean+Jerk as the protocol of Pre-test and Blood hemoglobin level was also measured using the above-mentioned kit under the supervision of the required medical and paramedical staff in a very hygienic environment.

All players were segregated into two Groups Experimental Group (n=20) and Control Group (n=20). Where the Experimental Group was treated with Iron bisglycinate (Fe-Ron, A product manufactured by Tehseen Laboratories (Pvt.) Ltd. and marketed by Nisma Pharmaceuticals (Pvt.) Ltd.) containing 130mg of protein chelated Iron (Iron bisglycinate chelate / Ferrochel) equal to 26mg of elemental Iron under the monitoring of medical and paramedical staff on once daily basis for 60 days (Hinton & Sinclair, 2007). Whereas Control Group (n=20) was treated with Placebo under the same protocol as the experimental group treated.

Same type of generalized 6 days training program with 7^{th} day rest was developed and applied to both groups with a change in Weightlifting activity intensities according to every individual on behalf of his best weightlifting capacity and body weight but the whole training protocol remained the same for both groups.

Blood hemoglobin level (g/dL) and best weightlifting capacity (Kgs) of Snatch and Clean+Jerk were measured and recorded in the post-test.

Statistical analysis was done using a t-test for change in Change in the Blood Hemoglobin level (g/dL) and Weightlifting capacity of Snatch and Clean+Jerk using t-test and data was generated and graphical analysis was done.

Data Analysis and Results

A significant increase i.e. 29.94Kgs in the average weightlifting capacity of Snatch and Clean+Jerk was found and the same significant increase was found in the average blood hemoglobin level (4.71 g/dL) in the experimental group whereas, in the case of the control group, a non-noticeable-average increase was

seen in average Blood Hemoglobin Level (0.58 g/dL) as well as average weightlifting capacity of Snatch and Clean+Jerk (2.96 Kgs) which showed that there is the positive effect of Ferrochel supplementation on increase in Weightlifting capacities as well in their Blood Hemoglobin level of weightlifters of the experimental group as compared to the control group. However minor increase in average best weightlifting capacities and blood hemoglobin level of the control group may be due to other dietary factors i.e. intake of iron as micronutrients from daily diet resources.

Table 1: *t-test Analysis for Weightlifting Capacity (Kgs) of Weightlifters and Blood Hemoglobin Level (g/dL)*

Measurement Parameters	**Pre-test (n=40)**	**Post-Test**		**SD**	**SEM**	**t**	**Sig.**
		Experimental Group (n=20)	**Control Group (n=20)**				
Average Weightlifting Events Capacity (Kgs)	304.20	334.14	307.16	14.8967	0.6899	2.1245	.000
Average Blood Hemoglobin Level (g/dL)	11.21	15.82	11.79	2.1147	0.7188	2.2351	.000

Where α=.05; t=t-test value; SD=Standard Deviation; n= Sample Population; Sig.=Significance; SEM=Standard Error of Mean

Figure 1: *Comparison of the Results of Experimental and Control Groups for Change in Average Best Weightlifting Capacity (Kgs)*

