Research Article / Araştırma Makalesi

Relationship Between Core and Respiratory Muscle Endurance in Elite Handball Players

Elit Hentbol Oyuncularında Kor ve Solunum Kas Enduransı Arasındaki İlişki

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Abstract

Background: Postural and respiratory control cooperation is crucial in handball, which requires high levels of postural control, strength, aerobic and respiratory endurance. In the literature, no study has been found that examines the relationship between respiratory and core endurance in handball players. This study aims to investigate the correlation between core muscle endurance and respiratory muscle function in elite handball players.
Materials and Methods: Twenty-four female handball players were (22.17±3.42 years) included in the study. Core endurance, pulmonary functions including Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV_1), FEV_1/FVC, Peak Expiratory Flow (PEF), respiratory muscle endurance and strength (Maximal Inspiratory Pressure; MIP, Maximal Expiratory Pressure; MEP) were evaluated in players.
Results: There were positive significant correlations between dominant wall sit hold test duration (s) and respiratory muscle performance, including respiratory muscle endurance (cmH_2Oxs) (r=0.536) and duration (T_{max}) (r=0.441), MIP (r=0.446; r=0.439), MEP (r=0.482;r=0.546) (cmH_2O/%). The positive significant correlations were observed between non-dominant wall sit hold duration and MIP (r=0.534; r=0.548) (cmH_2O/%), MEP (r=0.442) (%) ($p \leq 0.05$). The respiratory muscle endurance and expiratory muscle strength values (53.4%, p=0.001; r=0.764) have a significant influence on core muscle endurance.
Conclusions: Trainings that include core-respiratory muscle cooperation should be developed for better postural control, strength and endurance in handball players. The contribution of a comprehensive training program to improve postural stability and respiratory function on athletic performance should be investigated.

Keywords: Endurance, Maximal Inspiratory Pressure, Maximal Expiratory Pressure, Handball, Diaphragm

Öz

Amaç: Yüksek düzeyde postüral kontrol, kuvvet, aerobik ve solunum kas enduransı gerektiren hentbolda postüral kontrol ve solunum iş birliği çok önemlidir. Literatürde hentbol oyuncularında solunum-kor endurans ilişkisini inceleyen çalışmaya rastlanmamıştır. Bu çalışma elit hentbol oyuncularında gövde kas dayanıklılığı ile solunum kas fonksiyonu arasındaki ilişkiyi incelemeyi amaçlamaktadır.
Materyal ve Metod: Çalışmaya 24 (22.17±3.42 yıl) kadın hentbol oyuncusu dahil edildi. Sporcularda kor endurans, Zorlu Vital Kapasite (FVC), 1. saniyedeki Zorlu Ekspirasyon Hacmi (FEV_1), FEV_1/FVC, Zirve Ekspiratuar Akım Hızı (PEF)'nı içeren pulmoner fonksiyonlar, solunum kas kuvveti (Maksimal İnspirasyon Basıncı; MIP, Maksimal Ekspirasyon Basıncı; MEP) ve enduransı değerlendirildi.
Bulgular: Baskın ekstremite duvar destekli oturma tutma testi süresi (s) ile solunum kas performansını içeren solunum kası enduransı (cmH_2Oxs) (r=0,536) ve süresi (Tmax) (r=0,441), MIP (r=0,446; r=0,439), MEP (r=0,482; r=0,546) (cmH_2O/%) arasında pozitif yönde anlamlı ilişki vardı. Baskın olmayan ekstremite duvar destekli oturma süresi ile MIP (r=0,534; r=0,548) (cmH2O/%), MEP (r=0,442) (%) arasında pozitif yönde anlamlı ilişki gözlemlendi ($p \leq 0,05$). Solunum kas enduransı ve ekspiratuar kas kuvveti değerleri (%53,4, p=0,001; r=0,764) kor kas enduransı üzerinde önemli bir etkiye sahiptir.
Sonuç: Hentbol oyuncularında daha iyi postüral kontrol, kuvvet ve dayanıklılık için kor-solunum kası iş birliği içeren antrenmanlar geliştirilmelidir. Postüral stabiliteyi ve solunum fonksiyonunu iyileştirmeye yönelik kapsamlı bir eğitim programının atletik performansa katkısı araştırılmalıdır.

