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The relationship between diaphragm muscle thickness, respiratory functions and respiratory muscle strength in athletes

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Abstract

The aim of the study was to determine the relationship between diaphragmatic muscle thickness, respiratory function parameters and respiratory muscle strength in elite athlete groups. Cross-sectional method was used as research design. 58 male students (age= 20,14±2,71) studying at Yaşar Doğu Faculty of Sport Sciences participated in the study voluntarily. When analysed statistically; a positive significant difference was obtained between DiTeks and MEP. A higher positive significant difference was observed between DiTins and both MIP and MEP. In conclusion, this study showed that ultrasound imaging of the diaphragm is an important method to visualise many measurements and to obtain accurate results and that there is a relationship between diaphragmatic thickness and respiratory muscle strength and function parameters.

Keywords: Athletes, diaphragm, diaphragm thickness, respiration

Sporcularda diyafragma kas kalınlığının, solunum fonksiyonları ve solunum kas kuvveti arasındaki ilişki

Öz

Araştırmada elit sporcu gruplarında diyafragma kas kalınlığının, solunum fonksiyon parametreleri ve solunum kas kuvveti arasındaki ilişkinin belirlenmesi amaçlandı. Araştırma dizaynı olarak kesitsel yöntem kullanıldı. Araştırmaya randomize yöntemle belirlenen Yaşar Doğu Spor Bilimleri Fakültesinde öğrenim gören 58 erkek (yaş= 20,14±2,71) öğrenci gönüllü olarak katıldı. İstatistiksel olarak incelendiğinde; DiT_{eks} ile MEP arasında pozitif yönde anlamlı farklılık elde edildi. DiT_{ins} ile hem MIP hem MEP arasında daha yüksek düzeyde pozitif yönde anlamlı farklılık görüldü. Sonuç olarak; bu çalışma ile diyafragmanın ultrason ile görüntülenmesi birçok ölçümü görüntüleyebilmek ve doğru sonuçlar elde edebilmek adına önemli bir yöntem olduğu ve diyafragma kalınlığı ile solunum kas kuvveti ve fonksiyon parametreleri arasında ilişki olduğu görüldü.

Anahtar Kelimeler: *Sporcular, diyafram, solunum, diyafram kalınlığı*

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INTRODUCTION

Diaphragmatic muscle thickness and mobility can be visualized by ultrasound. With its advantages such as no radiation, portability and real-time imaging, ultrasound is increasingly used to evaluate diaphragmatic function in many situations (Ueki et al., 1995; Cohn et al., 1997; Kantarcı et al., 2004; Testa et al., 2011; Boon et al., 2013; Cardenas et al., 2018; Erail et al., 2022; Ho et al., 2022). Ultrasound imaging of the diaphragm eliminates many limitations of previously used standard imaging techniques (Matamis et al., 2013; Sarwal et al., 2013). Diaphragmatic ultrasonography is a non-invasive method that provides a very easy evaluation of diaphragmatic thickness and it is also low in cost (Dhungana et al., 2017). Diaphragm thickness can be measured by using B-mode with a linear probe, and diaphragmatic movement and thickness can be measured by using M-mode with a convex probe through ultrasonography (Beck et al., 2006; Boon et al., 2014; Oguri et al., 2022). While diaphragmatic imaging is mostly used in clinical cases (De Bruin et al., 1997; Jung et al., 2014; Kim et al., 2017), it has also recently been used in healthy individuals and athletes (Erail et al., 2017; Cardenas et al., 2018; Ho et al., 2022) to evaluate various diaphragmatic functions.

The diaphragm is considered the primary inspiratory muscle and also plays a vital role in breathing by providing 2/3 of the ventilation. Diaphragm muscle is involved in a very important part of the processes which are required during normal ventilation; other accessory respiratory muscles become active only when ventilation rate and depth increase (Polla et al., 2004). While diaphragmatic ultrasound can provide an accurate real-time imaging of diaphragmatic muscle structure and function, the relationship between diaphragm parameters and respiratory muscle strength and respiratory function parameters is not clearly known in athletes. Diaphragm thickness and extension are known to be associated with some respiratory parameters (forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), maximum inspiratory pressure (MIP), and maximum expiratory pressure (MEP)) in healthy adults (Cardenas et al., 2018; Spiesshoefer et al., 2020).

