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EFFECTS OF INDIVIDUALIZED TRAINING AND RESPIRATORY MUSCLE TRAINING ON PULMONARY FUNCTION AMONG COLLEGIATE SWIMMERS: AN EXPERIMENTAL STUDY

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Abstract

The study aimed to examine the effect of individualized (IT) and respiratory muscle training (RMT) on pulmonary function among collegiate swimmers.

Materials and methods. The study recruited 43 healthy collegiate swimmers aged 18 to 25, and they were freestyle non-elite swimmers who swam at least three days a week. The participants were divided into three groups of Usual training (Control Group A), Respiratory muscle training (Experimental Group B) and Combination of respiratory muscle training and individualized training (Experimental Group C). The repeated measures two-way ANOVA was used to evaluate the differences within and between (time x group) the groups upon completion of the four-week intervention.

Results. Both experimental groups (Group B and C) showed significant improvement within the groups. Whereas in between-group comparison, Group C (RMT and IT) showed tremendous improvement with significant differences in FVC value, predicted FVC value (percent), FEV1, FEV (percent), and predicted MVV, with the exception of the FEV1/FVC predicted ratio percent.

Conclusions. When RMT and IT are used combined, swimmers' performance increases more than when RMT and usual training are used separately. The findings suggest that training instructors may adapt RMT and IT techniques to fit the individual demands of swimmers in order to increase progress and performance efficiency, especially among competitive swimmers.

Keywords: individualized training, respiratory muscle training, pulmonary function, collegiate swimmers, swimming performance.

Introduction

Freestyle swimming is the common stroke technique used by participants at various sports levels. Swimming is a dynamic exercise controlled by multiple stroke techniques, muscle and lung physiology, as well as related anthropometry (Cohen et al., 2015). Swimming has a variety of effects on lung functions, such as increased lung capacity and endurance over a period of time (Pareek & Modak, 2013).

Despite this, swimming is a physically challenging sport that demands the diaphragm and respiratory muscles to function in order to counteract chest wall expansions and to tolerate the amount of stress throughout the breathing cycle caused by immersion in water pressures (Cunha et al 2019, Sable et al 2012). Water pressure in the thorax impairs respiratory function, resulting in fatigue and an alteration of the respiratory muscle metaboreflex (Hess & Hostler, 2018). Respiratory muscle activity is required not just for proper breathing but also for physical movements. Some research indicates that professional swimmers are more likely to experience exercise-induced respiratory symptoms and are more susceptible to exercise-induced bronchoconstriction even in the absence of asthma (Bougault & Boulet, 2012). Thus, swimmers in need of an excellent respiratory muscle strength and high aerobic capacity to overcome the challenges faced under the water (HajGhanbari et al., 2013).

Many studies have been conducted on training for the respiratory muscles in order to increase swimming performance (Lemaitre et al., 2013; Wells et al., 2005; Witt et al., 2007; Wylegala et al., 2007). One of the exercises that has been popularized is respiratory muscle training (RMT), a technique that aims to improve lung functions, reduce the development of respiratory muscle fatigue metaboreflex occurrences through specific exercises (Bağıran et al., 2019; Espinosa-Mendez et al., 2021; Ren-Jay Shei, 2018; Wilson et al., 2014). The RMT technique of high-force, low-velocity contractions improves respiratory muscle strength as well as pressure generation capacity in the inspiratory and expiratory muscles against a closed glottis (Illi et al., 2012). Further, the RMT would improve adaptations in muscle fibre structures and improve cross-section muscle strength and functional adaptations like endurance and inspiratory flow (Menezes et al., 2016). In addition, the individualized training (IT) combined with RMT has shown significant improvement in respiratory functions (Kim et al., 2014; Muthusamy et al., 2021). Evidently, IT enhances sports-related performances in a various of sporting specialties as the respiratory muscle strength improves significantly under dynamic conditions (HajGhanbari et al., 2013; Illi et al., 2012).