Anahtar Kelimeler: Endurans, Maksimal İnspirasyon Basıncı, Maksimal Ekspirasyon Basıncı, Hentbol, Diyafram

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Introduction

Respiratory muscle performance is important in ensuring adequate gas exchange and pulmonary ventilation during activities that require endurance (1). Reduced respiratory muscle function related to respiratory muscle fatigue activates the metaboreflex mechanism, increasing blood flow to respiratory muscles and decreasing blood flow to locomotor muscles. Respiratory muscle fatigue results in a decline in sports performance (2). Respiratory muscle strength and endurance are components of respiratory muscle function (3). The diaphragm plays a key role in maintaining respiratory muscle function. In addition, the diaphragm is a respiratory muscle and a postural stability muscle. The diaphragm mechanically supports the trunk by maintaining intra-abdominal pressure at a high level (4). Breathing and postural control are inevitably related and have a mechanism that supports each other (5). No studies have been found to evaluate the connection between core and respiratory muscle endurance in athletes so far.

Handball is a sport including multi-functional components that requires a high level of strength, power, and endurance (6). A study emphasized that better core endurance is connected with improved extremity stability, performance, and throwing ball velocity in handball players (7). A significant relationship has been found between core muscle endurance, to which the diaphragm also contributes, and extremity injury risk in athletes. Athletes with poor lumbopelvic-hip core muscle endurance are especially vulnerable to injury. Therefore, it is essential to evaluate core muscle endurance, which significantly impacts individuals' participation in sports and maintenance of their performance (8, 9). In the literature, unilateral wall sit hold, trunk flexion hold, and horizontal trunk hold tests were performed to assess lumbopelvic-hip endurance screening in athletes (8). However, the literature lacks information on the association between core muscle endurance and respiratory muscle function in athletes. The study focused on the correlation between core muscle endurance, respiratory muscle endurance, and strength by performing unilateral wall sit hold, trunk flexion hold, and horizontal trunk hold tests in elite handball players. We tested the hypothesis that elite female handball players who have better lumbopelvic-hip endurance have better respiratory strength and endurance.

Materials and Methods

In total, 25 elite female handball players came to the clinic for routine control. Because one player was unable to complete the tests due to dental braces, 24 players (22.17 ± 3.42 years) were included in this prospective, correlational study. The inclusion criteria were individuals who were playing handball and who had the same training program. Exclusion criteria were athletes with a history of any chronic lung disease, who could not comply with the test, who had an active infection that could affect the evaluation, and who were unwilling to participate in the study. Gazi University Ethics Committee approved (No: 2023-1199) this study. All players signed an informed consent form. The assessments were applied following the Declaration of Helsinki. Core and respiratory muscle endurance, respiratory muscle strength, pulmonary functions, and body compositions were evaluated in elite female handball players. Respiratory performance and core endurance tests were performed one hour apart. The demographic characteristics, including age, weight, height, sports age, and smoking exposure were noted.

Core muscle endurance was assessed with unilateral wall sit hold, trunk flexion hold, and horizontal trunk hold tests. The unilateral wall sit hold test was conducted on both dominant and non-dominant extremity. The players were asked to stand leaning against the wall and cross their arms across their chests. The players were instructed to squat in a 90-degree position with their hips and knees while maintaining this position and lift (3-5°) their dominant feet. The players were expected to maintain this position for as long as possible. The test was repeated for non-dominant extremities following rest. The rest period between tests was 5 minutes. The maximum time the players could endure was recorded. To perform the trunk flexion hold test, the players sat on the floor. The players were asked to lift their feet off the ground while the angle of the trunk with the ground was 60 degrees, the angle of the knees was 90 degrees, and the shoulder was in a horizontal abduction position of 90 degrees. The maximum reached time without changing position was recorded. The players were instructed to perform shoulder horizontal abduction with the thumbs pointed up while the hip and knee were in the 90-degree position in the crawling position to conduct the horizontal trunk hold test. The longest time in this position was recorded (10).

The respiratory muscle endurance was evaluated with a constant load inspiratory muscle endurance test using Powerbreathe® (POWERbreathe International Ltd., England). The players sat in an upright position and took the device into their mouths, keeping the device parallel to the ground. The test was applied at a load equivalent to 70% of MIP for 10 minutes. The metronome was adjusted to allow players to take 20 breaths per minute. It was stated that the test would be finished if the athletes could not take two correct breaths in a row or felt breathlessness that could not continue. The maximum time (Tmax) and percentage of maximal load (%) were recorded. Standard respiratory muscle endurance values were calculated by multiplying the 70% of maximum peak pressure and T_{max} for each player (11).

