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How Far Does Physical Training Modulate the Motor Unit Activities of Respiratory Muscles in Female Athletes: An Electromyographic Study

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Abstract: The pulmonary capacities of a person depend on the activities of the respiratory muscles. The Motor neurons and its units of the respiratory muscles regulate breathing and can be studied by using surface electromyography. The effect of physical training on motor unit involvement was the main concern of this study and the other is to understand the influence of physical exercise on respiratory muscles. It has focused on the associative strength in motor units during forceful and normal respiration of 15-20 years young female and nonathletes. The sEMG has the delicate and respiratory interplay or coordination of muscles recorded by placing the electrodes on the preferred anatomical places of three selected muscles in standing postures of thirty-eight trained female athletes and thirty-three nonathletes. Spirometric studies were performed simultaneously during normal and forceful respiration in each subject. One way ANOVA, Scheffe's multiple comparison tests, and Strength of association during different types of respiration were calculated. A significant difference has been observed in motor unit activity among the three muscles during maximum and normal respiration. Scheffe's multiple comparison tests showed the difference between Intercostal and Latissimus dorsi, Diaphragm, and Latissimus dorsi muscles in athletes during normal and forceful respiration. In nonathletes, significant differences were observed between Intercostal and diaphragm, Diaphragm, and Latissimus dorsi muscles only during normal respiration. But during forceful respiration, insignificant differences among the three muscles in females were observed in nonathletes. The strength of association of motor units for respiratory muscles and the duration of muscle responses are lower in athletes during normal and forceful respiration. But, motor unit activity is higher in athletes in all conditions. It means athletes produce better responses though there is a little motor unit involved. It has also been seen that the duration of EMG bursts, i.e. muscle response time is lower in athletes than nonathletes. So, this study concluded that with fewer motor units, athletes could produce more significant respiratory, muscular activity in less time and less associative strength than the non-athletes. It assumed that due to physical training, muscles improved pulmonary capacities by increasing the flexibility of respiratory muscles.

Keywords: Motor Units, Respiratory Muscles, Surface EMG, Spirometry

1. Introduction

Respiratory muscles perform a crucial role in normal and forceful respiration. Spirometric measurement could help to detect lung functions during healthy and unhealthy conditions. The sizes of different lung variables reflect the overall functional aspects of respiration. Still, they cannot determine the appropriate involvement and activities of respiratory muscles during normal and forceful respiration. Differences in various pulmonary variables reflect a relationship with lifestyle, and it has distinctly reflected in regularly exercised persons and non-exercised or sedentary persons [1]. Regular exercise enhances different pulmonary capacities when compared to non-exercising individuals. Some researchers have reported that an improved respiratory system after physical training causes an incremental increase in strength and exercise performance in trained athletes [2]. But, no studies have so far critically stated the basis of this improvement occurring in athletes.

The entire respiratory system involves the chest, chest cavity, and lungs perform essential roles. Without increasing or decreasing the chest cavity, inspiration and expiration couldn't happen, respectively. Because of expanding the chest cavity, the lung inflated, and thus air pressure falls inside the lung, so inspiration occurs. Similarly, during expiration, the opposite mechanism happens. The respiratory muscles initiate the inflation and standard conditions. Hence the pulmonary function tests are generally determined by the strength of respiratory muscles [3]. These variables used to describe pulmonary function are the lung volumes and capacities [4]. The pulmonary function may vary according to physical characteristics which include age, height, body weight, and altitude. Regular exercise in athletes produces a positive effect on the lung by increasing pulmonary capacity and by improving lung functioning [5]. This study is hypothesized based on this positive effect. What is the positive impact that leads to an increase in the chest cavity in trained people than the untrained person, and thus the lung variables are found higher in trained active people? This cross-sectional study tried to find out the possible reasons for that improvement in trained people.

