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RELATIONSHIP BETWEEN TRUNK MUSCLE ENDURANCE, PULMONARY FUNCTION, AND RESPIRATORY MUSCLE STRENGTH IN HEALTHY INDIVIDUALS

ORIGINAL ARTICLE

ABSTRACT

Purpose: Trunk muscles are acrive in the forceful expiration, and trunk this study aimed to examine the relationship between pulmonary function, respiratory muscle strength, and trunk muscle endurance.

Methods: The study was conducted with 60 volunteer and healthy individuals whose ages varied between 20 and 36 years. Pulmonary function and maximum inspiratory and expiratory pressure (MIP and MEP) were measured using a desktop spirometer. Trunk muscle endurance of the subjects was evaluated using the prone bridge, side bridge, flexor endurance, and Sorensen tests.

Results: A positive significant relationship was observed between the percentage of forced vital capacity (%FVC) and prone bridge (r=0.395, p=0.002), flexor endurance (r=0.256, p=0.049), and Sorensen (r=0.255, p=0.049) tests. Likewise, a positivesignificant correlation was found between the percentage of forced expiratory volume in 1 second (%FEV_1) and prone bridge (r=0.408, p=0.001), flexor endurance (r=0.358, p=0.005), and side bridge (r=0.277, p=0.032) tests. The results revealed a positive relationship between MIP and prone bridge (r=0.376, p=0.003) and side bridge tests (r=0.470, p<0.001). Likewise, there was a positive correlation between MEP and prone bridge test (r=0.401, p=0.004) and side bridge test (r=0.365 p=0.002).

Conclusion: Pulmonary function and respiratory muscle strength are associated with the endurance of the trunk muscles, which ensure core stability. Trunk muscle endurance exercises may have a positive influence on respiratory function.

Key Words: Diaphragm; Endurance; Pulmonary Function; Respiratory Muscles; Trunk.

SAĞLIKLI OLGULARDA GÖVDE KAS ENDURANSI, SOLUNUM FONKSİYONLARI VE SOLUNUM KAS KUVVETİ İLİŞKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Gövde kasları zorlu ekspirasyon ve gövde stabilizasyonunda aktiftir. Bu çalışmanın amacı solunum kas kuvveti, solunum fonksiyon testi değerleri ve gövde kas enduransı arasındaki ilişkiyi incelemekti.

Yöntem: Çalışma yaşları 20 ile 36 yıl arasında değişen 60 sağlıklı gönüllü üzerinde yapıldı. Olguların maksimum inspiratuar ve ekspiratuar kas kuvveti (MIP ve MEP) ve solunum fonksiyon testi masaüstü spirometre ile değerlendirildi. Bireylerin gövde kas enduransı yüzüstü köprü, yan köprü, fleksör endurans ve Sorensen testleri ile belirlendi.

Sonuçlar: Zorlu vital kapasite yüzdesi (%FVC) ile yüzüstü köprü (r=0,395, p=0,002), fleksor endurans (r=0,256, p=0,049) ve Sorensen testleri (r=0,255 p=0,049) arasında pozitif yönde anlamlı ilişki tespit edildi. Birinci saniyedeki zorlu ekspiratuar volüm (%FEV_1) ile yüz üstü köprü (r=0,408, p=0,001), fleksör endurans (r=0,358, p=0,005) ve yan köprü testleri (r=0,277, p=0,032) arasında pozitif anlamlı korelasyon bulundu. MIP ile yüz üstü köprü (r=0,376, p=0,003) yan köprü testleri (r=0,470, p<0,001) arasında pozitif ilişki saptandı. MEP ile yüzüstü köprü (r=0,401, p=0,002) ve yan köprü (r=0,365, p=0,004) testleri arasında pozitif yönde anlamlı korelasyon olduğu bulundu.

Tartışma: Solunum fonksiyonları ve solunum kas kuvveti ile gövde stabilizasyonu sağlayan kasların enduransı ilişkilidir. Gövde kas enduransı egzersizlerinin solunum fonksiyonlarına pozitif yönde etki edebileceği söylenebilir.