The respiratory muscle strength (maximal inspiratory/expiratory pressure) and pulmonary functions (Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV_1), Forced Expiratory Volume in First Second/Forced Vital Capacity (FEV_1/FVC), Peak Expiratory Flow (PEF)) of players were assessed using spirometer (Pony FX, COSMED Inc., Italy). To measure MIP and MEP values, at least five repetitions were performed, and the highest value was recorded for analysis. The reference values were used for calculating the percentage of expected MIP and MEP values (12). The dynamic lung volumes, including FVC, FEV_1, FEV_1/FVC, and PEF were evaluated at least three repetitions and expressed as percentages of the predicted values. The pressure-time curve was interpreted to determine the best measurement (13).

To evaluate the body composition, including weight, fat mass, fat mass percent, fat-free mass, and body mass index, TANITA bioelectrical impedance analysis (BC418-MA, TANITA Corporation, Tokyo, Japan) was used (14).

The statistical analyses were applied with the Windows-based Statistical Package for Social Sciences version 20 (SPSS-20) statistical analysis program. The suitability of the data for normal distribution was evaluated with the Shapiro-Wilk test. Percentage, mean, and standard deviation were used in the interpretation of descriptive data. Two-tailed Pearson's correlation analysis was used to evaluate the association between core endurance tests and respiratory performance variables. The correlation between core muscle endurance tests and respiratory muscle performance tests is expressed with Pearson correlation coefficient (strong relationship; $0.5 \leq r \leq 1.0$, moderate relationship; $0.3 \leq r < 0.5$, weak relationship; $r < 0.3$). The level of significance was determined as $p<0.05$ (15). After residual and goodness of fit statistics, the multiple linear regression forward model was performed for significant values to show how the MIP, MEP, and respiratory endurance influenced core endurance (wall sit hold-D test).

Model selection was performed by checking whether the variables known to be effective on the dependent variable meet the necessary assumptions for multiple regression analysis. The post-hoc power ($1-\beta=0.80$) analysis was performed according to the correlation between core and respiratory muscle endurance outcomes using the G-Power program 3.0.10 system (Franz Faul, Universität Kiel, Germany) (16).

Results

The twenty-four elite female handball players were included in this study. The demographic characteristics of handball players are given in Table 1. The results of respiratory muscle performance and core endurance tests in handball players are given in Table 2.

There were positive moderate-strong correlations between wall sit hold-D endurance test duration (s) and respiratory muscle performance, including respiratory muscle endurance ($r=0.536$) (cmH_2Oxs) and endurance test duration ($r=0.441$) (s), MIP ($r=0.446$; $r=0.439$), and MEP ($r=0.482$; $r=0.546$) (cmH_2O, %).

Table 1. Demographic Characteristics of Handball Players

Characteristics	M (SD)/n/% (n=24)
Age, y	22.17 (3.42)
Weight, kg	66.22 (10.57)
Height, cm	172.29 (6.34)
BMI, kg/m²	22.26 (3.11)
Fat mass, kg	13.92 (5.99)
Fat mass percent, %	20.29 (5.34)
Fat-free mass, kg	52.30 (5.15)
Smoking (current; non-smoker, n/%)	6/25%; 18/75%
Smoking exposure	2.70 (1.44)
Sports age, y	9.82 (3.40)

kg, kilogram; cm, centimeter; m, meter; y, year; M, mean, SD, standard deviation

Table 2. The Results of Respiratory Performance and Core Endurance Tests in Handball Players