The breathing process involves neural, chemical, and muscular components. Muscular components are the diaphragm, intercostal, latissimus dorsi muscles [6]. The breathing process occurs due to movements that increase and decrease the chest size causing air to move into the lungs and subsequently expire. The chest movement only becomes possible when there is sufficient effort to overcome the elastic retraction and airflow resistance [7]. The mechanical action of the respiratory muscles is determined by the bony structure(s) to which they attach and the displacement of these structures when the muscles contract. Breathing occurs consciously or unconsciously and both are controlled by a complex neural network [3]. The final output of phrenic motor nerves and intercostal neurons activate the diaphragm and intercostal muscles. The neuromotor control of respiratory muscles depends on the function of the motor unit of that muscle. Conditions leading to declining motor unit numbers and alteration of motor unit sizes may impact many aspects of neuromuscular function and physical performance [8]. Motor unit recruitment refers to the activation of additional motor units to increase contractile muscle strength. Activation of motor neurons will help to activate more muscle fibers and improve muscular contraction [9].

This cross-sectional study analyzed the electromyographic activity of female athletes and nonathletes during forceful, maximum and normal respiration. Emphasis has been given to motor units activity and strength of association of inspiratory muscles during forceful, maximal, and normal respiration. Exercise, as well as physical training, can increase respiratory muscle activities with neuromuscular activity. During forceful, maximum and normal respiration, the primary concern was the involvement of the three inspiratory muscles (diaphragm, intercostal and latissimus dorsi). As one of the accessory muscles, the latissimus dorsi is included in this study because of its large structure in the thoracic cage. Physical training, whether influencing the motor units or not, is the primary object of this study. The motor units activity becomes better with the help of proper physical exercise of respiratory muscles was the primary goal of this study.

2. Aim and Objective

To find out proper physical training can change the respiratory muscle activities.

3. Method

3.1. Participants

Thirty-eight (38) young female athletes and Thirty-three (33) nonathletes (aged 15-20 years) without a physical disability have participated in this study. The participants were informed in detail about the purposes of the research and the methods used in this research. Before enrolment, a consent letter of each participant was taken. Prior Ethical clearance was taken from Institutional Human Ethics Committee.

3.2. Materials

The materials used in this study were Surface Electromyogram (sEMG), Silver silver chloride electrode, and a Spirometer.

3.3. Procedure

Surface EMG recordings of the diaphragm, external intercostal, and latissimus dorsi muscles were measured using pairs of skin-taped silver/silver chloride electrodes (8 mm in diameter) filled with conductive paste. These electrodes were placed on the cleaned skin. The performances of forceful, maximal, and normal respiration were measured with the help of a Spirometer (Schiller SP1) after placing sEMG leads.

3.4. Statistical Analysis

EMG data were analyzed offline using the machine's software (iworx) installed on the computer. The IBM SPSS v.24 was used for statistical calculation. The Mean, Standard deviation, and One way ANOVA were performed among the three respiratory muscle groups ($p<0.05$). Omega square (ω^2) was computed to estimate the strength of association between motor units activity of respiratory muscles during forceful and normal respiration.

4. Result

The mean and Standard deviation (SD) of physical variables (age, height, weight) of female athletes and nonathletes was represented in Table 1.

Table 2 shows the mean and SD of surface electromyographic activity of three different respiratory muscles (Intercostal, Diaphragm, Latissimus dorsi) of female athletes and nonathletes during forceful respiration. One-way ANOVA was calculated to understand the significant difference among the three groups of muscles (Table 2). Similar calculations were done during maximum and normal respiration which is represented in Tables 3 and 4, respectively. Significant differences ($p<0.05$) exist between motor unit activity, only during normal respiration (both athletes and non-athletes).

Scheffe's multiple comparison tests were performed to understand which group means differ significantly from each other (Table 5). During normal respiration, the group means of Intercostal and Latissimus dorsi muscles, Diaphragm, and Latissimus dorsi muscles show significant differences in athletes. Still, only Diaphragm and Latissimus muscles show significant differences in nonathletes.