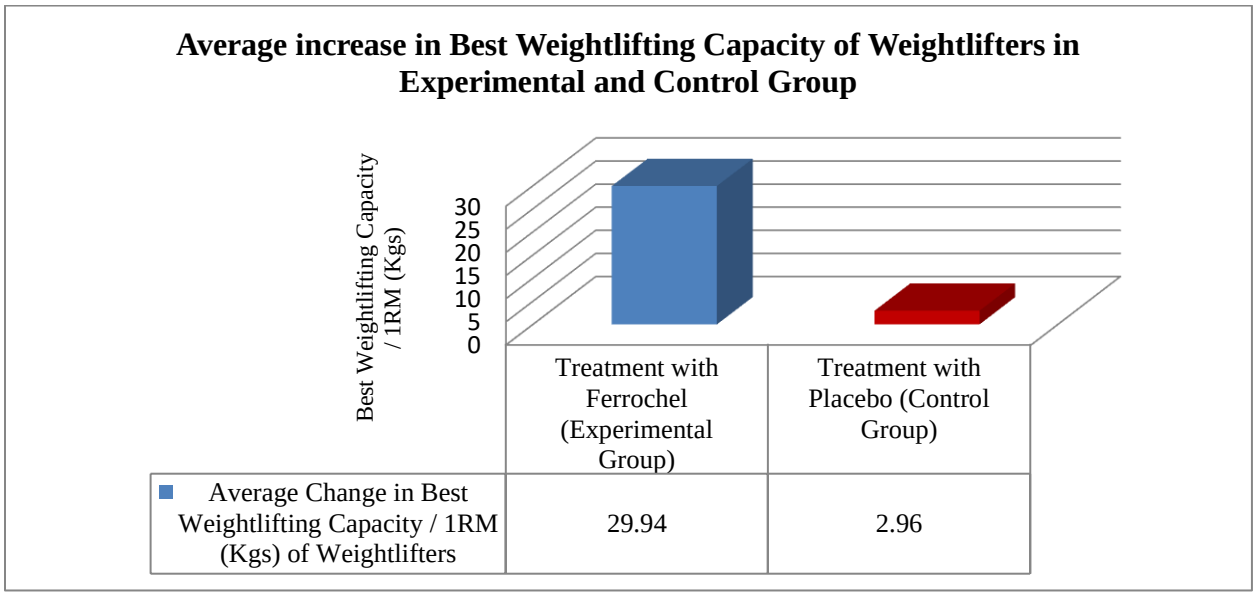
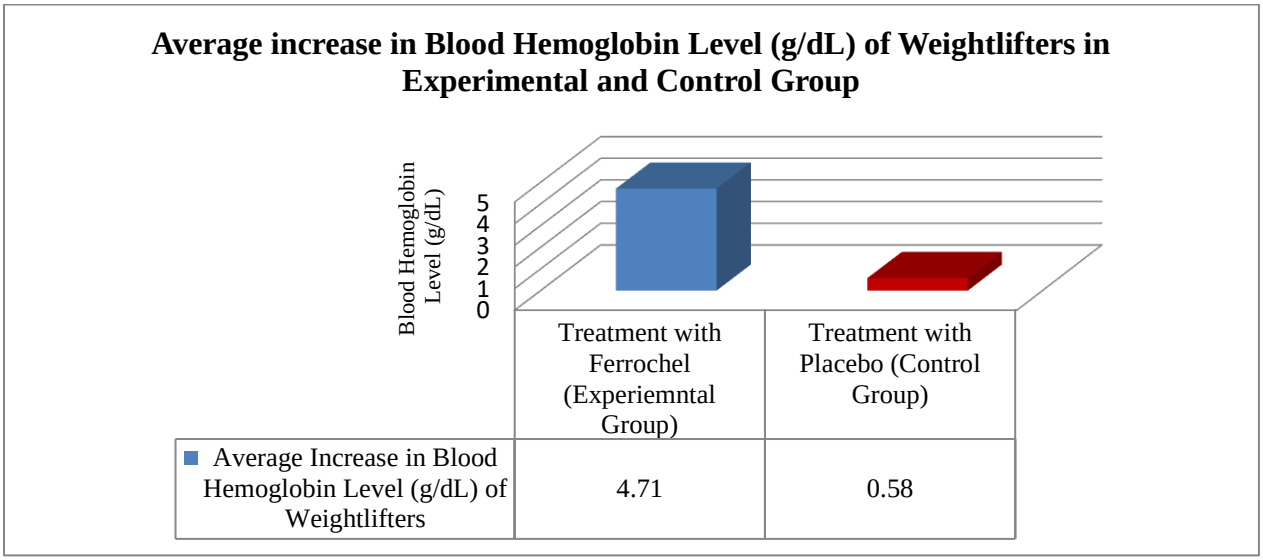


Figure 2: *Comparison of the Results of Experimental and Control Groups for Change in Average Blood Hemoglobin Level (g/dL)*