Anahtar Kelimeler: Diyafragma; Endurans; Solunum Fonksiyonları; Solunum Kasları; Gövde.

INTRODUCTION

Diaphragm constitutes the upper group for core stability (1). Diaphragm muscle, constitutes the upper part of the cylinder involving the muscles at the back and the abdominals. When it contracts, pressure in the abdomen increases, which contributes to core stability. Diaphragm contracts in advance before extremity movements and during extremity movements, thus helping to maintain postural control (2). The diaphragm is the primary respiratory muscle that is responsible for inspiration at the same time. Functional loss that could occur in the diaphragm, which is responsible for 65 to 80 percent of the vital capacity on its own, may lead to a significant decrease in inspiratory capacity (3,4).

Anatomically, diaphragm originates from the lumbar vertebrae, and the structures involved in the diaphragm are made up of the fascia of quadratus lumborum and psoas major, which contribute to core stability. Therefore, it has a vital role in the muscular endurance of the trunk (3,5).

Of the muscle fibrils in the diaphragm, 55% are Type I, while 21% and 24% of the muscle fibrils are Type IIa and Type IIb, respectively. Type I and Type IIa fibrils have a high oxidative capacity. They contract more slowly, yet are more resistant to exhaustion (6). The intensity of these fibers makes the diaphragm a significant muscle in terms of endurance.

It was previously shown that 10% of maximal contraction is adequate to ensure spinal stabilization (7), which reveals that endurance is more important than strength in core stability. Previous studies showed that trunk muscle endurance is more functional in supporting the core structure compared to muscle strength (8). Therefore, compared to the other structures, the diaphragm may be more critical in terms of supporting trunk stability endurance due to its fiber type.

During forced expiration, particularly M. rectus abdominis, M. transversus abdominis, M. obliquus internus, and externus function actively (4). Particularly M. transversus abdominis increases the pressure in the abdomen like the diaphragm, and thus supports trunk stabilization (1). Hackett et al. showed that maximal expiratory pressure is associated with the bench press, squat, and deadlift strengths (9). In another study, the relationship between lung function, respiratory muscle strength, and peripheral muscle strength has been demonstrated (10). On the other hand, the relationship of respiratory muscle strength with the endurance of the muscles that provide core stability is uncertain. In light of this information, this study aimed to examine the relationship between the endurance of the muscles that ensure trunk stabilization and respiratory muscle strength in healthy individuals.

METHODS

Subjects and Study Design

This study was conducted in March 2017 at Gazi University, Faculty of Health Sciences, Athlete's Health Unit. The study sample was selected from the volunteers who applied to the advertisement posted at the entrance of the Athlete's Health Unit. Inclusion criteria were no chronic disease and being the ages of 18-40 years. Exclusion criteria were history of cardiopulmonary and neurological diseases, pregnancy, morbid obesity, and major surgery. After the demographic data of 73 healthy cases were collected, pulmonary function and respiratory muscle strength were measured. Since twelve subjects were not cooperating during pulmonary function and respiratory muscle strength tests, they were excluded from the study. Additionally, one subject could not complete the trunk muscle endurance tests due to abdominal pain and was excluded from the study. Therefore, statistical analysis was conducted with 60 subjects who completed all the measurements (Figure 1).

Ethical approval was obtained from Osmangazi University, Clinical Research Ethics Committee (Approval Date: 09.03.2017 and Approval Number: 15). All the subjects who volunteered to participate in the study signed the written informed consent form. All the procedures were carried out following the Helsinki Declaration.

Pulmonary Function Test

Lung function testing was performed using a spirometer (Cosmed Pony FX Desktop Spirometer, Rome, Italy) using nose clips while the subjects were in a 90-degree relaxed sitting position. Each subject performed the test at least three times, at most eight times, and the subjects who failed to complete the maneuver successfully after eight tests were excluded from the study. Forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), peak expiratory flow (PEF), forced expiratory flow from 25–75% ($FEF_{25-75\%}$), and percentages of predictive values were recorded. Following three successful tests, the test with the highest FVC and FEV_1 was recorded as recommended by the American Thoracic Society and the European Respiratory Society (11). Percentages of predicted values were calculated (12).