Another statistical analysis that is Strength of association, represented by Omega square (ω^2) was performed in this study. The Omega square computes for estimating the strength of association between the motor unit activity of respiratory muscles during forceful and normal respiration.

Table 1. *Mean ± SD value of physical variables of Female Athletes and Nonathletes group.*

Variables	Athletes (n=38)	Non-athletes (n=33)
Age (years)	18.37±3.01	15.93±2.65
Height (cm)	158.44±7.34	157.38±6.35
Weight (kg)	52.62±9.42	51.14±6.51

Table 2. *Mean ± SD value of the surface electromyographic activity of the respiratory muscles of Female Athletes and Nonathletes groups during Forceful respiration [n=Sample size, F value=Analysis of variance (ANOVA) p=Level of significance].*

Variables	Intercostal	Diaphragm	Latissimus dorsi	F value with Level of Significance
ATHLETES (n=38) during Forceful respiration				
Integral of EMG signal	1.36±0.95	1.42±1.25	1.19±0.97	0.491, NS
The duration of EMG bursts	6.37±2.20	6.23±1.75	5.94±1.62	0.538, NS
Motor unit activity	0.31±0.21	0.35±0.29	0.29±0.19	1.010, NS
Peak Value	0.43±0.30	0.50±0.41	0.41±0.27	1.010, NS
Peak to Peak	0.87±0.60	0.99±0.83	0.82±0.54	1.010, NS
NON-ATHLETES (n=33) during Forceful respiration				
Integral of EMG signal	1.05±0.67	1.08±0.67	0.90±0.85	0.523, NS
The duration of EMG bursts	8.77±4.50	9.11±5.36	8.42±4.02	0.184, NS
Motor unit activity	0.17±0.11	0.20±0.09	0.15±0.11	1.872, NS
Peak Value	0.24±0.15	0.29±0.13	0.22±0.15	1.871, NS
Peak to Peak	0.49±0.30	0.57±0.26	0.43±0.31	1.875, NS

Table 3. *Mean ± SD value of the surface electromyographic activity of the respiratory and the delicate and respiratory interplay or coordination of muscles objectively muscles of Female Athletes and Non-athletes groups during Maximum respiration [n=Sample size, F value=Analysis of variance (ANOVA) p=Level of significance].*

Variables	Intercostal	Diaphragm	Latissimus dorsi	F value with Level of Significance
ATHLETES (n=38) during Maximum respiration				
Integral of EMG signal	4.84±4.03	4.39±4.00	4.16±4.21	0.278, NS
The duration of EMG bursts	12.95±0.80	13.30±0.89	13.49±0.84	3.620, p<0.05
Motor unit activity	0.50±0.41	0.45±0.38	0.42±0.41	0.427, NS
Peak Value	0.70±0.58	0.64±0.53	0.59±0.57	0.427, NS
Peak to Peak	1.40±1.16	1.29±1.06	1.18±1.15	0.427, NS
NON-ATHLETES (n=33) during Maximum respiration				
Integral of EMG signal	1.91±1.58	1.87±0.77	1.33±1.27	2.190, NS
The duration of EMG bursts	13.45±1.25	13.35±1.90	13.18±1.14	0.298, NS
Motor unit activity	0.19±0.17	0.21±0.09	0.14±0.13	2.943, NS
Peak Value	0.27±0.23	0.30±0.13	0.19±0.18	2.945, NS
Peak to Peak	0.53±0.47	0.61±0.26	0.39±0.36	2.942, NS

Table 4. *Mean ± SD value of surface electromyography activity of respiratory muscles of Female Athletes and Non-athletes groups during Normal respiration [n=Sample size, F value=Analysis of variance (ANOVA) and p=Level of significance].*