When current studies in the literature are examined, although a large number of studies have been conducted on the respiratory system and respiratory muscles, which are one of the most important factors for the performance of athletes (Karvonen, 1992; Sheel, 2002; Amonette et al., 2002; Forbes et al., 2011; Vasconcelos et al., 2017) and although there are studies examining various parameters on the diaphragm muscle thickness, which is the main muscle of this system (Ueki et al., 1995; De Bruin et al., 1997; Enright et al., 2006; Orrey, 2013; Kim et al., 2017), no studies have been found on the relationship between diaphragmatic muscle thickness and various respiratory parameters in athletes. Therefore, in order to evaluate the relationship between diaphragmatic parameters and respiratory parameters in different populations, there is a need to determine how thickness, expansion and some specific parameters are related to respiratory functions parameters. Thus, the aim of this study is to determine the relationship between diaphragmatic muscle thickness, spirometer parameters and respiratory muscle strength in elite athlete groups.

METHOD

Study scope and subjects

Cross-sectional method was used as the research design. 58 male (age= 20.14±2.71) students studying at Yaşar Doğu Faculty of Sports Sciences, who were determined by randomized method, participated in the study voluntarily. The number of subjects was determined by using G*Power analysis. The study was carried out in accordance with the Declaration of Helsinki. Ethical approval was obtained from Ondokuz Mayıs University Clinical Research Ethics Committee (OMU KAEK 2022/434).

Test procedure

Evaluations started at 12:00 every day. The volunteers were asked to maintain their normal dietary intake on days of evaluation. The volunteers made three visits to the laboratory in total. In their first visit, information was given about the protocols of the tests and the athletes were divided into two different groups. At the second visit, height, weight, body mass index and MIP, MEP and lung volume and capacity values were measured. At the third visit, diaphragmatic thickness measurements were made in the expiratory and inspiratory phases.

Respiratory function tests

Pulmonary function tests were performed by using MGC Diagnostics Brand CPFS/D USB TM Spirometer. The subjects were informed about the practice. All measurements were performed in the sitting position according to ATS/ERS standards. FVC (forced vital capacity), FEV1 (forced expiratory in the first second), and IC (inspiratory capacity) measurement results calculated at the end of the test were recorded.

Respiratory muscle strength tests

Respiratory muscle strength tests were performed by using a MicroRPM respiratory pressure gauge (Vyaire, Mettawa, IL, USA) with a flanged mouthpiece to find MIP and MEP according to American Thoracic Society (ATS) guidelines (ATS/ERS Respiratory Muscle Test Statement, 2002). Trials were conducted before each measurement. The participants performed three trials for each test and took a one-minute rest break in-between each trial. All tests were performed with a disposable nose clip in seated position, starting with the lungs at residual volume for MIP and MEP (Ho et al., 2022).

Diaphragm thickness measurement

Ultrasonography measurements were performed by a radiologist specialized in musculoskeletal ultrasonography with the help of Philips Affiniti 70G ultrasound device (Philips Healthcare, Bothell, WA USA) and a 12 MHz Linear transducer with a mouth part of 5 cm. The transducer was placed on the right mid-axillary line in the coronal plane for measurement by using the transducer liver window while the subjects were in the supine position. The intercostal space between the 8th and 9th ribs was determined for measurement during DKex, and the optimal diaphragm image was obtained from this window using the liver window. For measurement during DKins, the intercostal space between the 10th and 11th ribs was determined and the diaphragm was measured from where the best image could be obtained (Ueki et al., 1995; Hellyer et al., 2017; Erail et al., 2022). The measurement was performed in two steps. In the first step, the subjects were asked to exhale as deeply as possible and then hold their breath. After maximal expiration was achieved in this way, diaphragmatic muscle imaging and thickness measurements were performed. In the second step, the subjects were asked to breathe as deeply as possible and hold their breath. Diaphragmatic muscle thickness was measured by excluding two echogenic lines of the pleura and peritoneum. Measurements were repeated three times in different expiratory and inspiratory phases and the best measurement was recorded (Erail et al., 2022).

Statistical analysis

SPSS 26.0 package program (SPSS for Windows, 2008, SPSS Inc., Chicago, Illinois, USA) was used for data analysis in the study. The obtained data were presented as arithmetic mean and standard deviation. Pearson correlation was used to determine the relationship between pulmonary functions and diaphragmatic muscle thickness. Statistical results were evaluated at $p<0.05$ and $p<0.01$ significance level.