Discussion

Weightlifting requires a combination of explosive power, technique, flexibility, and overall strength (Hedrick & Wada, 2008). Athletes in this sport often engage in specific training programs to improve their performance, which may include exercises to increase strength, power, and mobility and practicing the specific lifts themselves (Myer et al., 2011). Weightlifting and iron supplementation can be interconnected in several ways. Iron is an essential mineral that plays a vital role in the body, including the production of hemoglobin, A protein in red blood cells that carries oxygen to muscles and tissues (Gupta, 2014). For weightlifters, maintaining adequate iron levels is important for optimal performance and overall health (Bytomski, 2018). Like any form of exercise, weightlifting can increase the body's iron requirements. Intense physical activity can lead to small amounts of iron loss through sweat, urine, and the breakdown of red blood cells. Additionally, weightlifters often focus on building muscle mass, which requires an increased oxygen supply to support the muscles (Nachtigall et al., 1996). Sufficient iron levels are necessary to support the production of new red blood cells and ensure proper oxygen delivery (Jensen, 2009). However, it is important to note that iron deficiency is a common concern among athletes, including weightlifters. Intense training, inadequate dietary intake, and other factors can contribute to iron depletion (Petrie et al., 2004). Iron deficiency can lead to reduced athletic performance, fatigue, decreased immune function, and other health issues (Williams, 2005). In some cases, weightlifters may choose to supplement with iron to maintain optimal iron levels (Thomas et al., 2016). Iron supplementation should be approached with caution and under the guidance of a healthcare professional. It is important to determine whether iron deficiency exists through appropriate testing before starting supplementation. Excessive iron intake can be harmful, leading to iron overload, organ damage, and other adverse effects. If iron deficiency is diagnosed, supplementation may be prescribed by a healthcare professional to restore iron levels (Zhang et al., 2019). Additionally, weightlifters can take measures to enhance iron absorption from dietary sources. Consuming iron-rich foods, such as lean meats, poultry, fish, legumes, leafy green vegetables, and fortified cereals, alongside vitamin C-rich foods, can aid in iron absorption (Skolmowska et al., 2022). Ultimately, weightlifters should aim for a balanced diet that includes adequate iron intake to support their training and overall health (Potgieter, 2013). Regular monitoring of iron levels and consultation with a healthcare professional can help ensure appropriate iron supplementation if needed, to optimize performance and well-being (Pedlar et al., 2018). Ferrochel is a branded form of iron

supplement that utilizes the chelated form of iron called ferrous bisglycinate (Mehansho et al., 2003). It is claimed to have superior bioavailability and better tolerability compared to other forms of iron supplements. Therefore, it is always recommended to consult with a healthcare professional or a registered dietitian before starting any new supplement, including Ferrochel or any other iron supplement. It is crucial to have iron levels evaluated through appropriate testing (Simelane, 2015). This can determine whether you have iron deficiency or if your iron levels are within a healthy range (Schroth et al., 2013). If a sports person is diagnosed with iron deficiency, your healthcare professional may recommend an iron supplement to help restore your iron levels. When it comes to specific iron supplements like Ferrochel, it is important to follow the instructions provided by the manufacturer and consult with a healthcare professional for personalized advice (Simelane, 2015). They can consider your individual needs, health status, and any other medications or supplements you may be taking to guide you on the appropriate dosage and duration of iron supplementation (Maughan et al., 2018). Iron supplementation should not be undertaken without proper guidance, as excessive iron intake can have adverse effects on health. It's also worth noting that optimizing iron levels is not solely achieved through supplementation (Pavord et al., 2012). Consuming a well-balanced diet that includes iron-rich foods, such as lean meats, poultry, fish, legumes, leafy green vegetables, and fortified cereals, is crucial for maintaining adequate iron levels (Purcell, 2013). Regarding this research, the positive effects of Ferrochel supplementation were found on total blood hemoglobin level as well as on the best weightlifting capacity of weightlifters which means that Ferrochel supplementation can be a good contributor to better performance in Weightlifting sports (Magnussen et al., 2008).

Conclusion

The objectives of this research were to test the effects of Ferrochel on change in total blood hemoglobin level (g/dL) and best weightlifting capacity of weightlifters and results showed the positive effects on both blood hemoglobin level as well as best weightlifting capacity of weightlifters which opened a new door of research for coming researchers to identify the mechanism that how Ferrochel improved Blood hemoglobin level and best weightlifting capacities of players on physiological grounds.

Future Recommendation

The current study only includes male Weightlifting Players on a very small scale which should be done on a larger population and on female players as well of different weight and age groups to check the authenticity of Ferrochel supplementation. Furthermore, it is needed to identify the mechanism that how Ferrochel effects on physiological systems of the body causing an increase in blood hemoglobin level as well as the best weightlifting capacities of players.

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Conflict of Interest

Authors declared no conflict of interest.