Although numerous studies have been published on the effectiveness of RMT and IT, there is a scarcity of research on the effectiveness of the exercises on swimming performance in terms of pulmonary function. Thus, the purpose of this study was to examine the effect of IT and RMT on pulmonary function among collegiate swimmers. The study hypothesized that there would be no difference in the swimmers' pulmonary functions following IT and RMT intervention.

Materials and methods

Study participants

An experimental study with forty-three collegiate swimmers (Age = 19.53 ± 1.12) were recruited in the current study. All the recruited participants were assessed based on the predefined criteria by a blinded assessor. The inclusion criteria were healthy swimmers aged 18 to 25, freestyle non-elite swimmers, and swims at least three days a week. The study excluded swimmers with recent infections in lungs, congenital pulmonary problems, known history of respiratory problems like asthma, COPD, etc., recent injuries to the lower limbs or upper limbs, BMI greater than 24 kg/m^2 and those participating in any other research. All swimmers were explained on the study and informed consent was obtained prior to the experiment. The current study obtained ethical approval from Department of Physical Education and Health Sciences, Alagappa University, India.

Study organization

Selected swimmers were divided randomly into three group; Group A: Usual training (control group), Group B: Respiratory muscle training (experimental group) and Group C: Combination of respiratory muscle training and individualized training (experimental group). Measurements of swimming performance were taken before and after the four weeks of intervention period for the respective groups. Prior to the intervention, the baseline measurement of the swimmers such as time taken to complete 100m distance, max HR, FVC, FEV1, FEV1/FVC, and MVV were obtained.

Participants in Group A (Usual training) had regular training sessions were given a standard exercise load and a standard land-based training regimen 0. Cardiovascular exercises such as jogging, cycling (both static and non-static), and light resistance training with an emphasis on freestyle swimming's major muscles were emphasized in the training session. Group B (RMT) received respiratory muscle training throughout the training session prior to warm-up and cool-down, followed by their normal routine activities (Cunha et al., 2019, Lemaitre et al., 2013). The RMT intensity ranged from a low level to a moderate level (Based on the medium resistance power breathe trainer) (Cunha et al., 2019). Group C's (RMT + IT) training intensity was prescribed based on each participant's resting heart rate, maximum heart rate (220-Age) and Borg's scale of 10 points (Grant, 2017; Sadowski et al., 2012). In the first week of training, exercise intensity was set at 75% and progressively increased depending on the swimmer's capacity, with RMT incorporated into the training sessions. Participants in all three groups were assigned to five-day weekly practice sessions with sufficient rest in between. An expert swimming coach kept track of the training sessions and progression, while an expert cardiorespiratory physiotherapist advised the RMT training and levels. The study procedure has been explained in Figure 1.

The Garmin Forerunner 935 watch was used to measure the swimmers' distance and monitor their heart rates. The data was recorded using the Garmin app on the smart phone. The Garmin watch was strapped to the chest with a sensor that connected to the watch, and it was worn throughout the 100-meter

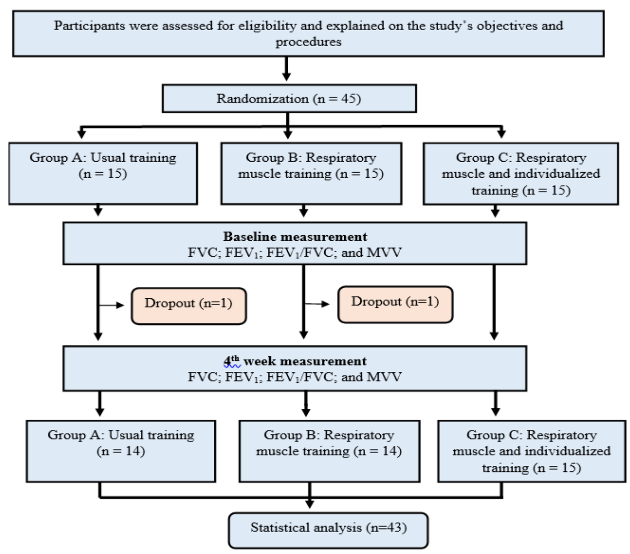

Fig. 1. Study flow chart.
Note. Forced Vital Capacity (FVC), Forced Expiratory Volume In 1 S (FEV1), Forced Expiratory Volume In 1s (FEV1), and Maximum Voluntary Ventilation (MVV)

swim to accurately measure the heart rate. Precautions were taken to ensure that the participant's breathing was not restricted or that any discomfort was avoided during the swim.

