ORIGINAL ARTICLE

Polish Journal of Sports Medicine / Medycyna Sportowa
© MEDSPORTPRESS, 2021; 4(4); Vol. 37, 201-206
DOI: 10.5604/01.3001.0015.6267

Author's Contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Zaangażowanie Autorów
A – Przygotowanie projektu badawczego
B – Zbieranie danych
C – Analiza statystyczna
D – Interpretacja danych
E – Przygotowanie manuskryptu
F – Opracowanie piśmiennictwa
G – Pozyskanie funduszy

Marcos Vinicios Ribeiro Prandi[1], Marcelo Palinkas[1,2], Veridiana Wanshi Arnoni[1], Guilherme Gallo Costa Gomes[1], Adriana Wanshi Silva[1], Saulo Cesar Vallin Fabrin[1], Isabela Hallak Regalo[1], Selma Siéssere[1,2], Simone Cecilio Hallak Regalo[1,2]

[1] School of Dentistry of Ribeirão Preto, University of São Paulo, Brazil
[2] National Institute for Translational Medicine (INCT-TM), Ribeirão Preto, Brazil

RESPIRATORY PERFORMANCE AND OCCLUSAL STRENGTH OF SOCCER PLAYERS: AN APPROACH AFTER TRAINING AND DETRAINING DURING THE LOCKDOWN DUE TO CORONAVIRUS DISEASE 2019 (COVID-19)

WYDOLNOŚĆ ODDECHOWA I SIŁA ZGRYZU PIŁKARZY: PODEJŚCIE PO TRENINGU I ROZTRENOWANIU PODCZAS BLOKADY Z POWODU KORONAWIRUSA 2019 (COVID-19)

Key words: *soccer, detraining, muscle strength, SARS-CoV-2*
Słowa kluczowe: *piłka nożna, roztrenowanie, siła mięśni oddechowych, SARS-CoV-2*

Summary

Background. *The aim of the study was evaluate the strength of the respiratory muscles, bite force, and occlusal force distribution of professional soccer players after training and detraining resulting from the lockdown that occurred during the coronavirus disease 2019 pandemic.*

Material and methods. *Twelve male soccer players (age, 19-34 years) were subjected to respiratory muscle strength analysis by examining the maximal inspiratory and expiratory pressures, maximum molar bite force (right and left sides), and occlusal force distribution of the first permanent molars. Comparisons of variables after training and detraining were analyzed using the paired-sample t-test ($p < 0.05$), and the correlation between respiratory variables was measured using the Pearson test ($p < 0.05$).*

Results. *There were no significant differences in the bite force and occlusal force distributions after training and detraining. The correlation results showed moderate positivity between the maximal inspiratory and expiratory pressures during the training period.*

Conclusions. *The results suggest that when soccer players strengthen the inspiratory muscles, they also strengthen the expiratory muscles and that detraining does not impact the athlete's organic function, especially the respiratory muscle function and the forces of the occlusal contact of the first permanent molars.*

Streszczenie

Wstęp. *Celem badania była ocena siły mięśni oddechowych, siły zgryzu i rozkładu siły zgryzu u zawodowych piłkarzy po treningu i roztrenowaniu wynikającym z blokady, która wystąpiła podczas pandemii koronawirusa 2019.*

Materiał i metody. *Dwunastu piłkarzy płci męskiej (wiek 19–34 lata) poddano analizie siły mięśni oddechowych, badając maksymalne ciśnienie wdechowe i wydechowe, maksymalną siłę zgryzu trzonowców (prawa i lewa strona) oraz rozkład siły zgryzu na pierwszych stałych zębach trzonowych. Porównania zmiennych po treningu i roztrenowaniu analizowano za pomocą testu t dla próby par ($p < 0,05$), a korelację między zmiennymi oddechowymi mierzono testem Pearsona ($p < 0,05$).*

Wyniki. *Nie stwierdzono istotnych różnic w rozkładzie siły zgryzu i siły zgryzu po treningu i roztrenowaniu. Wyniki korelacji wykazały umiarkowaną różnicę pomiędzy maksymalnym ciśnieniem wdechowym i wydechowym w okresie treningu.*

