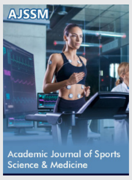

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Research Article

Evaluation of Inspiratory Performance Differences in Male and Female College Swimmers

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Abstract

Objective: Respiratory training has emerged as a supplementary approach to enhance athletic performance beyond traditional training methods. Respiratory training with POWER breath may be adapted to suit the demands of different sports.

Methods: This study used a convenience sample of 18 (female n=11, male n=7) division II collegiate swimmers, ages between 18-23 using a POWER breathe K2 to analyze four key indicators: Load, Power, Volume, and T-index.

Results: Analyzing the data comparing college women and men swimmers' inspiratory performance factors, we can observe that men had a higher mean value in load (38.57cmH20 vs 32.27 cmH20), power (7.66w vs 5.94w), and volume (2.96L vs 2.95L) but were not significant (p=.05). Concerning the T-index, female swimmers exhibit a significantly higher percentage than males (p=0.04).

Conclusion: This study found little differences among male and female swimmers, other than T-Index which may be due to females having higher activation of the diaphragm, scalene, and sternocleidomastoid muscles.

Keywords: Sports Performance, Respiration, Lung Compacity, T-Index

Introduction

Respiratory muscle training (RMT) has emerged as a supplementary approach to enhance athletic performance beyond traditional training methods [1-3] Studies have shown that RMT can improve respiratory muscle strength, potentially leading to enhanced performance in activities such as swimming and running [4-6]. While some performance-enhancing substances have been developed to push athletic achievements further, it is crucial to consider the legal, biological, and psychological risks associated with such substances [7].

Respiratory training has been shown to stimulate adaptations in lung capacity, respiratory muscle coordination, and overall pulmonary function [8]. Various forms of respiratory muscle training have been effective in improving respiratory muscle strength and endurance, leading to enhanced respiratory function and exercise capacity [9]. These training methods play a crucial role in addressing respiratory muscle weakness, improving lung volumes, and enhancing overall pulmonary function, highlighting the importance of incorporating respiratory training into rehabilitation protocols for various respiratory conditions [10]. Adaptations can delay the onset of respiratory muscle fatigue, reducing the perception of effort during exercise. The development of devices like POWERbreath has facilitated targeted training of these muscles, potentially leading to improved sports performance

[9]. In strength and power sports, enhanced oxygen delivery can delay fatigue, thereby optimizing training quality and competitive outcomes [11].

Respiratory training with POWERbreath can be adapted to suit the demands of different sports. In endurance activities, improved respiratory muscle endurance can lead to sustained performance during prolonged efforts [12]. POWERbreath has demonstrated improvements in various performance parameters across sports such as cycling, running, swimming, and endurance events [4,13,14]. Studies have reported enhanced respiratory muscle strength, increased lung capacity, delayed respiratory muscle fatigue, and reduced breathlessness during exercise [15,16]. These findings collectively indicate that POWERbreath training positively impacts both physiological and perceptual aspects of athletic performance.

The potential benefits of respiratory training using devices like POWERbreath may extend itself into the realm of competitive swimming, which may lead to improvements in overall athletic performance [4]. Competitive surface swimming necessitates precise regulation of breathing patterns with significantly higher volumes and flow rates than terrestrial exercise, requiring well-conditioned inspiratory and expiratory musculature to maintain efficient stroke mechanics [17]. The impact of respiratory training on swimmers is of particular interest due to the unique challenges they face in a horizontal or near-horizontal position subjected to hydrostatic forces. These challenges include reduced duty cycles from controlled frequency breathing, the expansion of the chest wall against increased water pressure during submersion [30], heightened flow-resistive loads during inspiration and expiration [18] and increased respiratory muscle contraction velocity and tidal volume [19].

This research study sets out to contribute to a deeper understanding of how gender may influence these factors and ultimately enhance our comprehension of the unique challenges faced by male and female collegiate swimmers, potentially leading to more tailored training strategies and improved athletic performance. The primary objective of this research study was to investigate, analyze, and compare specific inspiratory parameters utilizing the POWERbreath device, with a particular focus on discerning the physiological, anatomical, and performance differences between male and female college swimmers. By examining these parameters, we aim to gain valuable insights into the distinct characteristics and adaptations of the respiratory musculature in the context of competitive swimming.

Methods

Participants

This study used a convenience sample of 18 (female n=11, male n=7) division II collegiate swimmers, ages between 18-23. This diverse group of swimmers encompassed a variety of disciplines, including sprint, mid-distance, and distance swimmers. This study was conducted in compliance with the institution's IRB board.