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ORCID iDs

Muhammad Abdul Jabar Adnan [1] https://orcid.org/0000-0002-8712-1045
Muhammad Zafar Iqbal Butt [2] https://orcid.org/0000-0003-0613-1020
Alamgir Khan [3] https://orcid.org/0000-0003-4768-8407

References

Abbaspour, N., Hurrell, R., & Kelishadi, R. (2014). Review on iron and its importance for human health. *Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences*, *19*(2), 164.

ABREU, M. E. (2021). *Complexos ferro-peptídeos de soro de leite: obtenção, caracterização e avaliação do efeito pró-oxidante do ferro e de sua biodisponibilidade por modelo de cultura de células Caco-2* (Doctoral dissertation, Tese (Doutorado). Universidade Estadual de Campinas, 2017. Disponível em:< http://repositorio. unicamp. br/jspui/handle/REPOSIP/322794>. Acesso em: 21 out).

Adnan, M. A. J., Butt, M. Z. I., & Khan, A. (2023). Iron Bisglycinate Chelate (Ferrochel) and Strength/Power Development in Powerlifting Players of Pakistan. *Human Nature Journal of Social Sciences*, *4*(1), 473-481.

Allen, S., Dudley, G. A., Iosia, M., Stanforth, D., & Steuerwald, B. (2002). Core strength training. *Sports Science Exchange Roundtable*, *13*(1), 1-4.

Altepeter, M., & Mike, J. (2017). Snatch balance technique. *Strength & Conditioning Journal*, *39*(5), 82-88.

Armstrong, N., & Welsman, J. R. (2007). Aerobic fitness: what are we measuring?. *Pediatric Fitness*, *50*, 5-25.

Avery, H. L. (2021). *Iron Status and Iron-Vitamin C Co-Supplementation Effects on Cognition, Subjective Mood and Fatigue in Menstruating, Non Anaemic Women Aged 18–49 Years*. University of Northumbria at Newcastle (United Kingdom).

Baroni, B. M., Pinto, R. S., Herzog, W., & Vaz, M. A. (2015). Eccentric resistance training of the knee extensor muscle: training programs and neuromuscular adaptations. *Isokinetics and Exercise Science*, *23*(3), 183-198.

Buratti, P., Gammella, E., Rybinska, I., Cairo, G., & Recalcati, S. (2015). Recent advances in iron metabolism: relevance for health, exercise, and performance. *Med Sci Sports Exerc*, *47*(8), 1596-604.

Burke, L. M. (2021). Ketogenic low-CHO, high-fat diet: the future of elite endurance sport?. *The Journal of physiology*, *599*(3), 819-843.

Bytomski, J. R. (2018). Fueling for performance. *Sports health*, *10*(1), 47-53.

Calbet, J. A., Lundby, C., Koskolou, M., & Boushel, R. (2006). Importance of hemoglobin concentration to exercise: acute manipulations. *Respiratory physiology & neurobiology*, *151*(2-3), 132-140.

Castilla-Cortázar, I., Aguirre, G. A., Femat-Roldán, G., Martín-Estal, I., & Espinosa, L. (2020). Is insulin-like growth factor-1 involved in Parkinson's disease development?. *Journal of translational medicine*, *18*(1), 1-17.

di Corcia, M., Tartaglia, N., Polito, R., Ambrosi, A., Messina, G., Francavilla, V. C., ... & Albenzio, M. (2022). Functional Properties of Meat in Athletes' Performance and Recovery. *International Journal of Environmental Research and Public Health*, *19*(9), 5145.

Fischer, J. A., Cherian, A. M., Bone, J. N., & Karakochuk, C. D. (2023). The effects of oral ferrous bisglycinate supplementation on hemoglobin and ferritin concentrations in adults and children: a systematic review and meta-analysis of randomized controlled trials. *Nutrition Reviews*, nuac106.

Fragala, M. S., Cadore, E. L., Dorgo, S., Izquierdo, M., Kraemer, W. J., Peterson, M. D., & Ryan, E. D. (2019). Resistance training for older adults: position statement from the national strength and conditioning association. *The Journal of Strength & Conditioning Research*, *33*(8).

Garhammer, J. (2020). Weight lifting and training. *Biomechanics of sport*, 169-211.

Gupta, C. P. (2014). Role of iron (Fe) in body. *IOSR Journal of Applied Chemistry*, *7*(11), 38-46.

Hedrick, A., & Wada, H. (2008). Weightlifting movements: do the benefits outweigh the risks?. *Strength & Conditioning Journal*, *30*(6), 26-35.