Respiratory Muscle Strength

Following the pulmonary function tests, maximal inspiratory and expiratory pressure (MIP and MEP) measurements of the subjects were performed using the Cosmed Pony FX model (Cosmed, Rome, Italy) while the subjects were in the same position with a nose clip. In both measurements, the air leak was checked strictly. Minimum five maneuvers were performed, and special attention was paid not to have more than 10 cm H_2O or 10% difference between the two best measurements. Quality control of the measurements was conducted by interpreting the pressure-time curve. Careful attention was given to obtain the highest pressure value at the beginning of the measurement. The obtained values were recorded (13,14). Percentages of predicted values were calculated according to age and gender (15).

Trunk Muscle Endurance Tests

Trunk muscle endurance of the subjects was measured using four different tests; side sridge test (SBT), prone bridge test (PBT), flexor endurance test (FET), and Sorenson test (ST). Each test position was demonstrated to the subjects, and the subjects tried the positions for a few seconds. In side bridge test application, the subjects were initially in the side-lying position (on the dominant side), but when they were ready, they were asked to raise their hip without any instruction, to support themselves with one arm in a way to keep the body in a straight line and to keep this position as long as possible. The subjects were instructed to put their free hand on the other shoulder. The duration of time in which they could maintain their position was recorded in seconds (16). In the prone bridge test application, the subjects were face down on their knees and forearms as the starting position. The subjects were asked to raise their knees parallel to the ground without any instruction when they felt ready and stand on their forearms and toes. The duration of time in which they could maintain their position was recorded in seconds. In the flexor endurance test, the subjects lay on their back as the starting position. When they felt ready, without any instruction, they pulled their knees toward their abdomen in a way to keep the knees parallel to the ground and arms wrapped around, they raised their upper trunk in a way to raise the lower end of the scapula from the ground. The duration of time in which they could maintain their position was recorded in seconds (16). In the Sorenson test, the subjects lay on a stretcher face down as the starting position, and their upper trunk overhung the stretcher. The subjects were re-positioned in a way that the part of the body that contacted with the bed was spina iliaca anterior superior. The subjects kept their balance by holding a chair with their hands. A physiotherapist fixed the subjects' legs, and when the subjects felt ready, they crossed both hands on their shoulders without any instruction, and their position was parallel to the ground. The duration of time in which they could maintain their position was recorded in seconds (16,17).

Statistical Analysis

The IBM SPSS (Statistical Package for Social Sciences) Statistics 21.0 (IBM Corp. Armonk, NY, USA) was used to conduct the statistical analysis of the data. Percentage, mean, and standard deviation values of the descriptive data were calculated. The data were analyzed using the Kolmogorov-Smirnov test and according to their skewness and kurtosis coefficients. As it was found that the data showed a normal distribution, parametric tests were used. Pearson product-moment correlation coefficient (r) was used to assess the relationship between the variables. The level of significance was taken as $p<0.05$. Power analysis was calculated as post hoc with G*power 3.1.9.2 Software (Franz Faul, Universitat Kiel, Germany). The power of the study

Table 1: Characteristics of the Subjects.

Characteristics	Healthy Subjects (n=60)	
	Mean±SD	Min-Max
Age (years)	26.33±3.98	20-36
Weight (kg)	71.23±14.70	47-36
Height (cm)	172.40±8.51	155-190
Body Mass Index (kg/m²)	23.79±3.50	18-35.41

was calculated as 96%, with an effect size of 0.49.

RESULTS

Demographic data of 60 volunteers (33 males, 27 females) are given in Table 1. The measured and percent-predicted values of FEV_1, FVC, PEF, and $FEF_{25-75\%}$ are given in Table 2. The MIP, %MIP, MEP, and %MEP, as well as trunk muscle endurance, are presented in Table 2.

