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ORIGINAL SCIENTIFIC PAPER

The Relationship between Respiratory Muscle Strength and Physical Performance in College Volleyball Players

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Abstract

Physical performance and respiratory muscle strength are the effective factors that influence sport competence. This study aimed to determine the relationship between respiratory muscle strength and leg strength, power, speed, and agility in college volleyball players. Twenty-eight college volleyball players (age: 20.79±1.71 years; body mass index: 23.22±3.48 kg/m2; sport experience: 4.68±2.21 years; training frequency: 4.43±1.26 days/week) were included into the study. Maximal inspiratory and expiratory pressure (MIP and MEP) tests were performed using a mouth pressure meter for respiratory muscle strength assessment. Leg muscle strength and power were measured using a back and leg dynamometer and a Yardstick device, respectively. The 10-meter sprint test was performed to assess speed performance. Agility was measured by the agility T-test. MIP was positively correlated with leg strength (r=0.406; p=0.032), while it was negatively correlated with speed, and agility (r=-0.416; p=0.028, r=-0.469; p=0.012, respectively). There was no relationship between MIP and power (p=0.197). For MEP, it was negatively correlated with speed (r=-0.392; p=0.039). Other parameters of physical performance were not significantly correlated with MEP (p>0.05). In the light of the results, muscle strength, speed, and agility of college volleyball players develop parallel to respiratory muscle strength, particularly inspiratory muscle. Thus, it is believed that inspiratory muscle training should be added to exercise training programs for enhancing players' physical performance.

Keywords: *MIP, MEP, strength, speed, agility, volleyball*

Introduction

Volleyball is an intermittent sport in which players engage in short bouts of high-intensity action, followed by periods of low-intensity activity (Künstlinger, Ludwig, & Stegemann, 1987). During the competition, change of direction and jumping activities such as spike, block, topspin, and floating serves are required players' strength, power, speed, and agility, which are essential components of sports performance (Häkkinen, 1993).

Besides the considerable role of the neuromuscular system, respiratory function is also a crucial factor that affects the players' ability. Due to high-intensity activities with long duration of the volleyball match (around 90 minutes), work of respiratory system is increased to provide sufficient oxygen for energy reproduction (Baker, McCormick, & Robergs, 2010). Furthermore, it works to drive alveolar ventilation in proportion to metabolic requirements for maintaining acid-base homeostasis and preventing arterial hypoxemia (Romer & Polkey, 2008). The upper extremity (UE) movement also increases the respiratory work that can be explained by the connection between muscles of UE and core (Han & Kim, 2018). During arm movement, the upper limb muscles contract and pull on the origin of the diaphragm, which acts as a roof over the core. As a result, respiratory muscle works increasingly for controlling postural stability during movement (Hodges & Richardson, 1999).

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In some cases, the increased effort of breathing during sustained exercise causes respiratory muscle fatigue (Johnson, Babcock, Suman, & Dempsey, 1993) and could limit exercise performance (Aaron, Seow, Johnson, & Dempsey, 1992; Dempsey, Mckenzie, Haverkamp, & Eldridge, 2008). Because of higher metabolic demand on the inspiratory muscles, the activation of the respiratory metaboreflex is stimulated to contribute to the redirection of blood flow circulation from peripheral muscles to respiratory muscles (St Croix, Morgan, Wetter, & Dempsey, 2000). Previous studies demonstrated the relationship between respiratory muscle strength and strength of upper and lower extremities among athletes (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). However, there is a lack of studies that determine the relationship of respiratory muscle strength with other physical skills such as muscle power, speed, and agility which are important factors for sport performance among volleyball players. Thus, this study aimed to correlate respiratory muscle strength with leg muscle strength, power, speed, and agility in college volleyball players.