Wnioski. *Uzyskane wyniki sugerują, że trening mięśni wdechowych wzmacnia mięśnie wydechowe, a roztrenowanie nie wpływa na funkcje organiczne sportowca, zwłaszcza na funkcję mięśni oddechowych i siły kontaktu zgryzowego pierwszych stałych zębów trzonowych.*

Word count: 4218
Tables: 4
Figures: 0
References: 34

Address for correspondence / Adres do korespondencji
Marcelo Palinkas
School of Dentistry of Ribeirão Preto, University of São Paulo, Brazil
e-mail: palinkas@usp.br

Received / Otrzymano *14.03.2021 r.*
Accepted / Zaakceptowano *08.11.2021 r.*

Background

A soccer player's performance is considered multifactorial and is associated with the union of four dimensions: technical, tactical, physical, and psychological, which permeate the soccer game [1]. Many coaches choose training approaches for physical conditioning in an individual or specific way for a certain physical demand required within the soccer field [2,3].

Improvement in the metabolic capacity resulting from the training of high-performance athletes promotes an increase in the variables that determine lung function since the duration, type, and intensity of exercise affect the respiratory system [4,5].

High-performance athletes are constantly seeking to overcome physical limitations. To achieve this purpose, the body must exhibit perfect functional conditions, with the muscles responding to commands from the central nervous system [6,7]. In this sense, it is also essential to have excellent general health, including oral health, which makes the athlete maintain physical and sporting performance [8].

There are periods in the athlete's professional life when they undergo physical detraining, and these specific periods can promote the loss of adaptation of the cardiovascular system and the metabolism of skeletal muscle acquired with aerobic physical training, resulting in a reduction in the maximum amount of oxygen that the organism can absorb with each breathing process [9-11].

During the coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, restrictive measures of social distancing were implemented, and any collective activity was prohibited, making soccer athletes unable continue to physically condition themselves adequately through physical training in soccer matches.

Much has been discussed about how the suspension of official championships and physical training associated with the lockdown could lead to considerable losses of functional adaptation acquired by training, resulting in disruption to the athlete's performance by reducing his ability to train [12].

Therefore, this study aimed to evaluate the strength of the respiratory muscles and molar bite, in addition to the force distribution in the occlusal contacts of the first permanent molars of professional soccer players after training and detraining due to the lockdown during the COVID-19 pandemic. The null hypothesis of this study is that professional soccer athletes present differences in occlusal strength and respiratory variables when they interrupt training for a short period during detraining.

Material and methods

Sample

The study was approved by the Faculty of Dentistry of Ribeirão Preto, University of São Paulo (ethical approval code No. 35574920.0.0000.5419). Before testing, all subjects provided written informed consent to participate in the study and to have their results analyzed.

All soccer players training for the Limeira Clube soccer team participated in the Campeonato Paulista. which occurs once a year in the State of São Paulo, Brazil, thus characterizing the convenience sample.

The inclusion criteria were individuals who were high-performance soccer professionals, were males, were aged 19-34 years, and presented with normocclusion, without pulmonary involvement, and with all permanent teeth in the oral cavity, excluding the third molars.

The exclusion criteria were athletes who presented with ulceration, open wounds, or skin hypersensitivity, presented with cognitive deficits or neurological and systemic (decompensated) pathologies, used analgesics and muscle relaxants that could interfere with neuromuscular physiology, were smokers, and presented with chest deformities and scoliosis, and signs of flu in the week of evaluation.

After applying the inclusion and exclusion criteria, 12 athletes were included to perform the analysis after training and detraining without distinction of skin color. The detraining was characterized as a 2-month period in which soccer players did not train due to the COVID-19 pandemic lockdown instituted in the State of São Paulo, Brazil.

Respiratory pressure analysis

A calibrated analog manovacuometer (Murenas®) with a range of ±300 cmH_2O, positioned between the lips through a mouthpiece adapted to the athlete's mouth, with the nose occluded using a nose clip, was used to measure the maximum respiratory pressure, enabling the evaluation of quantitative changes in the respiratory muscle strength [13,14].