POWERbreathe

This research utilized POWERbreathe K2 for its data gathering. The K2 is one of the existing linear load resistor models on the market, which generates resistance via a spring-loaded system or an electronic valve. The POWERbreathe K2 assesses four key indicators: Load, Power, Volume, and T-index. Through these parameters, we hoped to gain a comprehensive understanding of respiratory function in college swimmers and its impact on overall inspiratory performance.

Load measure of the resistance to inhalation and is equivalent to the weight being lifted (cmH2O). Power is a metric that combines the strength of inhalation with the speed of airflow and is expressed in watts (W). A higher power output indicates the potential for improved lactic acid neutralization during intense physical exertion. Volume reflects the average amount of air inhaled per breath during a training session. Deeper breaths signify a fuller range of movement, enhancing the workout of respiratory muscles. T-index measures the effectiveness of expiration vs inspiration consistency based on energy expenditure. A lower t-index may suggest incomplete inhalation or exhalation, highlighting the importance of achieving full lung capacity during training repetitions.

Protocol

Each participant completed one Single Breath Test using a POWERbreathe K2. The K2 measures inspiratory muscle strength, peak inspiratory flow rate, and inhaled volume in a single breath. During the test, subjects were encouraged to perform maximum effort deep inspirations, as possible, for each effort with a target inspiration duration of 1–2 s for 30 repetitions. Four sets of data (load, power, volume, t-index) were collected and analyzed per participant.

Statistical Analysis

Microsoft Excel was employed as the primary tool for data analysis. Various statistical measures were computed, including the calculation of averages, medians, standard deviations, maximum, minimum, and variances for the collected data. These measures provided a comprehensive understanding of the central tendency and dispersion of the data. Furthermore, correlations were established between inspiratory parameters, namely Load, Volume, Power, and T-index, for both male and female participants, as well as between the male and female groups.

This correlation analysis allowed for the exploration of potential associations or dependencies between these parameters. To assess the significance of the differences observed, t-tests were conducted between the different parameters, facilitating the determination of whether statistically significant variations existed. The statistical analyses conducted in this study serve as a critical foundation for interpreting the findings and drawing meaningful conclusions from the collected data.

Results

The result of the combined data for all participants, as shown in Table 1, provides essential insights. The load (cmH20) averages 34.72 with notable variability (±8.01). Power (Watts) averages 6.61 (±2.70). Volume (L) averages 2.96 with relatively consistent performance (±0.61). The T-Index (%) averages 60.44 with

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substantial variability (±13.77). The highest and lowest values for each parameter offer context, and the variances demonstrate data heterogeneity. These findings establish a foundational understanding of the dataset's central tendencies and variability, which informs subsequent sections of this study.

Table 1: Mean, median, standard deviation, highest, lowest, and variance of load (cmH_20), power (Watts), volume (L), and T-Index (%) for all participants combined.

	Testing Information			
	Load (cmH_20)	**Power (Watts)**	**Volume (L)**	**T-Index (%)**
Average	34,72	6,61	2,96	60,44
Median	30,00	5,80	2,95	62,00
Stand Dev	8,01	2,70	0,61	13,77
High	56,00	14,50	4,40	94,00
Low	28,00	4,00	1,80	32,00
Variance	64,21	7,30	0,37	189,56
Count	18,00	18,00	18,00	18,00

Female Swimmers

Table 2 presents the statistical analysis of inspiratory parameters for female college swimmers. The average load (cmH20) is 32.27 (±5.69) indicates consistent load levels among female swimmers. The average power (Watts) is 5.94 (±1.97) reflecting stable power outputs. Volume (L) parameters show an average of 2.95 (±0.59) indicating consistent volume performance. The T-Index (%) averages 64.73 (±13.36) showing a moderate range of T-Index values among female swimmers.

Table 2: Inspiration Measures for Female College Swimmers.

	Testing Information			
	Load (cmH_20)	**Power (Watts)**	**Volume (L)**	**T-Index (%)**
Average	32.27	5.94	2.95	64.73
Median	30	5.4	2.9	64
Stand Dev	5.69	1.97	0.59	13.36
High	46	10.2	4.4	94
Low	28	4	2.4	42
Variance	32.42	3.88	0.35	178.62
Count	11	11	11	11

In the analysis of data specific to female college swimmers, a strong positive correlation of r2 = 0.818 was observed between Load (cmH20) and Power (Watts) (Figure 1). This correlation indicates that as the load values increase, there is a corresponding increase in power outputs among the female participants, highlighting the interdependence of these two key parameters in their inspiratory performance.