RESULTS

Table 1. Descriptive information of the subjects

Variables	N	Mean	S.D.
Age (years)	58	20.14	2.71
Height (cm)	58	181.45	8.92
Body weight (kg)	58	78.86	13.59

Table 2. Correlation between respiratory muscle strength and diaphragm thickness

Variables		DiT_{ex}	DiT_{ins}
MIP (cmH_2O)	r	0.171	0.321**
	p	0.099	0.007
MEP (cmH_2O)	r	0.237*	0.367**
	p	0.037	0.002

*. Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level, DiT_{ex}: Diaphragm Thickness In Expiration, DiT_{ins}: Diaphragm Muscle Thickness Inspiration,

The correlation between diaphragmatic muscle thickness and pulmonary functions was investigated. Significant positive difference was found between DiT_{ex} and MEP ($p<0.05$). A higher level of positive and significant difference was found between DiT_{ins} and both MIP and MEP ($p<0.01$).

Table 3. Correlation between pulmonary functions and diaphragmatic muscle thickness

Variables		DiT_{ex}	DiT_{ins}
FVC (L)	r	0.215	-0.027
	p	0.053	0.421
FEV1 (L)	r	0.180	0.076
	p	0.088	0.285
IC (L)	r	0.043	0.040
	p	0.374	0.383

*. Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level, DiT_{ex}: Diaphragm Thickness In Expiration, DiT_{ins}: Diaphragm Muscle Thickness Inspiration,

There was no statistically significant relationship between pulmonary parameters and diaphragm muscle thickness ($p>0.05$). There was only a positive correlation between DiT_{ins} and FVC ($p=0.053$).

DISCUSSION AND CONCLUSION

This study was designed to examine the relationship between diaphragmatic muscle thickness, spirometry and respiratory muscle strength parameters in athletes of various branches who continue their sports life at the elite level. As a result of this study, a relationship was found between diaphragmatic muscle thickness and pulmonary function parameters. A positive significant difference was found particularly between DK_{ex} and MEP data ($p<0.05$). In addition, a higher level of positive significant difference was found between DK_{ins} and both MIP and MEP parameters ($p<0.01$). Studies examining the relationship between diaphragmatic muscle thickness and various pulmonary data are quite superficial in the literature. In this context, we think that our study will make new and important contributions to the literature.

When previously conducted similar studies were examined, similar to the results we found in our study, Ho et al. (2022) showed in a study conducted on children that diaphragmatic parameters are closely related to pulmonary function and MIP-MEP in healthy children. Diaphragmatic thickness fraction was associated with higher MIP, enhancing the effect of muscle thickness and contractility on strength production (Farkas et al., 1996). It is an already known fact that higher pressure occurs with changes in the dimensions of the diaphragm (Wilson & De Troyer, 2010). In a study on healthy individuals, inspiratory mobility, total lung capacity and diaphragmatic thickening ratio were found to be statistically significant in relation to lung function and inspiratory strength (Cardenas et al., 2018). Similar to our study, other studies examining respiratory muscle strength and diaphragmatic parameters showed a correlation between diaphragm thickness and inspiratory muscle strength (Ueki et al., 1995; Souza et al., 2014).

In another recent study, the relationship between ultrasound parameters of the diaphragm and intercostal muscles and long and short distance running parameters was examined in adolescent football players (Pałac et al., 2023). It was stated that ultrasound parameters of respiratory muscles were related to velocity parameters in adolescent football players, while ultrasound parameters were not significantly related to all endurance parameters ($p>0.05$) (Pałac et al., 2023).

In terms of pulmonary function parameters, consistent with our study, a positive correlation was reported between diaphragmatic mobility during deep inspiration and FVC and FEV1 parameters (Cohen et al., 1994; Houston et al., 1994; Cardenas et al., 2018). Apart from these studies, there are also studies in which no significant relationship was found (Mccool et al. 1997; Summerhill et al. 2007; Brown et al. 2013). The reason for this difference is likely to be due to the sample groups included in the studies.

In addition, the diaphragm thicknesses of amateur and semi-professional athletes with and without lumbopelvic pain (LPP) were compared in a case control study, which was conducted from a different angle. Compared with healthy athletes, a decrease was found in bilateral diaphragmatic thickness in DK_{ins} in athletes with LPP ($p<0.05$) (Calvo-Lobo et al., 2019).

In conclusion, it was found with the present study that taking the images of the diaphragm with ultrasound is an important method to show many measurements and to obtain accurate results. As a result of the measurements made, a significant positive difference was found between DiT_{ex} and MEP. A higher level of positive significant difference was observed between DiT_{ins} and both MIP and MEP. However, studies evaluating diaphragmatic thickness and various respiratory parameters are scarce in the literature, planning studies with more participants in different sample groups is important in terms of contributing to the literature.

