Effects of COVID-19 on diaphragm thickness and physical performance of athletes

Efeitos da COVID-19 na espessura diafragmática e desempenho físico de atletas

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Abstract

Introduction: Studies suggest that diaphragm thickness (DT) is associated with inspiratory muscle strength and consequently, better ventilatory and mechanical efficiency. On the other hand, infectious diseases such as COVID-19 may impact the structure and function of the respiratory system. **Objective:** Assess the association between DT and the physical performance (PP) of athletes and the effects of COVID-19 infection on these parameters. **Methods:** This is a cross-sectional study of 63 athletes of both sexes from different sport modalities (women: 16.67 ± 5.03 years, 52.09 ± 14.01 kg, 155.90 ± 13.86 cm; men: 23.44 ± 9.65 years, 72.24 ± 14.18 kg, 174.84 ± 6.84 cm), submitted to DT assessment using ultrasound, followed by the PP(Yo-Yo) test to determine maximum oxygen intake (VO_{2max}). Pearson's correlation was used to determine the association between VO_{2max} and DT, and the Student's t-test for differences between athletes with a positive and negative diagnosis for COVID-19. The significance level was set at 5%. **Results:** There was no association between DT and PP (r = 0.30 and p = 0.22) or between athletes unaffected and affected by COVID-19 in relation to DT (57.00 ± 0.26 vs 52.00 ± 0.25%; p = 0.91) and PP (43.88 ± 2.29 vs 38.34 ± 13.61 ml/kg/min; p = 0.69). **Conclusion:** DT was not associated with maximum oxygen intake in athletes. In addition, athletes infected by COVID-19 exhibited no differences in VO_{2max} or DT when compared to nonaffected individuals.

Keywords: Athletes. COVID-19. Diaphragm. Physical performance.

Resumo

Introdução: *Estudos sugerem que a espessura diafragmática (ED) está associada à força muscular inspiratória e, consequentemente, à melhor eficiência ventilatória e mecânica. Por outro lado, doenças infecciosas como a COVID-19 podem impactar a estrutura e função do apa-relho respiratório.* ***Objetivo:*** *Avaliar a associação entre a ED e o desempenho físico (DF) de atletas e os efeitos da infecção por COVID-19 sobre esses parâmetros.* ***Métodos:*** *Trata-se de um estudo transversal envolvendo 63 atletas de diferentes modalidades esportivas, de ambos os sexos (feminino: 16,67 ± 5,03 anos, 52,09 ± 14,01 kg, 155,90 ± 13,86 cm; masculino 23,44 ± 9,65 anos, 72,24 ± 14,18 kg, 174,84 ± 6,84 cm), que foram submetidos à avaliação da ED por meio de ultrassom e, em seguida, ao teste de DF (Yo-Yo test) para determinar o consumo máximo de oxigênio (VO_{2max}). Utilizou-se a correlação de Pearson para verificar a associação entre VO_{2max} e ED, e o teste t de Student para diferenças entre atletas com diagnóstico positivo e negativo para COVID-19. O nível de significância foi ajustado em 5%.* ***Resultados:*** *Não houve associação entre ED e DF (r = 0,30 e p = 0,22) e não houve diferença entre os atletas não infectados e infectados por COVID-19 em relação à ED (57,00 ± 0,26 vs 52,00 ± 0,25%; p = 0,91) e DF (43,88 ± 2,29 vs 38,34 ± 13,61 ml/kg/min; p = 0,69).* ***Conclusão:*** *A ED não foi associada ao consumo máximo de oxigênio em atletas. Além disso, atletas infectados por COVID-19 não exibiram diferenças no VO_{2max} e ED em relação aos não infectados.*