In the muscle strength test, the maximum expiratory pressure (MEP) of the total lung capacity and the maximum inspiratory pressure (MIP) measured at the level of the residual volume were observed.

Soccer players were seated on a chair, office type, in Fowler's position [15], with the upper limbs on the side of the body and the lower limbs flexed at a 90° angle.

Verbal commands to perform the test were issued by a single trained assessor, where the athlete was instructed to exhale completely, try to empty their lungs as much as possible, and then inhale deeply and quickly through the mouth, measuring the residual volume (MIP). The first test was repeated three times, with an interval between one pressure and another of 1 min, considering the highest value to be valid.

The mouthpiece of the device was again attached to the athlete's mouth, still with the nose occluded by a nose clip, and the athlete was instructed to inhale completely, try to fill their lungs as much as possible, and then exhale deeply and quickly through the mouth, and then from the total pulmonary capacity, the MEP was measured.

This second test was repeated three times, with an interval of measurement from one pressure to another 1 min, considering the highest value to be valid. The procedure was performed by a single trained assessor to reduce bias during the study.

The respiratory pressure variables were analyzed after a collection of at least three and at most five measurements, where 1 min of rest between attempts was established, considered acceptable, with a difference of less than 10% between them. For data analysis, the highest value obtained was compared to the predicted values [16]. All soccer players were instruc-

ted on the applicability of the test and received training to be able to perform it accurately.

Molar bite force analysis

The records of the maximum molar bite force were obtained using a digital dynamometer (model IDDK; Kratos, Cotia, SP, Brazil), with a capacity of 980.66 N. The maximum molar bite force was obtained in the region of the first permanent molars, where the value was recorded through the dental occlusion of two dynamometer rods, whose final rods had two Teflon discs at their ends.

During collection, the athletes were seated on a chair, with their arms extended throughout the body with hands on their thighs, receiving guidance on how to bite the rods, thus ensuring the reliability of the procedure. As a biosafety procedure, the dynamometer rods were protected with disposable latex finger cots (Wariper-Sp) and cleaned with alcohol. The final value was the highest value of the three consecutive measurements of the maximum bite force, with an interval of 2 min between each execution [17,18].

Force distribution in occlusal contact analysis

Analysis of the force distribution in the occlusal contacts of the first permanent molars (upper and lower) was performed using the T-Scan® III Occlusal Analysis System (Tekscan, Inc. South Boston, MA. USA).

The equipment has an extra thin thickness sensor (0.102 mm), which does not interfere with the habitual bite and allows recording the distribution of occlusal contacts, enabling the analysis of the relationship of occlusal surfaces in terms of percentage strength [19,20].

At the beginning of collection, the guide support for the bite was tested in the athlete's mouth; it was inserted into the manual handle of the equipment, turning on the device, indicating that the equipment was ready to be used.

The strap of the device, together with the sensor, was connected to the computer, where a record was already established for each athlete, with the registration of the name, sex, date of birth, identification code, the width of the upper and lower central incisors (measured with a digital ruler) and clinical dental information, such as missing teeth and diastema. At this stage, with the sensor inserted into the athlete's oral cavity, the position guide, located on the support, was centralized and fitted between the upper central incisors. The soccer player was instructed to bite the sensor, reaching between 95% and 100% of the maximum force in the occlusal contacts.

Data were analyzed and stored using T-Scan software (Tekscan, Inc. South Boston, MA. USA), showing the maximum occlusal force contact (%) of each player for the occlusal force distribution of the first permanent molars.

Statistical analysis

Statistical analyzes were performed using the IBM SPSS 26.0 statistical software (IBM SPSS Inc., Chicago, IL, USA). A normality test was performed for the samples obtained for respiratory variables, maximum molar bite force, and occlusal force distribution. The result of the normality test indicates that these data are suitable for statistical analysis using parametric tests.

Comparisons of variables after training and detraining were analyzed using the paired-sample t-test ($p < 0.05$), and the correlation between respiratory variables was measured using the Pearson test ($p < 0.05$).