The respiratory muscles were trained with a medium-resistance trainer, Power breathe® device (Gaiam Ltd; Southam, Warwickshire, UK) (Nepomuceno Júnior et al., 2016). Before using the power breathe, all participants were given clear instructions and a practical demonstration. The resistance settings on this trainer range from level 0 to level 9 (Amaro et al., 2017). The resistance can be increased or decreased using an adjustable knob at the bottom of the device. The higher the level, the greater the resistance. Levels 2 to 8 were prescribed for different groups with different exercise sessions in the current study.

The UBREATH® Pro Spirometer System PF680 (e-Link-Care Meditech Co., Ltd, Manchester, United Kingdom) was used to measure pulmonary function among the swimmers. The data of three expiratory maneuvers with 1-min intervals were measured and collected using the best values obtained for forced vital capacity (FVC) [L], forced expiratory volume in 1 s (FEV1) [L], forced expiratory volume in 1s (FEV1)/ FVC [L], and maximum voluntary ventilation (MVV) [L].

Statistical analysis

IBM SPSS version 24.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. Continuous descriptive data was represented by mean and standard deviation, while categorical descriptive data was represented by frequency and percentages. A repeated measure two-way ANOVA (group x time) was conducted to examine the effects and interaction of within and between control group (Group A), respiratory muscle training (Group B) and respiratory muscle training combined with individualized training (Group C) during the four weeks of intervention. For repeated measure tests, the Shapiro-Wilk test revealed that normality was not violated, and Mauchly's test revealed that the assumptions of sphericity were not violated. The α level was set at 0.05.

Results

Forty-three collegiate swimmers were recruited in the current. The baseline demographic characteristic of the subjects was shown accordingly in Table 1.

The differences of usual training were evaluated pre and post 4 weeks intervention among fourteen swimmers. The predicted FVC value (%), FEV1, FEV (%) showed a significant improvement ($p < 0.05$) following 4 weeks training as shown in Table 2.

The differences of respiratory muscle training were evaluated pre and post 4 weeks intervention among fourteen swimmers. The FVC value, predicted FVC value (%), FEV1, FEV (%) and predicted MVV showed a significant improvement ($p < 0.05$) following 4 weeks training as shown in Table 3.

The differences of respiratory muscle and individualized training were evaluated pre and post 4 weeks intervention among fourteen swimmers. The FVC value, predicted FVC value (%), FEV1, FEV (%) and predicted MVV showed a significant improvement ($p < 0.05$) following 4 weeks training as shown in Table 4.

A repeated measure two-way ANOVA (group x time) was conducted to examine the effects and interaction of control group, respiratory muscle training and respiratory muscle training combined with individualized training. The Shapiro-Wilk test indicated that normality was not violated and Mauchly's test showed that the assumptions of sphericity was not violated for repeated measure tests.