Palavras-chave: *Atletas. COVID-19. Diafragma. Desempenho físico.*

Introduction

Studies conducted with athletes and healthy individuals suggest that diaphragm hypertrophy, that is, an increase in the cross-sectional area, may result in greater inspiratory muscle strength and consequently, better ventilatory and mechanical efficiency.[1,2] Greater diaphragm muscle thickness may be related to better oxidative metabolism, due to greater capillary density, better blood flow and a larger number of mitochondria. Thus, increased thickness may be linked to better oxygen capture and maximum oxygen intake (VO_{2max}), reduced fatigue and consequently, better aerobic performance.[1-3]

Diaphragmatic ultrasound is a technique used to assess the anatomy and function of the diaphragm, especially diaphragmatic excursion and thickening. Recently, the use of ultrasound (US) for diaphragmatic assessment has been increasingly explored in the literature for individuals with different pulmonary diseases, including COVID-19, an acute respiratory infection caused by the SARS-CoV-2 coronavirus.[4,5-8]

Diaphragmatic US has also been applied in healthy individuals to investigate the relationship between the strength and performance of this muscle with its thickness and mobility.[9,10] Factors such as age, high body mass index (BMI), hospitalizations and pulmonary diseases may negatively influence diaphragmatic thickness (DT).[7] In compensation, athletes that undergo inspiratory muscle training exhibit increased DT, which may be related to greater exercise tolerance and reduced sensation of dyspnea, resulting in better performance in competitions.[11-13] However, few studies have assessed the DT of athletes and its association with physical performance (PP), the technique being rarely applied in this population.

COVID-19 affects numerous tissues and body systems, but the lungs are the most affected and related to greater severity and mortality.[14,15] The development of COVID-19 is heterogeneous and may be asymptomatic, mild or severe.[16] The moderate or severe forms may leave sequelae such as fatigue, muscle weakness and persistent tiredness, which can be explained by the decline in pulmonary diffusion, pulmonary damage and reduced diaphragmatic mobility.[14,15] In mild and asymptomatic cases, no studies have completely assessed aspects of diaphragmatic morphology.

Diaphragmatic assessment may be essential, given that it can determine dysfunction, evaluate work of breathing (WOB) and identify diaphragm atrophy.[17] Based on this diagnosis, rehabilitation may be indicated, such as athlete-specific respiratory muscle training, aimed at improving training and competition performance. To the best of our knowledge no study proposes investigating the effects of COVID-19 infection on the DT of athletes. Thus, the aims of the present study were to assess the association between the DT and PP of athletes and determine the effects of COVID-19 infection on these parameters.

Methods

This cross-sectional exploratory study is part of the Federal University of Mato Grosso do Sul's (UFMS) *Projeto Medalha* and was approved by the institutional Research Ethics Committee (no. 2.409.248). Data were collected at unit VIII of the School of Education (FAED/UFMS), and the athletes and researchers gave written informed consent.

Sample

Included in the study were soccer referees and athletes that systematically trained in their respective sport modality in order to improve output/results; who had participated in sport competitions the year before the pandemic; were members of a local, regional or international sport federation, and whose main activity or personal goal was training and competitions, training for several hours a day/week (exceeding the time spent on other professional or leisure activities). Excluded were athletes who exhibited flu symptoms at the time of assessment and injured athletes unable to undergo the PP test.

FA total of 63 participants of both sexes, aged 18 years or older, with more than one year's experience in the sport were assessed. These sports included karate (n = 10), cycling (n = 6), soccer (n = 17), athletics (n = 2), swimming (n = 1), running (n = 2), triathlon (n = 1), martial arts (n = 4) and judo (n = 18), in addition to two soccer referees, all affiliated with the sport federations of Mato Grosso do Sul state. In order to assess the effects of COVID-19 on PP and DT, 20 athletes were selected, 10 of whom were affected by the disease and 10 who were not. For each infected individual, an age and sport modality-matched control was used. All the infected athletes were men. Participants were selected by nonprobability sampling and convenience. The diagnosis of all the infected and noninfected athletes and referees was confirmed using the rapid test (SARS-CoV-2 antigen), applied before the competitions.