Results

Table 1 shows the mean respiratory muscle strength, as represented by the MIP and MEP. It can be observed that after detraining, there was a reduction in the mean MIP and a slight increase in MEP compared to the period after training. The results were not statistically significant ($p < 0.05$).

As shown in Table 2, there was a moderate positive correlation between the MIP and MEP during the training period, demonstrating that the increased in muscle strength during inspiration favors increased strength during expiration.

In the analysis of the mean maximum molar bite force (right and left), no significant differences were found ($p < 0.05$) after training and detraining, but from a clinical point of view, we could suggest that there was a great molar bite force maximum after detraining. The data are presented in Table 3.

Table 4 shows the mean occlusal force distribution of the permanent first molars. There were no significant differences ($p < 0.05$) between training and detraining.

Tab. 1. The strength of respiratory muscles, represented by the maximum pressure between the period after training and detraining of soccer players

Maximum pressure	Period	Mean ± SD (cmH_2O)	p-value
MIP	Training	-132.66 ± 25.00	0.278
	Detraining	-122.91 ± 27.45	
MEP	Training	102.58 ± 38.52	0.831
	Detraining	104.58 ± 35.19	

MIP, maximum inspiratory pressure; MEP, maximum expiratory pressure

Tab. 2. The correlation of the variables maximum inspiratory pressure and maximum expiratory pressure between the period after training and detraining of soccer players

Period	Correlation type	Pearson correlation	p-value
Training	Positive	0.588	**0.04**
Detraining	Positive	0.636	**0.02**

Tab. 3. The comparison of soccer players' maximum molar bite force.

Molar bite force	Period	Mean ± SD (N)	p-value
Right	Training	538.39 ± 175.83	0.138
	Detraining	607.52 ± 135.14	
Left	Training	565.45 ± 134.35	0.412
	Detraining	593.69 ± 136.21	

Tab. 4. The comparison of the occlusal force distribution in soccer players' permanent first molars.

First permanent molar	Period	Mean ± SD (%)	p-value
Upper right	Training	10.23 ± 6.73	0.621
	Detraining	11.02 ± 6.24	
Upper left	Training	15.02 ± 4.82	0.854
	Detraining	15.37 ± 10.02	
Lower right	Training	12.07 ± 4.32	0.822
	Detraining	12.64 ± 7.76	
Lower left	Training	7.48 ± 4.35	0.607
	Detraining	8.25 ± 6.59	

Discussion

The hypothesis that high-performance soccer athletes would lose part of their physical conditioning was not supported by the findings of this study. However, the correlation between the levels of respiratory muscle strength during the two periods was slight.

Respiratory muscles are vital in the performance of athletes and significantly influence exercise tolerance [21,22]. From the results of our study, we observed that trained soccer players had higher MIP and MEP values compared to those after detraining. These data corroborate research that found results related not only to the increased inspiratory muscle strength during training but also to the improved metaboreflex, leading to increased oxygenation and blood supply to the peripheral muscles [23,24].

Statistical analysis showed that there were no significant losses during detraining related to respiratory muscle strength; that is, they lost the inspiratory force, and the expiratory force was practically the same (even increased slightly), that is, probably a little diaphragm force changed with detraining, showing that athletes are very well physically conditioned and that they require a period longer than 2 months without training to feel the effects of detraining.

In 2 months, these football players did not feel much of the effects of detraining when we analyzed the strength of the respiratory muscles. The data are aligned with the findings in the literature, where the detraining process for a few weeks does not affect the ventilatory efficiency of the respiratory system [9].

A hypothesis that could explain the non-loss of respiratory muscle strength during detraining would be that the body undergoing physiological resistance training has a high number of myonuclei per muscle fiber, which are the cellular components of muscle memory, which would be preserved during a period of detraining [25,26].

However, some studies do not support our results; they reported that the 2-month period of home confinement resulting from the COVID-19 pandemic caused by the SARS-CoV-2 infection, promoted a significant reduction in the aerobic abilities of athletes after detraining [10,27].