Variables	Intercostal	Diaphragm	Latissimus dorsi	F value with Level of Significance
ATHLETES (n=38) during Normal respiration				
Integral of EMG signal	1.21±0.57	1.77±0.79	1.33±1.34	3.496, p<0.05
The duration of EMG bursts	12.25±2.10	13.06±1.64	12.79±2.21	1.625, NS
Motor unit activity	0.13±0.06	0.34±0.28	0.16±0.17	4.660, p<0.05
Peak Value	0.19±0.08	0.50±0.41	0.23±0.24	4.652, p<0.05
Peak to Peak	0.37±0.17	0.99±0.83	0.45±0.48	4.665, p<0.05
NON-ATHLETES (n=33) during Normal respiration				
Integral of EMG signal	2.15±1.39	2.42±0.84	1.63±1.26	2.303, NS
The duration of EMG bursts	29.25±21.81	29.18±22.12	29.40±22.77	0.001, NS
Motor unit activity	0.11±0.06	0.16±0.07	0.09±0.03	14.182, p<0.05
Peak Value	0.16±0.09	0.23±0.10	0.13±0.04	14.213, p<0.05
Peak to Peak	0.32±0.18	0.46±0.19	0.26±0.08	14.179, p<0.05

Table 5. *Scheffe's Multiple Comparison Test.*

Variables		During FVC		During MVV		During MV	
		Athletes	Non-athletes	Athletes	Non-athletes	Athletes	Non-athletes
Motor unit	Intercostal and Diaphragm	NS	NS	NS	NS	NS	p<0.05
activity	Intercostal and Latissimus dorsi	NS	NS	NS	NS	p<0.05	NS
between	Diaphragm and Latissimus dorsi	NS	NS	NS	NS	p<0.05	p<0.05

Strength of Association which is represented by Omega square computes for estimating the strength of association between the motor unit activity of respiratory muscles and forceful and normal respiration.

$$\omega 2 = \frac{(k-1)(F-1)}{(k-1)(F-1)+N}$$

[where k = number of groups, F = F ratio, N = total number of sample size]

Strength of association during forceful respiration of athletes: $\omega 2 = \frac{(3-1)(1.010-1)}{(3-1)(1.010-1)+114} = 0.0002$

Strength of association during forceful respiration of Non-athletes: $\omega 2 = \frac{(3-1)(1.872-1)}{(3-1)(1.872-1)+99} = 0.17$

Strength of association during maximum respiration of athletes: $\omega 2 = \frac{(3-1)(0.427-1)}{(3-1)(0.427-1)+114} = -0.010$

Strength of association during maximum respiration of Non-athletes: $\omega 2 = \frac{(3-1)(2.943-1)}{(3-1)(2.943-1)+99} = 0.04$

Strength of association during normal respiration of athletes: $\omega 2 = \frac{(3-1)(4.660-1)}{(3-1)(4.660-1)+114} = 0.07$

Strength of association during normal respiration of Non-athletes: $\omega 2 = \frac{(3-1)(14.182-1)}{(3-1)(14.182-1)+99} = 0.21$

5. Discussion

According to Hande Türker and Hasan Sözen (2013), sEMG reveals the involvement of any muscles during its activity in different postures and movements and as in resting conditions. Moreover, it demonstrates delicate and respiratory interplay or coordination of muscles objectively. This study performs for finding the same purpose and focused on the involvement of motor units of two primaries and one respiratory accessory muscle of trained and untrained females. The involvement of motor units reflects the neuromuscular activities of a particular muscle during its resting and forceful conditions. Once a motor neuron discharges, action potentials are generated at its neuromuscular junction and then propagate along the muscle fibers toward the tendon regions [10]. The summation of these potentials are termed motor unit action potentials and is responsible for muscle contraction [11], which is the main objective of this study.

According to Pattichis CS et al. (1999), Electromyography is also using for the motor unit's morphological analysis. It is essential to synchronize the system that supplies cinematic data with electromyography to determine when different muscles are involved in movement [13].