GENİŞLETİLMİŞ ÖZET

GİRİŞ

Diyafragma kas kalınlığı ve hareketliliği ultrason ile görüntülenebilmektedir. Radyasyonun olmaması, taşınabilirlik, gerçek zamanlı görüntüleme gibi avantajlarıyla birlikte birçok durumda diyafragma fonksiyonunu değerlendirmek amacıyla giderek daha fazla kullanılmaktadır (Ueki ve ark., 1995; Cohn ve ark., 1997; Kantarcı ve ark., 2004; Testa ve ark., 2011; Boon ve ark., 2013; Cardenas ve ark., 2018; Erail ve ark., 2022; Ho ve ark., 2022). Diyafragmanın ultrason ile görüntülemesi önceden kullanılan standart görüntüleme tekniklerinin sınırlamalarının birçoğunu ortadan kaldırmaktadır (Matamis ve ark., 2013; Sarwal ve ark., 2013). Diyafragma birincil inspiratuar kas olarak kabul edilir ve aynı zamanda ventilasyonun 2/3'ünü sağlayarak solunum için çok hayati bir rol oynamaktadır. Normal ventilasyon ensasında gerekli olan işlemlerin çok önemli bir kısmında diyafragma kası görev almaktadır, diğer yardımcı solunum kasları yalnızca ventilasyon hızı ve derinliği arttığında etkin hale gelmektedir (Polla ve ark., 2004).

Literatürdeki mevcut çalışmalar incelendiğinde sporcuların performansını sürdürebilmesinde en önemli faktörlerden biri olan solunum sistemi ve solunum kasları üzerine birçok çalışma yapılmış (Sheel, 2002; Karvonen, 1992; Amonette ve ark., 2002; Forbes ve ark., 2011; Vasconcelos ve ark., 2017) ve bu sistemin temel kası olan diyafragma kas kalınlığı üzerine çeşitli parametrelerin incelendiği çalışmalar (Ueki ve ark., 1995; De Bruin ve ark., 1997; Enright ve ark., 2006; Orrey, 2013; Kim ve ark., 2017) olmasına rağmen, diyafragma kas kalınlığının sporcular üzerinde doğrudan çeşitli solunum parametreleri ile ilişkisi üzerine herhangi bir çalışmayla karşılaşılmamıştır. Bu nedenle farklı popülasyonlarda diyafragma paremetreleri ile solunum paremetreleri arasındaki ilişkinin değerlendirilebilmesi için kalınlık, genişleme ve bazı spesifik parametrelerim solunum fonksiyonları parametreleri ile nasıl bir ilişkisi olduğunu belirlemeye ihtiyaç olduğu görülmektedir. Bu doğrultuda elit sporcu gruplarında diyafragma kas kalınlığının, spirometre paremetreleri ve solunum kas kuvveti arasındaki ilişkinin belirlenmesi amaçlanmıştır.

YÖNTEM

Çalışma kapsamı ve denekler

Araştırma dizaynı olarak kesitsel yöntem kullanıldı. Araştırmaya randomize yöntemle belirlenen Yaşar Doğu Spor Bilimleri Fakültesinde öğrenim gören 58 erkek (yaş= 20,14±2,71) sporcu gönüllü olarak katıldı. Denek sayısı G*Power analizi kullanılarak belirlendi. Araştırma helsinki bildirgesine uygun olarak yürütüldü. Araştırma etik onayı Ondokuz Mayıs Üniversitesi Klinik Araştırmalar Etik Kurulu'ndan alındı (OMU KAEK 2022/34).

BULGULAR

Diyafragma kas kalınlığı ile pulmoner fonksiyonlar arasındaki ilişki incelenmiştir. DiTeks ile MEP arasında pozitif yönde anlamlı farklılık elde edilmiştir ($p<0,05$). DiTins ile hem MIP hem MEP arasında daha yüksek düzeyde pozitif yönde anlamlı farklılık görülmüştür ($p<0,01$).

TARTIŞMA VE SONUÇ

Bu çalışmada elit seviyede spor hayatına devam eden çeşitli branşlardaki sporcularda diyafragma kas kalınlığının, spirometre ve solunum kas kuvveti paremetreleri arasındaki ilişkinin incelenmesi planlanmıştır. Bu çalışma sonucunda; diyafragma kas kalınlığı ile pulmoner fonksiyon parametreleri arasında ilişki olduğu görülmüştür. Özellikle DK_{eks} ile MEP verileri arasında pozitif yönde anlamlı farklılık elde edilmiştir ($p<0,05$). Ayrıca DK_{ins} ile hem MIP hem MEP parametreleri arasında daha yüksek düzeyde pozitif yönde anlamlı farklılık görülmüştür ($p<0,01$). Litaratürde diyafragma kas kalınlığı ile çeşitli pulmoner veriler arasındaki ilişkinin incelendiği çalışmalar oldukça sığdır. Bu bağlamda çalışmamızın literatüre yeni ve önemli katkılar sağlayacağını düşünüyoruz.