This study showed a positive and moderate correlation in the training and detraining conditions, but the mean MIP cut-off after the training period was reduced when comparing the two conditions. This demonstrates that in these athletes, increasing respiratory muscle strength also increases expiratory muscle strength, but if inspiratory muscle strength decreases, there is no significant reduction or negative correlation in expiratory strength. These athletes benefit from a positive correlation when the MIP increases, but when it decreases, the MEP values do not follow this reduction, which shows that the effects of detraining in 2 months are not significant.

An important factor that may be related to the lack of training in professional athletes is the possibility of involvement of the stomatognathic system because it may be directly related to the functional state of the skeletal striated musculature and morphofunctional changes in the human body that interfere with the variables that make up this complex system [28].

It is known that organic systems are interdependent functional units, and any change in the dynamics of the structures that make up the stomatognathic system can interfere with the physical performance of an individual. Therefore, the assessment of molar bite force is a method to determine whether there are functional limitations in the human body through a careful analysis of the objective quantitative index of masticatory function [29]. However, no study in the literature analyzed the maximum molar bite force of professional soccer players after detraining; therefore, the comparison of our results with those of other studies was compromised.

The results of this study did not show significant differences in the maximum molar bite force of soccer players after detraining, but when observed from a clinical point of view, the bite force (right and left sides) was slightly high. This shows that the stomatognathic system, especially when analyzing the bite force, was not compromised after detraining, demonstrating the importance of performing functional training that has very specific protocols to maintain the performance of the human body [30].

Physical training aims to increase the ability to obtain and use energy efficiently, promoting physio-

logical adaptations of organic systems, which reach organs, tissues, and cells and improve body capacity [31]. We believe that after detraining, professional soccer players maintained their aerobic capacity, increasing energy promotion for a certain period. Therefore, using oxidative phosphorylation, which is a metabolic pathway that uses energy released by oxidation of nutrients to produce adenosine triphosphate, can preserve this organic function [32]. This could explain the maintenance of strength, especially the maximum molar bite after the athletes' detraining.

The occlusal biodynamics of permanent molars was another variable analyzed in this study. In the evaluation of the percentage values of the occlusal force of the permanent first molars, no significant differences were observed in the period of 2 months during detraining. It is scientific knowledge that controlling mechanical overload in the skeletal striated musculature promotes increases strength and muscle mass [33], and athletes are subjected to constant training that also improves the strength of the upper body; consequently, there is a functional improvement in the complex muscle that makes up the craniocervical postural system, which can maintain the balance of static and dynamic structures of the stomatognathic system [34].

The results of this study suggest that soccer athletes lost very little physical conditioning when analyzing the variables of this study and that a long period of paralysis would probably be necessary to cause a considerable loss of physical conditioning that could promote functional consequences in the respiratory musculature and the stomatognathic system.

It is also necessary to emphasize that strengthening the construction of the oral health policy in sports with the inclusion of dental sciences and integration (multidisciplinarity) between the health areas of high-performance sports, such as physical exercise as a whole, improves the understanding of the performance of elite athletes, especially football players.

Conclusions

The correlation results of this study showed that professional soccer players, when strengthening the inspiratory muscles, also strengthen the expiratory muscles. For these athletes, this shows that the training they receive as soccer players, which includes training and games, favors the strengthening of the respiratory muscles (inspiratory and expiratory); moreover, they do not need to perform additional strengthening of the respiratory muscles, since, when training and playing soccer, the inspiratory muscles gain strength and favor the gain in strength of the expiratory muscles. Regarding the bite force and distribution of occlusal contacts of the first permanent molars, no differences were observed after training and detraining of professional soccer players.