Variables	M (SD)
Core endurance	
Wall sit hold-dominant, s	39.56 (24.74)
Wall sit hold-nondominant, s	45.21 (30.68)
Trunk flexion, s	101.24 (44.07)
Horizontal trunk hold, s	85.23 (58.88)
Respiratory muscle endurance	
T_{max}, s	236.84 (217.18)
Endurance, cmH_2Oxs	17791.30 (16623.81)
Respiratory muscle strength	
MIP, cmH_2O	114.74 (24.77)
MEP, cmH_2O	96.21 (18.45)
MIP, %	109.25 (21.89)
MEP, %	68.47 (12.65)
Pulmonary functions, %	
FVC	107.83 (11.90)
FEV_1	102.58 (12.79)
FEV_1/FVC	98.79 (9.16)
PEF	92.04 (17.46)

s, second; FEV_1, Forced expiratory volume in the first second; FVC, Forced vital capacity; FEV_1/FVC, Forced expiratory volume in the first second/forced vital capacity; PEF, Peak expiratory flow; FEF_{25-75}%, Forced expiratory flow from 25% to 75%; cmH2O, centimeter water

In addition, positive moderate-strong correlations were observed between wall sit hold-ND endurance test duration and MIP (r=0.534; r=0.548) (cmH_2O, %) and MEP (r=0.442) (%) ($p \leq 0.05$; Table 3). No significant correlations were revealed between other core endurance tests and respiratory muscle performance. There were no significant correlations between core endurance tests, dynamic lung volumes, and body composition values (p>0.05; Table 3). The Model 1, including MEP value, explained 31.4% of the variance test (p=0.006; r=0.592; Table 4). and the Model 2, including respiratory muscle endurance and MEP values, explained 53.4% of the variance in core endurance (wall sit hold-D) test (p=0.001; r=0.764; Table 4).

Table 3. The Correlation Between Core Endurance Tests, Respiratory Functions and Anthropometric Features

Variables	Wall sit hold-D r	Wall sit hold-ND r	Trunk flexion r	Horizontal trunk hold r
Respiratory muscle endurance				
Endurance, cmH_2Oxs	**0.536****	0.254	0.035	0.187
T_{max}, s	**0.441***	0.155	0.039	0.202
Respiratory muscle strength				
MIP, cmH_2O	**0.446***	**0.534****	0.367	0.010
MEP, cmH_2O	**0.482***	0.387	0.317	0.307
MIP, %	**0.439***	**0.548****	0.339	0.030
MEP, %	**0.546****	**0.442***	0.349	0.369
BMI, kg/m^2	-0.024	-0.100	-0.062	-0.133
Fat mass, kg	-0.049	-0.206	-0.175	-0.209
Fat mass percent, %	-0.170	0.016	-0.108	-0.222
Fat free mass, kg	-0.272	-0.145	-0.147	-0.199
Pulmonary functions, %				
FVC	0.140	0.127	0.086	-0.043
FEV_1	0.165	0.335	0.032	-0.091
PEF	0.037	0.060	0.069	-0.211

MIP, Maximal inspiratory pressure; MEP, Maximal expiratory pressure; FEV_1, Forced expiratory volume in the first second; FVC, Forced vital capacity; FEV_1/FVC, Forced expiratory volume in the first second/forced vital capacity; PEF, Peak expiratory flow; FEF_{25-75}%, Forced expiratory flow from 25% to 75%; cmH_2O, centimeter water; D, Dominant; ND, Non-Dominant; s, sec
**p≤0.05,*
***p≤0.01*

Table 4. The Results Of Linear Regression Analysis

Model	Model		B	β	P
	R(Adjusted R^2)	R^2 significance (p)			
Model 1	0.592 (0.314)	0.006*			
MEP			0.720	0.592	0.006*
Model 2	0.764 (0.534)	0.001*			
MEP			0.619	0.509	0.005*
Endurance, cmH_2Oxs			0.001	0.490	0.007*

MIP, Maximal inspiratory pressure; MEP, Maximal expiratory pressure; cmH_2O, centimeter water; s, sec

Discussion

This study first revealed the association between core muscle endurance and respiratory muscle function in handball players. Consistent with our hypothesis, our results showed that the wall sit hold core endurance test (D), which is an effective test to especially demonstrate fatigue of lumbopelvic, hip, and lower extremities significantly related to inspiratory and expiratory muscle strength and respiratory muscle endurance. In addition, the respiratory muscle endurance and expiratory muscle strength values (53.4%, p=0.001) have a significant influence on core muscle endurance.