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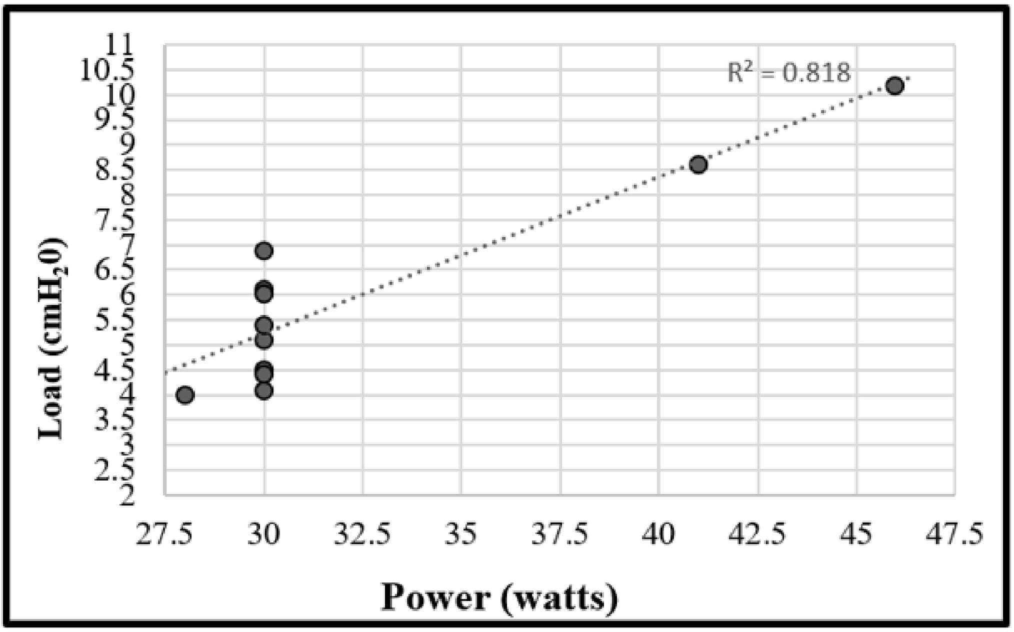

Figure 1: Female Load (cmH20) and Power (Watts) Correlation.

Male Swimmers

Table 3 presents the statistical analysis of inspiratory parameters for male college swimmers. The average load (cmH20) is 38.57 (±9.98) and Power (watts) averages 7.66 (±3.48) indicating a wide range of power output. Volume (L) shows an average of 2.96 (±0.68) reflecting some variability in volume performance. The T-Index (%) averages 53.71 (±12.37) indicating a moderate range of T-Index values among male swimmers.

Table 3: Inspiration Measures for Male college swimmers.

	Testing Information			
	Load (cmH$_2$0)	Power (Watts)	Volume (L)	T-Index (%)
Average	38.57	7.66	2.96	53.71
Median	35	6.8	3	59
Stand Dev	9.98	3.48	0.68	12.37
High	56	14.5	4	64
Low	30	4.4	1.8	32
Variance	99.62	12.12	0.46	152.9
Count	7	7	7	7

Females vs. Males

Table 4 presents the results of a T-test comparing the T-index scores between female and male swimmers. Based on the provided data, the calculated t-value is -1.75. Since these falls beyond the critical value of -1.74 for a one-tailed test at a significance level of 0.05, but not beyond the critical value of 2.11 for a two-tailed test. There is evidence to suggest a significant difference in T-index scores between male and female swimmers, but only in one direction (i.e., females having higher T-index scores), at the 0.05 significance level with a large effect size of d = 0.86.

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Table 4: Differences between Female vs. Male Swimmers.

	Male T-Index	*Female T-Index*
Mean	53.71428571	64.72727273
Variance	152.9047619	178.6181818
Observations	7	11
Pooled Variance	168.9756494	
Hypothesized Mean Difference	0	
df	16	
t Stat	-1.752274638	
P(T<=t) one-tail	**0.049432702**	
t Critical one-tail	1.745883676	
P(T<=t) two-tail	0.098865404	
t Critical two-tail	2.119905299	

Discussion

Analyzing the data comparing college women and men swimmers' inspiratory performance factors, we can observe that men have significantly higher values in both load and power. This difference can be attributed, to some extent, to the inspiratory physiology of men, particularly in specific inspiratory muscles such as the diaphragm, which is the most active inspiratory muscle during exercise [3, 5, 20]. Consequently, due to this physiological distinction and the fact that women experience a greater workload in terms of breathing and oxygen uptake in their respiratory muscles, college women swimmers tend to experience more significant diaphragmatic fatigue [18, 21]. In terms of volume, we found no significant difference between women and men.