Questionnaire and interview

The participants responded to an online questionnaire obtained on the *Projeto Medalha* website, previously created and tested by the research group of the present study, containing training data (modality, specialty, frequency, duration, and time involved in the sport).

On the second assessment day (in person), the participants responded to the COVID-19 questionnaire containing questions on the time of the last diagnosis, symptoms, hospitalizations, training interruption and resumption. After the interview, participants were submitted to anthropometric tests, DT assessment and a physical test.

Diaphragm thickness assessment

All the participants underwent right hemidiaphragm ultrasound (Dp10 Power Mindray). Diaphragmatic US was performed with athletes in the semirecumbent position,[9,18,19] by a single physiotherapist, trained and certified in kinesiology ultrasonography. In order to assess DT, B mode measurements were taken with a 6-13 MHz liner transducer placed in the zone of opposition of the diaphragm, near the costophrenic angle between the right anterior and midaxillary line.[20]

DT was measured from the most superficial hyperechoic line (pleural line) to the deepest (peritoneal line) in residual functional capacity (RFC) and then in total functional capacity (TFC). The average of three consecutive measures was used. Next, the thickening fraction was calculated (TF, proportional diaphragm thickening from RFC to TFC), defined by the following equation: TF: [(Tmin – Tmax)/Tmin] x 100, where Tmin is the minimum DT (measured in RFC) and Tmax the maximum DT (measured in TFC).[19,21]

Assessment of physical performance

The Yo-Yo Intermittent Recovery Test Level 1 was executed at a progressive pace increased by the sound signals used for each test. The athletes were instructed to run back and forth 20 m, and a further five meters for a 10-second active recovery, waiting at the starting point for another run. Thus, at each sound signal emitted, the athletes were to run past the line with one of their feet for as many laps as possible. The test ended when the athlete was exhausted or could no longer maintain the established test speed for two consecutive laps. The number of displacements during the sound stimulus was recorded. In order to estimate maximum aerobic power, the following calculation was used: VO_{2max} (ml.min.kg) = distance (m) x 0.0084 + 36.4.[22]

Statistical analysis

The results were expressed as the mean and standard deviation. Pearson's correlation was used to determine the association between performance variables (VO_{2max}) and diaphragm thickness. In addition, the Student's t-test was applied to determine the differences between athletes with positive and negative diagnosis for SARS-CoV-2. The significant level was set at 5%. Prisma v8 software (GraphPag, California, USA) was used for all the analyses.

Results

Participant characteristics are presented in Table 1 and those of the athletes/referees infected (n = 10) and not infected by COVID-19 (n = 10) in Table 2.

Figure 1 shows the association between the DT (%) and VO_{2max} of the participants. The data exhibited in Figure 1 show no association between the DT and aerobic PP of athletes/referees (p = 0.22). Figure 2 compares DT between athletes/referees not infected and infected by COVID-19. There was no significant intergroup difference in DT (p = 0.91).

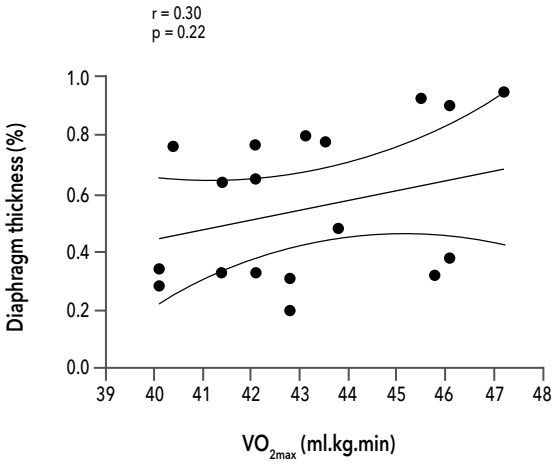

Figure 1 - Diaphragm thickness versus the physical performance test (VO_{2max}) of the athletes/referees analyzed (n = 63), conducted using the Yo-Yo test.