References

1. Hammami A, Zois J, Slimani M, et al. The efficacy and characteristics of warm-up and re-warm-up practices in soccer players: a systematic review. J Sports Med Phys Fitness 2018; 58(1-2): 135-49. doi:10.23736/S0022-4707.16.06806-7.
2. Davis JA, Brewer J, Atkin D. Pre-season physiological characteristics of English first and second division soccer players. J Sports Sci. 1992; 10(6): 541-7. doi:10.1080/02640419208729950.
3. Olthof SBH, Frencken WGP, Lemmink KAPM. A match-derived relative pitch area facilitates the tactical representativeness of small-sided games for the official soccer match. J Strength Cond Res 2019; 33(2): 523-30. doi:10.1519/JSC.0000000000002978.
4. Carrick-Ranson G, Hastings JL, Bhella PS, et al. The effect of lifelong exercise dose on cardiovascular function during exercise. J Appl Physiol 2014; 116(7): 736-45. doi:10.1152/japplphysiol.00342.2013.
5. Losnegard T, Hallén J. Elite cross-country skiers do not reach their running VO2max during roller ski skating. J Sports Med Phys Fitness 2014; 54(4): 389-93.
6. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and performance in sport: consensus statement. Int J Sports Physiol Perform 2018; 13(2): 240-5. doi:10.1123/ijspp.2017-0759.
7. Suchomel TJ, Nimphius S, Bellon CR, et al. The importance of muscular strength: training considerations. Sports Med 2018; 48(4): 765-85. doi:10.1007/s40279-018-0862-z.
8. Gallagher J, Ashley P, Petrie A, et al. Oral health and performance impacts in elite and professional athletes. Community Dent Oral Epidemiol 2018; 46(6): 563-8. doi:10.1111/cdoe.12392.
9. Alvero-Cruz JR, Ronconi M, Garcia Romero J, et al. Effects of detraining on breathing pattern and ventilatory efficiency in young soccer players. J Sports Med Phys Fitness 2019; 59(1): 71-5. doi:10.23736/S0022-4707.17.07619-8.
10. Joo CH. The effects of short term detraining and retraining on physical fitness in elite soccer players. PLoS One 2018; 13(5): e0196212. doi:10.1371/journal.pone.0196212.
11. Rodríguez-Fernández A, Sánchez-Sánchez J, et al. Effects of short-term in-season break detraining on repeated-sprint ability and intermittent endurance according to initial performance of soccer player. PLoS One 2018; 13(8): e0201111. doi:10.1371/journal.pone.0201111.
12. Fabre JB, Grelot L, Vanbiervielt W, et al. Managing the combined consequences of COVID-19 infection and lockdown policies on athletes: narrative review and guidelines proposal for a safe return to sport. BMJ Open Sport Exerc Med 2020; 6(1): e000849. doi:10.1136/bmjsem-2020-000849.
13. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis 1969; 99(5): 696-702. doi:10.1164/arrd.1969.99.5.696.
14. Pereira JLF, Galant LH, Rosa LHTD, et al. Capacity of exercise and survival in patients with cirrhosis with and without hepatopulmonary syndrome after liver transplantation. Arq Gastroenterol 2020; 57(3): 262-6. doi:10.1590/ S0004-2803.202000000-49.
15. Cohen J, Pignanelli C, Burr J. The effect of body position on measures of arterial stiffness in humans. J Vasc Res 2020; 57(3): 143-51. doi:10.1159/000506351.