Handball is a known sport containing high-level aerobic and anaerobic components and requiring various motor abilities such as endurance, strength, substantial throwing velocity and power, and speed (6). It is critical for handball players to have an elevated level of endurance capacity during prolonged training and competitions (17). In addition, better aerobic endurance and athletic performance are related to improved core muscle endurance (7). On the other hand, respiratory muscle fatigue also mutually affects performance in athletes (1). Diaphragm, one of the core stability muscles, provides postural stability by modulating intra-abdominal pressure and is also a respiratory muscle that has a pivotal role in maintaining respiratory function (18). The intra-abdominal pressure modulation supports the connection of breathing-postural control and maintaining extremity movement in a controlled manner (5). The respiratory function and core muscle endurance have important effects in enhancing performance in athletes; therefore, there is a need to better explain the cooperation of core-respiratory muscle endurance due to insufficient data. In our study, core endurance tests, including unilateral wall sit hold, trunk flexion, and horizontal trunk hold tests, which are frequently used in athletes for injury risk monitoring, were performed (10, 19). According to the results of the wall sit hold test (D), there was positive moderate-strong relationship between core muscle endurance and respiratory muscle endurance and strength in the current study. It was also observed that respiratory performance including respiratory muscle endurance and expiratory muscle endurance had a high impact on core muscle endurance (53.4%). However, core endurance test results for non-dominant extremity were related only to respiratory muscle strength. Considering other core endurance test results, there was no relationship between core endurance and respiratory performance in this study.

The wall sit test was commonly used to evaluate the lumbopelvic-hip and lower extremity stability in previous studies (10, 19). In addition, Chimera et al. (19) found that decreased wall sit hold test duration is related to reduced trunk stability, core endurance, and performance. Given that our respiratory performance test results are related to the results of the wall sit test, it was thought that the possibility of more functional effort of the diaphragm may be required to provide better lower pelvic and limb stabilization. Beales et al. (20) emphasized that functional load transfer is achieved between the trunk and pelvis in the “Active Straight Leg Raise” test, thanks to the internal stability provided by intra-abdominal pressure. Based on this study, a possible explanation for the relationship between core and respiratory endurance in our study, the role of the diaphragm in maintaining the balance between intra-abdominal and thoracic pressure may be increasing to provide better lower extremity stabilization. However, large-scale studies are needed to reach more definitive inferences.

Yuksel et al. (21) found a relationship between trunk muscle endurance, dynamic lung volumes, and respiratory muscle strength in healthy individuals. Our study has similar and different aspects to this study. Unlike this study, no significant relationship between dynamic lung volumes, body compositions, and core muscle endurance in our research. A possible explanation for the difference could be that the included sample and the methods, especially core endurance tests applied in the mentioned study, are different from our study. In addition, pulmonary functions may be affected by individual differences such as age and gender. On the other hand, both studies emphasize the association between respiratory muscle strength and core muscle endurance.

Our study additionally reveals the positive relationship between respiratory and core muscle endurance with effective results in players. Respiratory-core endurance cooperation was also emphasized in a recent study (22) that evaluated the relationship between respiratory and trunk muscle endurance in healthy individuals with different assessment tools and methods than our study. Although there are not enough studies examining the respiratory-core connection in athletes, intervention studies are proving that inspiratory and core muscle training improves athletic performance. Tong et al. (23) focused on the effects of functional inspiratory and core muscle training to enhance running performance. Mackala et al. (24) found the positive effect of inspiratory muscle training using inspiratory muscle trainers on aerobic endurance in young soccer players. Saeterbakken et al. (25) emphasized that core stability training improves throwing velocity in handball players. Furthermore, some previous studies found that decreased diaphragm function causes deteriorated movement control and ability, postural control, and balance (26-28). Given the clear contribution of respiratory and core muscle training on athletic performance, increasing interventions to improve diaphragm function in athletes' training programs is vital. On the other hand, Hubscher et al. (29) emphasized that core and lower extremity neuromuscular control which enhances balance, strength, and endurance, contributes to reducing injury rates. Future studies should focus on the effect of better respiratory-core cooperation on injury rates.

The limitation of this study is that more athletes could not be included to reach over 80 percent power because only one elite female handball team with the same training level and program could be reached.

Conclusion

This study reveals the relationship between core endurance and respiratory performance in elite female handball players. Because of the interrelation between respiratory-core muscle endurance and both contributions to athletic performance, we think that the evaluation of respiratory muscle functions and inclusion of respiratory and core muscle training will enrich the athlete training program.

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