Hilton, E. N., & Lundberg, T. R. (2021). Transgender women in the female category of sport: perspectives on testosterone suppression and performance advantage. *Sports Medicine*, *51*, 199-214.

Hinton, P. S., & Sinclair, L. M. (2007). Iron supplementation maintains ventilatory threshold and improves energetic efficiency in iron-deficient nonanemic athletes. *European journal of clinical nutrition*, *61*(1), 30-39.

Izquierdo, M., Ibáñez, J., Häkkinen, K., Kraemer, W. J., Ruesta, M., & Gorostiaga, E. M. (2004). Maximal strength and power, muscle mass, endurance and serum hormones in weightlifters and road cyclists. *Journal of sports sciences*, *22*(5), 465-478.

Jensen, F. B. (2009). The dual roles of red blood cells in tissue oxygen delivery: oxygen carriers and regulators of local blood flow. *Journal of Experimental Biology*, *212*(21), 3387-3393.

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: the physiology of champions. *The Journal of physiology*, *586*(1), 35-44.

Kohl III, H., Murray, T., & Salvo, D. (2019). *Foundations of physical activity and public health*. Human Kinetics Publishers.

Lee, E. C., Fragala, M. S., Kavouras, S. A., Queen, R. M., Pryor, J. L., & Casa, D. J. (2017). Biomarkers in sports and exercise: tracking health, performance, and recovery in athletes. *Journal of strength and conditioning research*, *31*(10), 2920.

Magnussen, K., Bork, N., & Asmussen, L. (2008). The effect of a standardized protocol for iron supplementation to blood donors low in hemoglobin concentration. *Transfusion*, *48*(4), 749-754.

Marwat, M. K., Zia-ul-Islam, S., Waseem, M., Khattak, H., & BiBi, S. (2014). Sport performance of Muslim women and different constraints in their way to participation in sport. *International Journal of Humanities and Social Science*, *4*(10), 208-214.

Maughan, R. J., Burke, L. M., Dvorak, J., Larson-Meyer, D. E., Peeling, P., Phillips, S. M., ... & Engebretsen, L. (2018). IOC consensus statement: dietary supplements and the high-performance athlete. *International journal of sport nutrition and exercise metabolism*, *28*(2), 104-125.

McGee, E. J. T., & Diosady, L. L. (2018). Prevention of iron-polyphenol complex formation by chelation in black tea. *LWT*, *89*, 756-762.

Mehansho, H., Mellican, R. I., Hughes, D. L., Compton, D. B., & Walter, T. (2003). Multiple-micronutrient fortification technology development and evaluation: from lab to market. *Food and Nutrition Bulletin*, *24*(4_suppl_1), S111-S119.

Mendonca, G. V., Pezarat-Correia, P., Vaz, J. R., Silva, L., & Heffernan, K. S. (2017). Impact of aging on endurance and neuromuscular physical performance: the role of vascular senescence. *Sports medicine*, *47*, 583-598.

Myer, G. D., Faigenbaum, A. D., Chu, D. A., Falkel, J., Ford, K. R., Best, T. M., & Hewett, T. E. (2011). Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance. *The Physician and sportsmedicine*, *39*(1), 74-84.

Nachtigall, D., Nielsen, P., Fischer, R., Engelhardt, R., & Gabbe, E. E. (1996). Iron deficiency in distance Runners A reinvestigation using 59Fe-Labelling and non-invasive liver iron quantification. *International journal of sports medicine*, *17*(07), 473-479.

Nolfi-Donegan, D., Braganza, A., & Shiva, S. (2020). Mitochondrial electron transport chain: Oxidative phosphorylation, oxidant production, and methods of measurement. *Redox biology*, *37*, 101674.

Pavord, S., Myers, B., Robinson, S., Allard, S., Strong, J., Oppenheimer, C., & British Committee for Standards in Haematology. (2012). UK guidelines on the management of iron deficiency in pregnancy. *British journal of haematology*, *156*(5), 588-600.

Pedlar, C. R., Brugnara, C., Bruinvels, G., & Burden, R. (2018). Iron balance and iron supplementation for the female athlete: a practical approach. *European journal of sport science*, *18*(2), 295-305.

Petrie, H. J., Stover, E. A., & Horswill, C. A. (2004). Nutritional concerns for the child and adolescent competitor. *Nutrition*, *20*(7-8), 620-631.