Positive relationships were observed between FVC, and prone bridge test (r=0.432, p=0.001) and side bridge test (r=0.295, p=0.022) tests. The relationships between %FVC and prone bridge test (r=0.395, p=0.002), and flexor endurance test (r=0.256, p=0.049) and Sorenson test (r=0.255, p=0.049) were found to be positive and significant. There were positive significant relationship between FEV_1 and prone bridge test (r=0.414, p=0.001), flexor endurance test (r=0.268, p=0.038), and side bridge test (r=0.313, p=0.015) tests. Positive significant relationships were found between %FEV_1 and prone bridge test (r=0.408, p=0.001), flexor endurance test (r=0.358, p=0.005), and side bridge test (r=0.277, p=0.032) tests. The relationship between PEF and the prone bridge test (r=0.380, p=0.003) test was found to be positive as

Table 2: Lung Function, Respiratory Muscle Strength, and Trunk Stabilization.

Measurements	Healthy Subjects (n=60)	
	Mean±SD	Min-Max
Lung Function		
FVC (L)	4.75±1.04	3-6.92
FVC (%)	104.06±10.09	81-130
FEV_1 (L)	3.87±0.76	2.47-5.26
FEV_1(%)	99.51±8.19	81-123
FEV_1/FVC	81.85±5.22	68.7-93.1
PEF (L/s)	8.60±2.07	4.05-13.41
PEF (%)	98.15±14.23	61-141
$FEF_{25-75\%}$ (L)	3.94±0.96	2.37-7
$FEF_{25-75\%}$ (%)	85.95±16.65	56-134
Respiratory Muscle Strength		
MIP (cmH_2O)	95.86±32.97	36-229
%MIP	102.86±31.09	49-204
MEP (cmH_2O)	126.60±41.20	46-268
%MEP	104.00±23.17	50-187
Trunk Stabilization		
Prone Bridge Test (s)	76.05±38.37	28-180
Flexion Endurance Test (s)	72.35±44.49	17.36-180
Side Bridge Test (s)	50.26±22.09	13.46-100.7
Sorensen Test (s)	100.49±36.58	35.82-180

FVC: Forced vital capacity, FEV_1: Forced expiratory volume in one second, PEF: Peak Expiratory Flow, $FEF_{25-75\%}$: Forced expiratory flow from 25–75%, MIP: Maximum Inspiratory Pressure, MEP: Maximum Expiratory Pressure.

Table 3: Relationship between Trunk Muscle Endurance and Lung Function and Respiratory Muscle Strength.

Measurements		Prone Bridge Test	Flexor Endurance Test	Side Bridge Test	Sorensen Test
FVC (L)	r	0.432	0.241	0.295	0.099
	p	**0.010***	0.064	**0.022***	0.450
FVC (%)	r	0.395	0.256	0.229	0.255
	p	**0.002***	**0.049***	0.078	**0.049***
FEV_1 (L)	r	0.414	0.268	0.313	0.075
	p	**0.001***	**0.038***	**0.015***	0.569
FEV_1 (%)	r	0.408	0.358	0.277	0.214
	p	**0.001***	**0.005***	**0.032***	0.101
FEV_1/FVC	r	-0.167	0.36	-0.083	-0.071
	p	0.203	0.785	0.530	0.592
PEF (L)	r	0.380	0.227	0.248	0.030
	p	**0.003***	0.081	0.056	0.819
PEF (%)	r	0.259	0.207	0.092	0.091
	p	**0.045***	0.112	0.485	0.491
$FEF_{25-75\%}$ (L)	r	0.191	0.257	0.205	-0.22
	p	0.144	**0.047***	0.116	0.869
$FEF_{25-75\%}$ (%)	r	0.059	0.239	0.085	-0.029
	p	0.653	0.066	0.517	0.827
MIP (cmH_2O)	r	0.376	0.147	0.470	0.100
	p	**0.003***	0.263	**0.001***	0.447
%MIP	r	0.160	0.030	0.259	0.139
	p	0.221	0.820	0.045*	0.291
MEP (cmH_2O)	r	0.401	0.166	0.365	0.148
	p	**0.002***	0.205	**0.004***	0.260
%MEP	r	0.197	0.086	0.180	0.244
	p	0.131	0.512	0.169	0.060

*p<0.05. r: Pearson correlation coefficient. FVC: Forced vital capacity, FEV_1: Forced expiratory volume in one second, PEF: Peak expiratory flow, $FEF_{25-75\%}$: Forced expiratory flow from 25–75%, MIP: Maximum inspiratory pressure, MEP: Maximum expiratory pressure.

well. In addition, a positive correlation was found between %PEF and prone bridge test (r=0.049, p=0.047). There was also a positive relationship between $FEF_{25-75\%}$ and flexor endurance test (r=0.257, p=0.047) (Table 3).