The integral of EMG activity was higher in athletes during forceful and maximum respiration (Tables 2 & 3). An opposite result during normal respiration was showed that the essential EMG activity of nonathletes is greater than athletes. The duration of EMG bursts was higher in nonathletes during both forceful and normal respiration. That means nonathletes are taking more time than athletes to complete a contraction. The motor units activity, Peak value, and Peak to Peak amplitude were higher in the case of athletes during forceful, maximum and normal respiration. It signifies that motor units of athletes show better involvement and better function (contraction and relaxation). Athletes take less time than nonathletes to complete a forceful and normal respiration cycle. So it is said that their muscle activity is much better than nonathletes. According to these findings and with the reference of a recent study [9], training can improve respiratory muscles to function properly and stay very active to respond quickly in different conditions.

The integral of EMG activity was showed a higher response in Diaphragm muscle in athletes during both forceful and normal respiration. This indicates electromyographic activity is higher in the diaphragm than in other respiratory muscles during forceful and normal conditions. But Intercostal muscles show higher response in athletes during maximum respiration. That means during maximum ventilation, two inspiratory muscles (diaphragm, intercostal muscles) are highly activating. The same results show in Non-athletes during these three respiratory conditions.

The motor unit activity, Peak value, and Peak to Peak amplitude were also higher in the Diaphragm muscle than the other two muscles in athletes as well as Non-athletes during forceful and normal respiration. But there was a variation in maximum respiration. Intercostal muscle response is higher in athletes during maximal respiration, whereas in non-athletes, it is the diaphragm. That means during maximal breathing; the intercostal muscle is highly active. This muscle takes less time than the diaphragm but produces better motor unit activity during maximum respiration. This study also proves that Diaphragm is the primary muscle of breathing [9]. In maximal respiration, the Intercostal muscle supports the diaphragm for better performance.

According to the Henneman size principle [15], the relationship between the properties of motor neuron and the muscle fiber is that they innervate and control, which together is called motor units. Motor neuron in large cell body tends to provide fast-twitch, high force, less fatigue resistance muscle fibers, and motor neuron with small cell body tends to provide slow-twitch, low force, fatigue resistance muscle fibers. For this reason, during the contraction of a particular muscle, a motor neuron with a small cell body is recruited (that helps to begin a fire action potentials) before a motor neuron with a large cell body.

This study shows that an association of motor unit activity is lower in athletes during forceful, maximum, and normal respiration. That means the activation of the motor unit is higher for the nonathlete group after activation and starting of contraction of all fibers. Some activated motor units control the force of a muscle contraction. So, it considered that performing the forceful, maximum, and normal respiration, nonathlete group produces more muscle force than the athlete. Forceful respiration requires much force, but motor units are recruited precisely according to the magnitude of force output, with small units being recruited first, which exhibiting appropriate task recruitment. The proportion of fatigue minimizes the relative change in force which is produced by additional recruitment but remains relatively constant [15]. A strength exercise is any activity that makes muscles work harder than usual. It helps to increase muscle strength, size, power, and endurance. This study supports this statement, and here it is observed that motor unit association is low in athletes, but the muscle activity is much higher and better than non-athletes. That means athletes produce a better response in less time. It is due to long-term physical activity. So this study claimed that training could enhance the strength and endurance of respiratory muscles and thereby helps to improve pulmonary capacities by influencing the involvement of the motor units in primary and accessory respiratory muscles.

6. Conclusion

The strength of association in the motor unit is lower in athletes during three respiratory conditions (forceful, maximum, and normal respiration). It is observed that motor unit activity is higher in athletes than non-athletes for the intercostal, diaphragm, and latissimus dorsi muscles. So it is clear that athletes produce a better response with small motor unit involvement. It is also seen that the duration of EMG bursts, i.e. muscle response time is lower in athletes. So, this study concludes that athletes can produce better motor unit activity with minimum time and minimum strength of association of motor unit. It might be due to the effect of physical training in athletes increasing the flexibility of respiratory muscles. It is also clear from this study that motor units of respiratory muscles are one of the main factors influencing the higher values of different lung capacities in athletes. The proper physical exercise of those relevant muscles would improve the lung capacities in people.

Conflicts of Interest

The authors claim no conflicts of interest for this research work.

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