Methods

Participants

This cross-sectional study was approved in advance by the ethical committee of Walailak University (WUEC-20-038-01). All participants signed informed consent before enrollment for the study. The sample size was calculated by the G*Power (version 3.1.9.4) from the relevant study (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017), the correlation was equal to 0.475, $Z\propto$ was set to 0.05, and $Z\beta$ was set to 0.8. Twenty-eight collegiate volleyball players who had volleyball practice at least three days a week, and had volleyball competition experience for at least two consecutive years were enrolled in this study: 19 males (67.86%) and 9 females (32.14%), with a mean age of 20.79±1.71 years. The average body mass index (BMI) of the participants was 23.22±3.48 kg/m2. The average volleyball competition experience and frequency of practice were 4.68±2.21 years and 4.43±1.26 days/week, respectively. All participants did not have a history of smoking and a chronic respiratory disease such as asthma. Moreover, they were free from moderate pain (pain scale ≥4/10) from upper limbs, lower limbs, or back injury during three months before participating in the study.

Procedures

Before testing, participants were asked to sleep at least 7 hours during the night; refrain from eating for at least 2 hours; avoid alcohol or caffeine consumption, and engaging in strenuous activity for at least 24 hours. Assessment of respiratory muscle strength was performed firstly. The participants were then instructed to warm up by jogging and dynamic stretching for 10 minutes. After that, leg muscle strength, power, speed, and agility of all participants were measured.

Measurement

Respiratory Muscle Strength

The respiratory muscle strength values were obtained from maximal inspiratory and expiratory pressure (MIP and MEP) tests using a mouth pressure meter (MicroRPM®, England). The protocol was performed in a sitting position. For the MIP test, each participant was asked to exhale entirely at the residual volume (RV) and then take a quick and deep breath. For the MEP test, participants were asked to inhale the air fully at the total lung capacity (TLC) and then exhale fast and strongly. The inspiratory and expiratory efforts had to be maintained for at least 1 second. Three maximum maneuvers, which difference of less than 20%, were recorded. The highest values of MIP and MEP were used for analysis (Laveneziana et al., 2019).

Physical Performance

Leg strength

The leg muscle strength was measured by the back and leg dynamometer (T.K.K.5402, Japan). Participants were instructed to stand on the platform of the equipment. They then flexed their knees to about 110 degrees and held the center of the bar with both hands. The chain length was adjusted appropriately. Then, participants extended the legs with maximal effort and pulled the hand bar simultaneously. This test was performed three times with 1 minute of rest between trials, and the best value was used for analysis (Sonchan, Moungmee, & Sootmongkol, 2017).

Leg power

The leg power was measured by the Swift Yardstick vertical jump device. Participants were instructed to reach their dominant hand to the Yardstick for assessing baseline value, while the non-dominant hand was placed on the waist. They then flexed their knees to about 90 degrees and jumped to reach their hand as far as they can to the Yardstick for maximum jump height. Participants were not allowed to swing their arms or take any preparatory step before jumping. This test was measured three times with 1 minute of rest between trials. Leg muscle power was calculated from the difference between baseline value and maximum jump height. The best value was used for statistical analysis (Young, MacDonald, Heggen, & Fitzpatrick, 1997).

Speed performance

Speed performance was measured by a 10-meter sprint test. The length of the trial was 10 meters in a straight line. Participants were instructed to run as fast as possible from the starting to the finishing point. The time was started when participants passed the starting point, and the time was stopped when they passed the finishing point. Each participant completed the test three times with two minutes rest between trials. The fastest value was used for analysis (Duthie, Pyne, Ross, Livingstone, & Hooper, 2006).

Agility

The agility of participants was assessed by the agility T-test which includes forward, lateral, and backwards running. Four cones were placed at the starting/finishing and three turning points. Participants were instructed to run as fast as possible from the starting to the finishing point. Firstly, they sprinted forward 10 meters and touched the cone with their right hand. They then shuffled to the left 5 meters and touched the cone with their left hand. After that, they shuffled to the right 10 meters and touched the cone with their right hand. They then shuffled to the left 5 meters and touched the cone with their left hand again. Lastly, participants sprinted backward to pass through the finishing point, which was the same point as starting. The time was started when participants passed the starting point, and the time was stopped when they passed the finishing point. This test was measured three times with 3 minutes of rest between trials, and the fastest value was used for statistical analysis (Sonchan, Moungmee, & Sootmongkol, 2017).