In the FVC [L] value, no significant differences between groups $F_{(2,26)} = 1.307$, $p = 0.288$, small effect size. There is a significant difference in improvement of four weeks of intervention of the training, $F_{(1.13)} = 179.09$, $p = 0.000$, large

Table 1. Baseline characteristics of the participants

Variables	Group A (n=14)	Group B (n=14)	Group C (n=15)
Gender (n/%)			
Male	8 (57.14)	7 (50.0)	7 (46.67)
Female	6 (42.86)	7 (50.0)	8 (53.33)
Age	19.50 ± 1.092	19.50 ± 1.225	19.60 ± 1.121
Time taken for 100m distance	3.42 ± 0.40	3.54 ± 0.35	3.66 ± 0.30
Max HR	166.93 ± 9.19	165.29 ± 14.24	161.00 ± 12.49
BMI	14.90 ± 4.00	13.56 ± 3.03	22.18 ± 1.49

All the data presented in mean ± standard deviation except gender presented in frequencies (percentage), HR – Heart rate

Table 2. Comparison before and after four weeks of usual training protocol (Group A)

Variables	Pre-training (Mean ± SD)	Post-training (Mean ± SD)	Mean differences	95% CI for the Mean (Lower to Upper)	t (df)	P value
FVC	4.22 ± 0.27	4.25 ± 0.26	0.002	-0.045 to 0.000	2.132 (13)	0.053
FVC Predicted (%)	82.40 ± 1.95	82.85 ± 2.27	0.045	-0.889 to -0.001	2.168 (13)	0.049
FEV1 (L)	3.45 ± 0.23	3.47 ± 0.23	0.022	-0.004 to -0.008	3.429 (13)	0.004
FEV1 (%)	84.09 ± 3.00	84.64 ± 2.95	0.561	-0.903 to -0.218	3.537 (13)	0.004
FEV1/FVC Ratio Predicted (%)	81.82 ± 3.24	81.93 ± 3.05	0.106	-0.586 to 0.375	0.475 (13)	0.643
MVV Predicted (%)	80.14 ± 2.03	81.14 ± 2.69	1.000	-2.109 to 0.109	1.947 (13)	0.073

Forced Vital Capacity (FVC), Forced Expiratory Volume In 1 S (FEV1), Forced Expiratory Volume In 1s (FEV1), and Maximum Voluntary Ventilation (MVV)

Table 3. Comparison before and after four weeks of respiratory muscle training group (Group B)

Variables	Pre-training (Mean ± SD)	Post-training (Mean ± SD)	Mean differences	95% CI for the Mean (Lower to Upper)	t (df)	P value
FVC	4.23 ± 0.24	4.44 ± 0.28	0.211	-0.026 to -0.166	10.034 (13)	0.000
FVC Predicted (%)	82.72 ± 2.27	86.82 ± 2.51	4.103	-4.920 to -3.286	10.854 (13)	0.000
FEV1 (L)	3.36 ± 0.16	3.90 ± 0.22	0.543	-0.227 to -0.132	8.112 (13)	0.000
FEV1 (%)	86.14 ± 1.38	90.75 ± 2.20	4.611	-5.857 to -3.365	7.995 (13)	0.000
FEV1/FVC Ratio Predicted (%)	79.49 ± 2.67	79.820 ± 3.74	0.325	-1.507 to 0.856	0.595 (13)	0.562
MVV Predicted (%)	80.00 ± 1.96	93.43 ± 5.32	13.429	-16.245 to -10.612	10.299 (13)	0.000

Forced Vital Capacity (FVC), Forced Expiratory Volume In 1 S (FEV1), Forced Expiratory Volume In 1s (FEV1), and Maximum Voluntary Ventilation (MVV)

Table 4. Comparison before and after four weeks of respiratory muscle training group (Group B)

Variables	Pre-training (Mean ± SD)	Post-training (Mean ± SD)	Mean differences	95% CI for the Mean (Lower to Upper)	t (df)	P value
FVC	4.22 ± 0.256	4.25 ± 0.252	0.024	-0.045 to -0.003	2.437 (14)	0.029
FVC Predicted (%)	82.42 ± 1.88	82.90 ± 2.19	0.481	-0.898 to -0.064	2.472 (14)	0.027
FEV1 (L)	3.44 ± 0.23	3.47 ± 0.22	0.024	-0.038 to -0.010	3.804 (14)	0.002
FEV1 (%)	83.80 ± 3.11	84.39 ± 3.01	0.587	0.910 to -0.266	3.917 (14)	0.002
FEV1/FVC Ratio Predicted (%)	81.59 ± 3.26	81.69 ± 3.09	0.099	-0.544 to 0.344	0.483 (14)	0.637
MVV Predicted (%)	82.27 ± 2.99	101.20 ± 3.91	18.933	-20.588 to -17.279	24.547 (14)	0.000