Figure 3 presents the VO_{2max} of athletes/referees not infected and infected by COVID-19. The results demonstrate no statistically significant difference in the PP of athletes/referees not infected and infected by COVID-19 (p = 0.69).

Table 1 - Mean values and corresponding standard deviations of the respiratory and anthropometric variables of the participants

Sex	Variables				
	Age (years)	Weight (kg)	Height (cm)	VO_{2max} (ml.kg.min)	Diaphragm thickness (%)
Women (n = 12)	16.67 ± 5.03	52.09 ± 14.01	155.90 ± 13.86	39.34 ± 1.74	61.00 ± 0.20
Men (n = 51)	23.44 ± 9.65	72.24 ± 14.18	174.84 ± 6.84	41.25 ± 6.84	55.00 ± 0.25

Note: VO_{2max} = maximum oxygen intake.

Table 2 - Mean values and corresponding standard deviations of the respiratory and anthropometric variables of athletes/referees in the COVID-19 (n = 10) and non-COVID-19 groups (n = 10)

Group	Variables				
	Age (years)	Weight (kg)	Height (cm)	VO_{2max} (ml.kg.min)	Diaphragm thickness (%)
COVID-19	25.30 ± 10.39	68.03 ± 8.20	171.90 ± 4.04	38.34 ± 13.61	52.00 ± 0.25
Non-COVID-19	22.09 ± 7.29	71.09 ± 8.30	178.42 ± 2.11	43.88 ± 2.29	57.00 ± 0.26

Note: VO_{2max} = maximum oxygen intake.

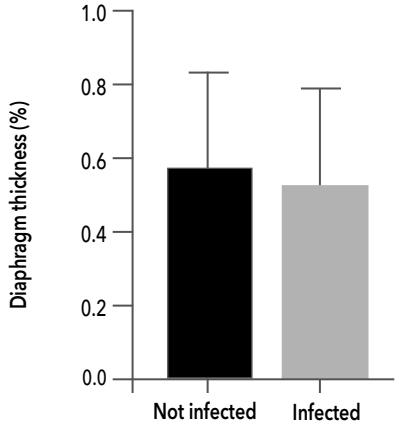

Figure 2 - Diaphragm thickness assessment in athletes/referees not infected (n = 10) and infected (n = 10) by COVID-19

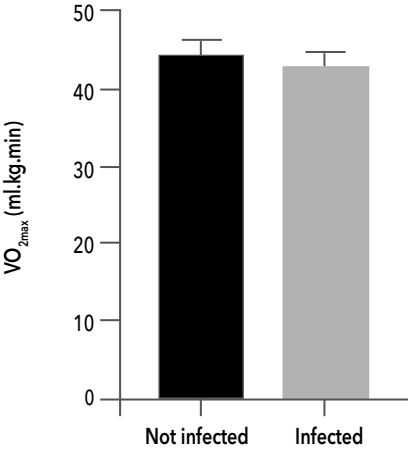

Figure 3 - Physical performance assessment (VO_{2max}) of athletes not infected (n = 10) and infected by COVID-19 (n = 10), using the Yo-Yo test.

Discussion

This is the first study that proposes to assess the association between the DT and PP of athletes. In addition, we analyzed the effects of COVID-19 infection on these parameters. The results reveal no association between DT and maximum oxygen intake in athletes. Moreover, athletes infected by COVID-19 showed no differences in VO_{2max} or DT compared to their non-infected counterparts.

To the best of our knowledge, few studies have investigated the relationship between DT and physical/functional performance or tolerance to exertion, and those that did used patients and clinical contexts.[23-25] In these contexts, studies show that in individuals with chronic obstructive pulmonary disease,[24,26] pulmonary fibrosis,[27] neuromuscular diseases,[28] and COVID-19,[29] low DT is a risk factor for worse clinical prognosis.