T-Index

The higher T-index in female collegiate swimmers compared to their male can be due to sex gender differences of respiratory parameters. The finding suggests that women, on average, exhibit greater consistency in expiration versus inspiration during training repetitions, indicating potential variations in respiratory mechanics. This observation prompts a thorough exploration of the factors influencing these gender-specific differences and their implications for training and performance optimization. Anatomical disparities in lung capacity and respiratory mechanics between genders may contribute to the observed higher T-index in women [22]. Studies emphasize gender-specific variations in lung function, highlighting factors like thoracic size and shape [23]. Additionally, hormonal influences, particularly estrogen levels, could play a role in shaping respiratory patterns, as discussed in the study by [24].

Load and Power

Examining the correlations among breathing parameters in female college swimmers, a noteworthy and statistically significant association was found between Load and Power. This correlation suggests a strong relationship between the load exerted during breathing and the power generated in the respiratory system during swimming. While other correlations between various respiratory parameters did not achieve statistical significance in this study, the pronounced link between Load and Power is clearly significant. The observed correlation aligns with the principles of respiratory physiology and the unique demands placed on the respiratory muscles during swimming. The concept of "Load" in this context likely pertains to the resistance encountered during inhalation and exhalation, considering factors such as water resistance, breathing patterns, and the need for efficient oxygen exchange during physical exertion [25].

Competitive swimmers must possess a dynamic nature of respiratory load in aquatic environments, where they must contend with the resistance of water while executing breathing maneuvers [17-19,21]. This inherent load necessitates a powerful and coordinated effort from respiratory muscles to maintain optimal breathing patterns and facilitate efficient gas exchange [10,26,27]. The identified correlation with Power suggests that a more effective management of respiratory load corresponds to enhanced power generation within the respiratory system during swimming. While the significance of other correlations remains elusive in this study, the focus on Load and Power underscores the intricate interplay between breathing mechanics and performance. Further research may delve into specific aspects of breathing techniques, training interventions, and individual variations to unravel the complexity of respiratory dynamics in swimmers.

Estrogen

The relationship between estrogen and breathing economy is a complex and multifaceted one, and research in this area is ongoing. Estrogen receptors are present in various tissues, including the respiratory muscles and airway smooth muscle, suggesting that estrogen could have an impact on respiratory function [23,28-29]. However, the specific effects of estrogen on breathing economy are not fully understood, and results from studies have been mixed [24,30]. It is suggested that estrogen may influence respiratory mechanics and ventilation. This could potentially influence breathing efficiency and economy by ensuring effective respiratory muscle function [30,31]. Estrogen has been implicated in affecting

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airway smooth muscle tone. Changes in airway resistance could impact the work of breathing and, consequently, breathing economy [29]. Estrogen may play a role in ventilation-perfusion matching, optimizing the distribution of air and blood in the lungs. This could potentially contribute to more efficient gas exchange during breathing [28]. It's important to note that the effects of estrogen on breathing economy can be influenced by various factors, including the menstrual cycle phase, hormonal fluctuations, and individual differences.

Conclusion

In conclusion, our analysis of inspiratory performance factors among college women and men swimmers showed significant differences, especially in load and power, with men having higher values in these aspects. These differences can be attributed to physiological variations in inspiratory muscle strength, with men generally exhibiting greater force generation capacity. Furthermore, the higher T-index observed in female swimmers suggests some gender-specific differences in respiratory mechanics, possibly influenced by anatomical disparities and hormonal factors such as estrogen levels. The correlation between load and power highlights the importance of efficient management of respiratory load for optimizing power generation during swimming. While the precise mechanisms linking estrogen and breathing economy remain complex and there is not a lot of studies on this topic, further research is warranted to study their implications for respiratory health and exercise performance, particularly in the context of female athletes and more specific in swimming.

Overall, this study emphasizes the complex relationships between respiratory dynamics, gender-specific physiology, and performance outcomes in competitive swimming, providing valuable insights for training and performance optimization strategies in this population. Further research is needed to better understand the specific mechanisms through which estrogen may influence breathing economy and how these factors might be relevant to respiratory health and exercise performance, especially in the context of female athlete swimmers.

Acknowledgement

None.

Conflict of Interest

No conflict of interest.

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