16. Neder JA, Andreoni S, Lerario MC, et al. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res 1999; 32(6): 719-27. doi:10.1590/s0100-879x1999000600007.
17. Palinkas M, Nassar MS, Cecílio FA, et al. Age and gender influence on maximal bite force and masticatory muscles thickness. Arch Oral Biol 2010; 55(10): 797-802. doi:10.1016/j.archoralbio.2010.06.016.
18. Moreto Santos C, Palinkas M, Mestriner-Júnior W, et al. Stomathognatic system function in indigenous people from Brazilian Xingu villages: An electromyographic analysis. PLoS One 2020; 15(12): e0243495. doi:10.1371/journal. pone .0243495.
19. Di Berardino F, Filipponi E, Schiappadori M, et al. The occlusal imaging and analysis system by T-scan III in tinnitus patients. Biomed J 2016; 39(2): 139-44. doi:10.1016/j.bj.2016.04.001.
20. Ruttitivapanich N, Tansalarak R, Palasuk J, et al. Correlation of bite force interpretation in maximal intercuspal position among patient, clinician, and T-Scan III System. Eur J Dent 2019; 13(3): 330-4. doi:10.1055/s-0039-1693755.
21. Laveneziana P, Albuquerque A, Aliverti A, et al. ERS statement on respiratory muscle testing at rest and during exercise. Eur Respi J 2019; 53(6): 1801214. doi:10.1183/13993003.01214-2018.
22. Tiller NB. Pulmonary and respiratory muscle function in response to marathon and ultra-marathon running: A Review Sports Med 2019; 49(7): 1031-41. doi:10.1007/s40279-019-01105-w.
23. Smith JR, Alexander AM, Hammer SM, et al. Cardiovascular consequences of the inspiratory muscle metaboreflex: effects of age and sex. Am J Physiol Heart Circ Physiol 2017; 312(5): H1013- H20. doi:10.1152/ajpheart. 00818. 2016.
24. Archiza B, Andaku DK, Caruso FCR, et al. Effects of inspiratory muscle training in professional women football players: a randomized sham-controlled trial. J Sports Sci 2018; 3697: 771-80. doi:10.1080/02640414.2017.1340659.
25. Lee H, Kim K, Kim B, et al. A cellular mechanism of muscle memory facilitates mitochondrial remodelling following resistance training. J Physiol. 2018; 18(596): 4413-26. doi:10.1113/JP275308.
26. Murach KA, Vechetti IJ Jr, Van Pelt DW, et al. Fusion-independent satellite cell communication to muscle fibers during load-induced hypertrophy. Function (Oxf) 2020; 1(1): zqaa009. doi:10.1093/function/zqaa009.
27. Dauty M, Menu P, Fouasson-Chailloux A. Effects of the COVID-19 confinement period on physical conditions in young elite soccer players. J Sports Med Phys Fitness 2021; 61(9): 1252-7. doi: 10.23736/S0022-4707.20.11669-4.
28. Piancino MG, Dalmasso P, Borello F, et al. Thoracic-lumbar-sacral spine sagittal alignment and cranio-mandibular morphology in adolescents. J Electromyogr Kinesiol 2019; 48: 169-75. doi:10.1016/j.jelekin.2019.07.016.
29. Hashimoto S, Kosaka T, Nakai M, et al. A lower maximum bite force is a risk factor for developing cardiovascular disease: the Suita study. Sci Rep 2021; 11(1): 7671. doi:10.1038/s41598-021-87252-5.
30. Westcott WL. Resistance training is medicine: effects of strength training on health. Curr Sports Med Rep 2012; 11(4): 209-16. doi:10.1249/JSR.0b013e31825dabb8.
31. Khoramipour K, Basereh A, Hekmatikar AA, et al. Physical activity and nutrition guidelines to help with the fight against COVID-19. J Sports Sci 2021; 39(1): 101-7. doi:10.1080/02640414.2020.1807089.
32. Hargreaves M, Spriet LL. Skeletal muscle energy metabolism during exercise. Nat Metab 2020; 2(9): 817-28. doi:10.1038/ s42255-020-0251-4.
33. Aguilar-Agon KW, Capel AJ, Martin NRW, et al. Mechanical loading stimulates hypertrophy in tissue-engineered skeletal muscle: Molecular and phenotypic responses. J Cell Physiol 2019; 234(12): 23547-58. doi:10.1002/ jcp. 28923.
34. Gutierrez GM, Conte C, Lightbourne K. The relationship between impact force, neck strength, and neurocognitive performance in soccer heading in adolescent females. Pediatr Exerc Sci 2014; 26(1): 33-40. doi:10.1123/pes.2013-0102.

Funding information

This research was supported by Foundation for Research Support of the State of São Paulo and the National Institute for Translational Medicine.

Declaration of interest statement

All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence the present study.

Confirmation of ethical compliance

The authors of this manuscript confirm that this research was approved by the ethical committee at the Faculty of Dentistry of Ribeirão Preto, University of São Paulo, Brazil.

Acknowledgments

The authors would like to thank all soccer players training for the Limeira Futebol Clube soccer team, São Paulo, Brazil who participated in the study.