Extrapolating these data to athletes is complex, since this population exhibits high tolerance to exertion and, in general, good nutritional, anti-inflammatory and antioxidant status.[30] Thus, low DT is an intrinsic muscle dysfunction caused by several factors (inflammatory and oxidative stress, sedentary behavior and malnutrition), which are not commonly found in athletes.[31] This would at least partially explain the lack of association between DT in the athletes of the present study.

It is expected that the lower the diaphragmatic function, the higher the thickness and VO_{2max}, given that a larger cross-sectional area may increase vascularization, blood flow, number of mitochondria and, consequently, inspiratory muscle efficiency, with an impact on physical/functional performance.[31] As such, a relationship is expected between these parameters in the present study. In regard to the lack of association between VO_{2max} and DT, it can be speculated that diaphragmatic function is not necessarily related to its thickness, such as a marathon runner who does not exhibit large muscle mass, but aerobically efficient muscles.

The biochemical and structural adaptations of muscle cells resulting from aerobic exercise (increases in the number and size of mitochondria, oxidative enzyme activity and greater intramuscular lipid substrate deposition)[31,32] also occur in the diaphragm, since it is composed of approximately 60% type I fibers. Thus, it is assumed that the athletes of the present study exhibit highly efficient diaphragm muscles without necessarily having greater diaphragm muscle thickness.

It is important to note that maximum oxygen intake may be influenced by genetics, physical training, sex, body composition, age and exercise modality, given that aerobic exercises promote greater VO_{2max} gains.[25,33,34] These parameters may be more important than DT in VO_{2max}, especially in healthy individuals. Thus, it is speculated that DT assessment may be more relevant in patients[25,33,34] than in athletes, given that athletes in general exhibit good health and excellent physical conditioning. This is likely why no significant associations were observed in the present study.

With respect to the second study objective, that is, assess and compare the DT and PP of athletes infected and not infected by COVID-19, the results show no

intergroup differences. It is important to note that infectious states, including viruses, trigger a cascade of inflammatory mediators and compromised pulmonary parenchyma, capable of lowering gas exchanges and causing mitochondrial dysfunction and muscle damage that leads to exercise intolerance.[35] Thus, it is expected that individuals affected by the disease exhibit a decline in performance, including VO_{2max}.[36,37] In the present study, however, no COVID-19 infection effects on oxygen intake and diaphragm thickness were observed in the athletes. One of the hypotheses to explain the absence of a difference is related to the time between contamination and test execution. In the present study this was approximately one year, which was likely sufficient for the athletes to fully recovers.

Recovering from COVID-19 varies considerably between individuals and may take days or weeks, but it is known that athletes exhibit better immunological status when compared to physically inactive individuals. In addition, once infected by COVID-19, athletes are less likely to evolve to moderate or serious levels of the disease.[38-40] In the present study, no serious cases or hospitalizations occurred in the athletes infected by COVID-19. Furthermore, all the athletes with positive diagnosis reported only mild symptoms. This supports the idea that this population is less susceptible to evolving the serious form of the disease, which may result in fewer respiratory effects and faster recovery.

It is therefore important to conduct more studies on this topic in order to identify whether DT is associated with performance, especially in aerobic modalities, as well as if the impacts of COVID-19 are related to DT in both clinical populations and athletes.

A study limitation is its observational nature, which precludes establishing cause and effect. The small number of individuals also may have limited data analysis and possible adjustments for sex and age, since these factors are related to DT and/or PP.[33] Given that the study was carried out in athletes from several modalities may have interfered in the results, making the sample very heterogeneous. Thus, studies with larger samples of this population are needed.

Conclusion

Diaphragm thickness was not associated with maximum oxygen intake. Moreover, athletes infected by COVID-19 also showed no differences in VO2max or diaphragm thickness when compared to their infection-free counterparts.

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Authors' contributions

ASF, SFZ, AOS and LCR participated in the study concept and design, data analysis and interpretation. ASF and SFZ wrote the manuscript and VMS participated in editing and formatting. CFCR contributed to revising the contents.

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