Forced Vital Capacity (FVC), Forced Expiratory Volume In 1 S (FEV1), Forced Expiratory Volume In 1s (FEV1), and Maximum Voluntary Ventilation (MVV)

effect size. Besides, the interaction of the group x time also showed significant differences with $F_{(2,26)} = 45.163$, $p = 0.000$, large effect size.

The FVC [L] predicted (%) showed significant changes between groups, $F_{(2,26)} = 3.871$, $p < 0.05$, large effect size; within the groups over the four weeks intervention, $F_{(1,13)} = 216.55$, $p = 0.000$, large effect size; and a significant difference in the interaction between group x time, $F_{(2,26)} = 47.97$, $p = 0.000$, large effect size.

The FEV1 (L) showed significant changes between groups, $F_{(2,26)} = 14.093$, $p = 0.000$, large effect size. Significant differences were also seen within the groups over the four weeks intervention, $F_{(1,13)} = 383.48$, $p = 0.000$, large effect size; and a significant difference in the interaction between group x time, $F_{(2,26)} = 171.34$, $p = 0.000$, large effect size.

Whereas in the FEV1 [L] (%), all the interaction showed a significant difference between the groups, $F_{(2,26)} = 2303.72$, $p = 0.000$, large effect size, within the groups, $F_{(1,13)} = 6871.93$, $p = 0.000$, large effect size and between group x time, $F_{(2,26)} = 6685.49$, $p = 0.000$, large effect size.

The FEV1/FVC [L] ratio showed significant difference between the groups, $F_{(2,26)} = 5.114$, $p < 0.05$, large effect size were seen. The improvement over four weeks also showed a significant difference with $F_{(1,13)} = 23.329$, $p < 0.05$, large effect size and the interaction between group x time, $F_{(2,26)} = 16.616$, $p < 0.05$, large effect size.

The final variables, MVV [L] Predicted (%) also showed a significant difference in the analysis. There was a significant difference between the groups, $F_{(2,26)} = 74.618$, $p = 0.000$, large effect size. Significant differences were also reported within the group over the four weeks of intervention, $F_{(1,13)} = 360.85$, $p = 0.000$, large effect size and the interaction between group x time, $F_{(2,26)} = 103.99$, $p = 0.000$, large effect size.

Discussion

The purpose of the study was to examine the effect of individualized training and respiratory muscle training on pulmonary function among forty-three healthy collegiate swimmers.

The comparison within the group in RMT and RMT + IT demonstrated a significant improvement over the four weeks intervention in the FVC value, predicted FVC value (%), FEV1, FEV (%) and predicted MVV except the FEV1/FVC predicted ratio % in the current study. The current study's findings are consistent with previous studies that found RMT to have a positive impact on swimmers' performance (Vašíčková et al., 2017; Kilding et al., 2010; Wylegala et al., 2007). Under normocapnic hyperpnoea conditions, (RMT) is proven to improve respiratory muscle strength and enhance pulmonary function (Szczepan et al., 2020). Researchers found that RMT has a number of positive physiological adaptations, including diaphragm hypertrophy and increased nitric oxide concentration in airways, as well as a change in muscle fibre contraction efficiency, advancement in nervous control and economy of respiratory muscle work and reduced dyspnoea, as well as enhanced pulmonary function that led to decreased ratings of perceived breathlessness or exertion (Szczepan et al., 2020; Held and Pendergast, 2014; Ren-Jay Shei, 2018; Wylegala et al., 2007).