Statistical analysis

Baseline characteristics were summarized as mean and standard deviation (SD). The Shapiro-Wilk test was used to verify the normality of the data. All of the data used to evaluate MIP, MEP, leg strength, power, speed, and agility had a normal distribution. As a result, the Pearson correlation coefficient was used to examine the relationship between these parameters. All data were analyzed using the SPSS (version 24). The statistical level was set as $p<0.05$.

Results

Table 1 showed baseline characteristics data of all participants. The average maximal inspiratory and expiratory pressure were 106.96±26.76 and 91.00±20.46 cmH2O, respectively. The average leg strength and power were 126.30±27.36 kilogram and 47.54±10.22 centimeter. The mean speed of the participants was 2.41±0.27 seconds and the mean agility was 12.52±1.17 seconds.

Table 1. Baseline characteristics data of participants (n = 28)

Variable	Mean ± standard deviation
Maximal inspiratory pressure (cmH_2O)	106.96 ± 26.76
Maximal expiratory pressure (cmH_2O)	91.00 ± 20.46
Leg strength (kg)	126.30 ± 27.36
Leg power (cm)	47.54 ± 10.22
Speed (s)	2.41 ± 0.27
Agility (s)	12.52 ± 1.17

There were the moderate relationships between MIP and several physical performance parameters ($p<0.05$). MIP was positively correlated with leg muscle strength ($r=0.406$; $p=0.032$) (Figure 1a), whereas it was negatively correlated with speed, and agility ($r=-0.416$; $p=0.028$, $r=-0.469$; $p=0.012$, respectively) (Figure 1b and c). In the other hand, there was no significant correlation between MIP and leg power ($p=0.197$). For MEP, it was negatively correlated with speed in moderate level ($r=-0.392$; $p=0.039$) (Figure 2). The relationship between this parameter with leg muscle strength and power, and agility were not found ($p>0.05$).

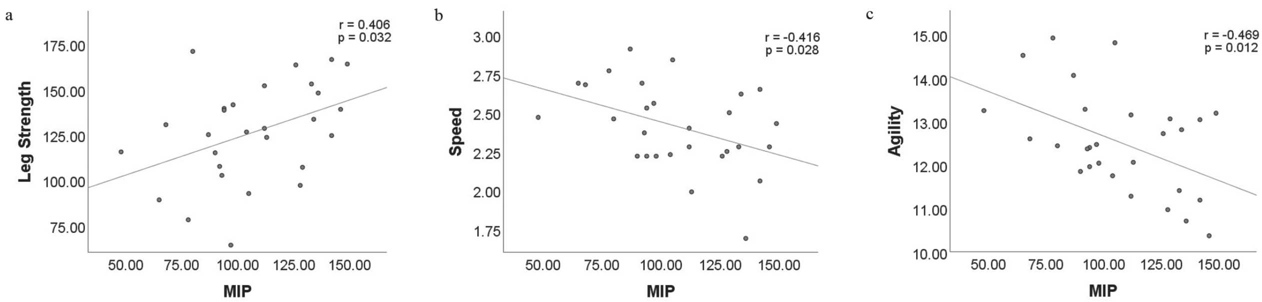

FIGURE 1. Correlation between MIP and a: Leg strength; b: Speed; c: Agility

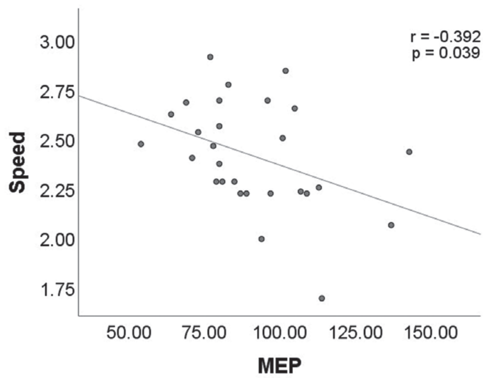

FIGURE 2. Correlation between MEP and Speed

Discussion

This is the first study to provide data regarding the relationship between respiratory muscle strength and leg muscle strength, power, speed, and agility in college volleyball players. The results of the present study demonstrated the significant moderate relationship between MIP and leg muscle strength, speed, and agility, while MEP has a significant moderate relationship with speed.