When the correlation tests were examined, positive relationships were observed between MIP and prone bridge test (r=0.376, p=0.003) and side bridge test (r=0.470, p<0.001). When the correlation between the %MIP values and side bridge test was examined, a positive relationship was revealed (r=0.259, p=0.045) (Table 3). In addition, the relationships between MEP and prone bridge test (r=0.401, p=0.002) and side bridge test (r=0.365, p=0.004) were found to be positive and statisticly significant (Table 3).

DISCUSSION

This study was conducted to examine the relationship between the endurance of the core muscles, which have a significant role in trunk stabilization, respiratory muscle strength, and pulmonary function. In this context, it was shown in this study that strong core stability is associated with better respiratory muscles and better pulmonary function. While previous studies have shown the relationship between lung function, peripheral muscle strength, and handgrip strength, this is the first study to show the relationship between core stability and respiratory dynamics (10,18,19).

The handgrip is an important marker that reflects general muscle strength (20). Smith et al. showed that handgrip strength and spirometry values are related in their comprehensive study in adolescents (19). This situation reveals a possible relationship between general muscle strength and respiratory functions. In this study, it has been shown that there

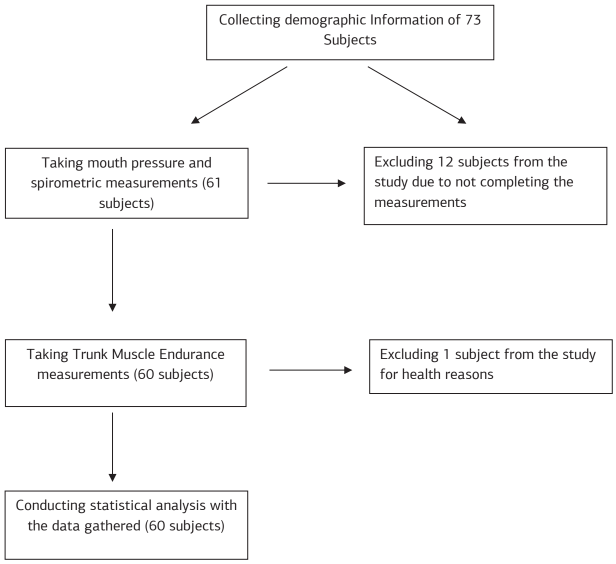

Figure 1: Flow Chart of the Study.

is a relationship between core stability, endurance, and lung function. Core stability is a major phenomenon leading to peripheral movements. It is possible that there is a relationship between handgrip force, peripheral muscle strength, core stabilization, and respiratory parameters in the body, which moves as a whole through the kinetic chain.

Al-Bilbeisi and McCool showed that during weight lifting activities, transdiaphragmatic pressure (PDI) increased by 20 percent. This rate increases to 40% during the bench press movement, depending on the weight. The same study demonstrated that PDI increased to more than 40% during sit-ups (21). The PDI helps gain an insight into the extent of the diaphragm activity. Strongoli et al. (22) conducted a study of six healthy individuals and compared the transdiaphragmatic pressure in the rest position with PDI during 13 different abdominal exercises. The results pointed to a significant difference. In the same study, PDI measurements were conducted during maximal inspiratory pressure, and the measurements were compared with 13 different abdomen exercises. Of all the 13 exercises, it was found that in seven exercises, the PDI measured during MIP increased 50-65% (22). All these exercises support both respiratory parameters and core stability with an increased diaphragm and abdominal muscle activation. All movements in daily life, including exercises, create an adaptation in accordance with the (specific adaptations the imposed demands) (SAID) principle (23,24). This adaptation also applies to respiratory muscles and trunk stabilization. Our study also showed to the positive relationship between prone bridge and side bridge exercises, and respiratory muscle strength (MEP and MIP).