Despite the improvement within the RMT groups, the analysis between the groups (group x time), RMT + IT showed significant differences in comparison to RMT and usual training over the four weeks of intervention. Our results were supported by previous research that stated that athletes frequently train excessively hard during recovery sessions, impairing their ability to achieve the desired intensity during more challenging training sessions (Wallace et al., 2008). By adopting an individualized training approach, coaches perhaps would be able to measure the intensity of each training session using the RPE approach, enabling increased intensity during high-intensity training and better recovery periods (Wallace et al., 2008). Furthermore, a comparable study on collegiate swimmers found a considerable improvement with RMT and IT combination approach on perceived effort, VO2 max, and a sharp increase in the swimmers' performance (Muthusamy et al., 2021).

To our knowledge, there has been no study on the use of RMT in combination with IT in swimming, despite the fact that it has been widely employed in other sports. The current study shown that by combining the RMT and IT methods, the pulmonary functions (FVC, FEV1, FEV1/FVC, and MVV) of swimmers may be significantly improved. The current study has some limitations, including a focus on solely recreational collegiate swimmers, an emphasis only on pulmonary functions rather than swimming performances or general fitness, and a short duration of intervention (four weeks). Future research should be undertaken over a longer period of time to assess the long-term effects of RMT and IT on swimming performance and among competitive swimmers.

Conclusions

The current study's findings demonstrate that when RMT and IT are combined, the swimmers' performance improves more than when RMT and usual training are used alone. The findings imply that training instructors can adjust RMT and IT approaches to their training to meet the specific demands of swimmers in order to improve development and performance even among the athletic swimmers.

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Conflict of interest

No potential conflict of interest was reported by the author(s).

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ВПЛИВ ІНДИВІДУАЛІЗОВАНИХ ТРЕНУВАНЬ І ТРЕНУВАНЬ ДИХАЛЬНИХ М'ЯЗІВ НА ФУНКЦІЮ ЛЕГЕНЬ У ПЛАВЦІВ-СТУДЕНТІВ КОЛЕДЖУ

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Метою дослідження було вивчення впливу індивідуалізованих тренувань (ІТ) і тренувань дихальних м'язів (ТДМ) на функцію легень у плавців-студентів коледжу.

Матеріали та методи. Для участі в дослідженні було відібрано 43 фізично здорових плавці-студенти коледжу віком від 18 до 25 років, які були непрофесійними плавцями вільним стилем і займалися плаванням принаймні три дні на тиждень. Учасників розподілили на три групи: «Звичайні тренування» (Контрольна група А), «Тренування дихальних м'язів» (Експериментальна група В) та «Комбінація тренувань дихальних м'язів та індивідуалізованих тренувань» (Експериментальна група С). Для оцінки відмінностей у групах і між групами (час х група) після завершення чотиритижневої інтервенції використовували двофакторний дисперсійний аналіз повторних вимірювань.

Результати. Обидві експериментальні групи (групи B та C) показали статистично значуще покращення показників у цих групах. Тоді як у міжгруповому порівнянні група C (ТДМ та ІТ) показала величезне покращення показників зі статистично значущими різницями значення форсованої життєвої ємності легень ФЖЄЛ, прогнозованого значення ФЖЄЛ (відсоток), значення об'єму форсованого видиху за першу секунду ОФВ1, значення ОФВ (відсоток) і прогнозованого значення максимальної довільної вентиляції МДВ, за винятком прогнозованого значення відсоткового співвідношення ОФВ1/ФЖЄЛ.

Висновки. У разі комбінованого використання ТДМ та ІТ показники плавців підвищуються більше, ніж у разі окремого використання ТДМ та звичайних тренувань. Одержані результати означають, що тренери можуть адаптувати методи ТДМ та ІТ відповідно до індивідуальних вимог плавців із метою покращення показників професійного розвитку та продуктивності, особливо серед спортсменів-плавців.

Ключові слова: індивідуалізовані тренування, тренування дихальних м'язів, функція легень, плавці-студенти коледжу, показники в плаванні.

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