Daha önce yapılan benzer araştırmalar incelendiğinde; Ho ve arkadaşları (2022)'nın, çocuklar üzerinde yaptıkları çalışmada sonucu itibariyle çalışmamızda elde ettiğimiz sonuçlara benzer olarak; diyafragma parametrelerinin sağlıklı çocuklarda pulmoner fonksiyon ve MIP-MEP ile yakından ilişkili olduğunu göstermektedir. Diyafragma kalınlık fraksiyonu daha yüksek MIP ile ilişkilendirilerek kas kalınlığı ve kontraktilitenin kuvvet üretimi üzerindeki etkisini güçlendirmiştir (Farkas ve ark., 1996). Diyafragmanın boyutlarındaki değişikliklerde daha yüksek basınç ortaya çıktığı daha önceden bilinen bir durumdur (Wilson & De Troyer, 2010). Sağlıklı bireyler üzerinde yapılan bir çalışmada; inspirasyondaki mobilite, toplam akciğer kapasitesinde ve diyafragma kalınlaşma oranı ile akciğer fonksiyonu ve inspirasyon gücü ile ilişkisinin istatistiksel olarak anlamlı olduğu belirtilmiştir (Cardenas ve ark., 2018). Solunum kas kuvveti ve diyafragma parametrelerinin incelendiği diğer çalışmalarda da bu çalışmamıza benzer olarak diyafram kalınlığı ile inspiratuar kas gücü arasında korelasyon göstermiştir (Ueki ve ark., 1995; Souza ve ark., 2014).

Pulmoner fonksiyon parametrelerine bakıldığında; çalışmamızla uyumlu olarak, derin inspirasyon sırasındaki diyafragma hareketliliği ile FVC ve FEV1 parametreleri arasında pozitif korelasyon olduğu bildirilmiştir (Cohen ve ark., 1994; Houston ve ark., 1994; Cardenas ve ark., 2018). Bu çalışmaların dışında anlamlı ilişkinin olmadığı çalışmalarda vardır (Mccool ve ark., 1997; Summerhill ve ark., 2007; Brown ve ark., 2013). Bu oluşan farklılığın sebebi olarak çalışmalarda yer alan örneklem gruplarından kaynaklı olma ihtimali yüksektir.

Sonuç olarak; bu çalışma ile diyafragmanın ultrason ile görüntülenmesi birçok ölçümü görüntüleyebilmek ve doğru sonuçlar elde edebilmek adına önemli bir yöntem olduğu görülmüştür.

Yapılan ölçümler sonucunda; DiT_{eks} ile MEP arasında pozitif yönde anlamlı farklılık elde edilmiştir DiT_{ins} ile hem MIP hem MEP arasında daha yüksek düzeyde pozitif yönde anlamlı farklılık görülmüştür. Ancak, literatürde diyafragma kalınlığı ile çeşitli solunum parametrelerinin değerlendirildiği çalışmalar azdır, bu alanda daha farklı örneklem gruplarında çok daha fazla katılımcı ile çalışmaların planlanması literatüre katkı açısından önemlidir.

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KATKI ORANI ***CONTRIBUTION RATE***	**AÇIKLAMA** ***EXPLANATION***	**KATKIDA BULUNANLAR** ***CONTRIBUTORS***
Fikir ve Kavramsal Örgü *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak *Form the research hypothesis or idea*	Serhat ERAİL
Tasarım *Design*	Yöntem ve araştırma desenini tasarlamak *To design the method and research design.*	M. Hakan MAYDA Serhat ERAİL
Literatür Tarama *Literature Review*	Çalışma için gerekli literatürü taramak *Review the literature required for the study*	M. Hakan MAYDA Serhat ERAİL
Veri Toplama ve İşleme *Data Collecting and Processing*	Verileri toplamak, düzenlemek ve raporlaştırmak *Collecting, organizing and reporting data*	M. Hakan MAYDA Serhat ERAİL
Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların değerlendirilmesi *Evaluation of the obtained finding*	M. Hakan MAYDA Serhat ERAİL

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