It was previously shown that respiratory muscle training could be used in healthy individuals to increase sports performance (25). There are studies showing that respiratory functions are associated with athletic performance (26,27). Similarly, some studies show that core stability is associated with athletic function and performance (28-31). In this context, the current study connects these two concepts. While respiratory dynamics and core stabilization support performance, they are also interrelated.

Pulmonary function test values may change depending on age, gender, race, weight, and height. Therefore, it would be more accurate to evaluate the percentage values taken over the determined values based on standards. This study revealed positive relationships between %FVC value and prone bridge, flexor endurance test, and Sorensen test. The relationships between %FEV_1 and prone bridge, flexor endurance test, and side bridge were also found to be positive. Pulmonary function is shaped by the interaction between the diaphragm, chest wall, and lung. When it is considered that there is no pathology in the lung, diaphragm, and chest wall of the healthy subjects we examined, diaphragm strength may have a direct effect on the emergence of these parameters. The positive correlation between %FVC, %FEV_1, and MIP values supports this finding. The FVC and FEV_1 maneuvers may change depending on effort. In healthy individuals, the other factor that affects the effort is the strength of the abdominal muscles that leads to a sudden, explosive expiration following maximal inspiration (4). Strong abdominals increase the effort and directly directly affect FVC and FEV_1 values. Furthermore, this muscle group affects the values in the endurance tests because of its role in trunk stabilization.

In the literature, although it is stated that FVC measurement depends on both inspiration and expiration effort, and thus it could be used instead of MEP and MIP measurements. However, it has also been reported that FVC does not reflect the state of muscle functions in a standing or sitting position (32). In 2016, Oh et al. worked with 18 patients who had a stroke. In addition to the routine rehabilitation program, the patients performed lumbar stabilization exercises three times a week for eight weeks. Respiratory parameters were measured at the beginning, at week 4, and the end of week 8. The study revealed a significant increase in week 4 and week 8 in FVC, FEV_1, and PEF values of the stabilization group (33) Another study combined 4-week dynamic upper extremity exercises with respiratory exercises and revealed a positive effect on FVC values. This improvement was explained by increased diaphragm activation during extremity movements (34). In a study conducted by Kim and Lee in healthy students, deep abdominal muscles were strengthened, and as a result, positive and significant changes were observed in respiratory function (35).

On the other hand, Cavaggioni et al. conducted a study in which they compared the effects of traditional abdominal exercises (prone bridge, side bridge, crunch, and rotational crunch) with those of diaphragmatic respiration-based core stability exercises. They found that diaphragmatic respiration-based exercises are superior to the traditional exercises (in terms of their contribution to respiration parameters) (36). However, shorter duration and less repetition frequency of traditional exercises might have affected the results in the study.

There are several limitations to this study. The first is that it was performed only in healthy individuals. Current results may differ in disease states. In addition, our study was conducted in a limited age range, and results could not be generalized for other age groups. Although diaphragm and abdominal muscles are very important for ventilation, mouth pressure measurement does not only reflect the strength of the diaphragm and abdominal muscles.

In conclusion this study revealed that a strong core muscle structure is observed together with strong respiratory muscles. Although the function of the diaphragm and abdominal muscles in ventilation and trunk stabilization is different, there is a clear relationship between them. Studies may be conducted to examine respiratory muscle strength following the strengthening exercises performed for core structure and to show how transdiaphragmatic pressure and the diaphragm affect electromyographic values during core exercises. Similar studies may be conducted with different age groups, with patients who have respiratory disorders, and with groups having different body mass. It may also be beneficial to evaluate the respiratory muscle strength measurements of individuals to be included in a trunk endurance training program before and after the program.

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Conflict of Interest: None.

Ethical Approval: Ethical approval was obtained from Osmangazi University, Clinical Research Ethics Committee (Approval Date: 09.03.2017 and Approval Number: 15).

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and/or Interpretation –FY, NAG, BT, AB; Literature Research - FY, NAG; Writing Manuscript - FY, NAG; Critical Review – BT, AB.

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