Potgieter, S. (2013). Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the International Society for Sports Nutrition. *South African journal of clinical nutrition*, *26*(1), 6-16.

Purcell, L. K., Canadian Paediatric Society, & Paediatric Sports and Exercise Medicine Section. (2013). Sport nutrition for young athletes. *Paediatrics & child health*, *18*(4), 200-202.

Santisteban, K. J., Lovering, A. T., Halliwill, J. R., & Minson, C. T. (2022). Sex differences in VO2max and the impact on endurance-exercise performance. *International Journal of Environmental Research and Public Health*, *19*(9), 4946.

Schreurs, M., Suttorp, C. M., Mutsaers, H. A., Kuijpers-Jagtman, A. M., Von den Hoff, J. W., Ongkosuwito, E. M., ... & Wagener, F. A. (2020). Tissue engineering strategies combining molecular targets against inflammation and fibrosis, and umbilical cord blood stem cells to improve hampered muscle and skin regeneration following cleft repair. *Medicinal research reviews*, *40*(1), 9-26.

Schroth, R. J., Levi, J., Kliewer, E., Friel, J., & Moffatt, M. E. (2013). Association between iron status, iron deficiency anaemia, and severe early childhood caries: a case–control study. *BMC pediatrics*, *13*, 1-7.

Shubham, K., Anukiruthika, T., Dutta, S., Kashyap, A. V., Moses, J. A., & Anandharamakrishnan, C. (2020). Iron deficiency anemia: A comprehensive review on iron absorption, bioavailability and emerging food fortification approaches. *Trends in Food Science & Technology*, *99*, 58-75.

Simelane, L. S. (2015). *Effect of a multiple micronutrient enriched maize-based liquid meal supplement on iron status of grade 3 and 4 learners attending Sunnyside primary school, Pretoria* (Doctoral dissertation, University of Pretoria).

Skolmowska, D., Głąbska, D., Kołota, A., & Guzek, D. (2022). Effectiveness of Dietary Interventions to Treat Iron-Deficiency Anemia in Women: A Systematic Review of Randomized Controlled Trials. *Nutrients*, *14*(13), 2724.

Snetselaar, L. G., de Jesus, J. M., DeSilva, D. M., & Stoody, E. E. (2021). Dietary guidelines for Americans, 2020–2025: understanding the scientific process, guidelines, and key recommendations. *Nutrition today*, *56*(6), 287.

Storey, A., & Smith, H. K. (2012). Unique aspects of competitive weightlifting: performance, training and physiology. *Sports medicine*, *42*, 769-790.

Tardy, A. L., Pouteau, E., Marquez, D., Yilmaz, C., & Scholey, A. (2020). Vitamins and minerals for energy, fatigue and cognition: a narrative review of the biochemical and clinical evidence. *Nutrients*, *12*(1), 228.

Tardy, A. L., Pouteau, E., Marquez, D., Yilmaz, C., & Scholey, A. (2020). Vitamins and minerals for energy, fatigue and cognition: a narrative review of the biochemical and clinical evidence. *Nutrients*, *12*(1), 228.

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.

Tsai, K. Z., Lai, S. W., Hsieh, C. J., Lin, C. S., Lin, Y. P., Tsai, S. C., ... & Lin, G. M. (2019). Association between mild anemia and physical fitness in a military male cohort: The CHIEF study. *Scientific reports*, *9*(1), 11165.

Wang, J., Li, D., Zhou, Q., Wiltse, A., & Zand, M. S. (2021). Antibody mediated immunity to SARS-CoV-2 and human coronaviruses: multiplex beads assay and volumetric absorptive microsampling to generate immune repertoire cartography. *Frontiers in Immunology*, *12*, 696370.

Wilhelmsson, P. (2020). Nutrition with Movement for Better Energy and Health. *Integrative and Functional Medical Nutrition Therapy: Principles and Practices*, 595-612.

Williams, M. H. (2005). Dietary supplements and sports performance: minerals. *Journal of the International Society of Sports Nutrition*, *2*, 1-7.

Zhang, C. (2014). Essential functions of iron-requiring proteins in DNA replication, repair and cell cycle control. *Protein & cell*, *5*(10), 750-760.

Zhang, H., Zhabyeyev, P., Wang, S., & Oudit, G. Y. (2019). Role of iron metabolism in heart failure: From iron deficiency to iron overload. *Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease*, *1865*(7), 1925-1937.