Muscle contraction requires energy from the breakdown of adenosine triphosphate (ATP). The efficiency of musculature performance for prolonged periods depended on the ability to constantly reproduce ATP (Baker, McCormick, & Robergs, 2010). During continuous activity, the skeletal muscle needs a great deal of oxygen to replenish the hydrolyzed ATP. Consequently, the respiratory system works increasingly to provide sufficient oxygen to contracted muscles. Furthermore, UE movement during playing volleyball is closely related to inspiratory muscle due to the connection between upper limb muscles and diaphragm. For this reason, it can be explained a significant positive relationship between MIP and leg muscle strength in our result, which is consistent with previous studies (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). However, there was no significant correlation between MEP and leg muscle strength. This result was not consistent with previous studies (Kocahan, Akınoğlu, Mete, & Hasanoğlu, 2017; Akınoğlu, Kocahan, & Özkan, 2019). It was possible that the work of expiratory muscles occurred during forced exhalation. Thus, these muscles were involved indirectly to produce energy for muscle contraction. Agility has been defined as the ability of the body to change direction quickly (Šimonek, Horička, & Hianik, 2017). We found a negative correlation between MIP and agility. Although there is a lack of data to discuss the correlation between this performance and respiratory muscle strength, the probable explanation for this relationship might be described by the relation of agility to muscular strength (Paul, Gabbett, & Nassis, 2016). During the change of direction movements, muscle strength, especially eccentric contraction, is required to decelerate the player's velocity and prepare for acceleration of new directional changes (Spiteri, Wilkie, Hart, Haff, & Nimphius, 2013).

In our result, the leg muscle power measured by the vertical jump height was not significantly correlated with respiratory muscle strength. The possible reason might be that because the vertical jump is an essential part of the spike, block, topspin, set, and floating serves in volleyball, all positions of volleyball players had to mainly practice this skill (Borràs, Balius, Drobnic, & Galilea, 2011). Thus, similar training programs may lead to analogous vertical jump performance among volleyball players. The result of a previous study seems to support this explanation that there was no significant difference in vertical jump performance between Thai national and Youth national volleyball players (Limroongreungrat & Kamutsri, 2014).

Regarding speed, the result of the present study showed a significant negative correlation between respiratory muscle strength and this performance. Previous studies that demonstrated the effect of inspiratory muscle training (IMT) on speed in athletes were used for discussing this relationship (Archiza et al., 2018; Sunthonghao & Tongtako, 2019). After 6-week of IMT, the lactic acid removal and sprint performance in Futsal players were improved (Sunthonghao & Tongtako, 2019). Lactic acid is a chemical response from anaerobic glycolysis. When the body has insufficient oxygen during intense activity, anaerobic glycolysis transformed glucose into lactic acid, resulting in muscle fatigue and limiting physical performance (Sahlin, 1986). Thus, the increased lactic acid removal may improve the ability to sprint. In addition, Archiza et al. (2018) reported that IMT reduced deoxyhemoglobin and total hemoglobin blood concentration in the respiratory muscle, while oxyhemoglobin and total hemoglobin blood concentration in the peripheral muscle were increased. This finding suggested that IMT may attenuate the inspiratory muscles metaboreflex and improve oxygen and blood supply to limb muscles during high-intensity exercise (Callegaro, Ribeiro, Tan, & Taylor, 2011). Moreover, the chest and ribcage expanded as a result of deep inspiration. This positioned the thoracic spine to be able to rotate freely from side to side during sprint, and allowed the runner to efficiently transfer energy from the arm strides, through the chest, and into the legs, resulting in increased power output.

One limitation in this study should be acknowledged. We enrolled the participants unequally between male and female. Thus, it may affect the physical performance parameter, and might impact the relationship between respiratory muscle strength and physical performance. We suggested controlling the gender of participants equally or choose only male or female. Additionally, these correlations are needed to be considered among the athletes who have higher performance in further study.

In conclusion, physical performance such as muscle strength, speed, and agility were moderately correlated with inspiratory muscle strength, while expiratory muscle strength was moderately correlated with speed among college volleyball players. These findings suggested respiratory muscle strength and physical performance should be developed parallelly.

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Conflict of interest
The authors declare that there are no conflicts of interest

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