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Immediate effects of chest wall stretching on the pulmonary function of the 21k marathon runners

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Abstract
Introduction: An increased popularity of the marathon running and has been used widely as a model to investigate the limits of physiological function. Sufficient capacity of the respiratory system to meet the endurance exercise demands pressure-generating potential from the respiratory muscles. Marathon running is sufficient to induce substantial reductions in pulmonary function which are directly influenced by aspects of respiratory muscle fatigue. The respiratory muscle fatigue has been evidenced by decrements in inspiratory and expiratory mouth pressures, FEV1, FVC and MVV. The effectiveness of stretching protocols on the muscular systems are known and hence are given to recover from fatigue of the endurance run. These mostly comprise of the lower body stretches but the respiratory muscle fatigue is left to the time course recovery. The effect of Chest Wall Stretching on dynamic pulmonary function parameters among Healthy Marathon Runners remains unexamined. Therefore, the main purpose of the study was to observe the effect of Chest Wall Stretching on pulmonary function parameters like FVC, FEV1, MVV, SpO2, RR, PR changes in 21k marathon runners.
Materials and methodology: Study design was Quasi-Experimental study design. Study was conducted on 8th edition of Shaheed Marathon 21k Runners. Sampling method used was convenient sampling on a sample size of 60 subjects. Elite Normal healthy 21k runners of age group 25-45 years, both male and female with normal BMI were included in the study. Subjects with any respiratory, cardiac, musculoskeletal and neurological pathology with 5k and 10k runners were excluded.
Results: Significant changes in pulmonary function parameters with FVC, MVV, SpO2, RR and PR ($p=<0.0001$) was seen showing increase in their ventilatory volumes. FEV1 ($p=0.03$) showed significant improvements in individual groups but in comparison there was no statistical significance in between the two groups in 21k marathon runners.
Conclusion: It can be concluded that Chest Wall Stretching is significantly effective in improving the Ventilatory Parameters thus, reducing the acute effects of respiratory fatigue, of the Marathon Runners in comparison to Conventional Lower limb Streching hence it can be incorporated as one of the Therapeutic Stretching maneuvers after endurance running.

Keywords: Chest wall stretching, forced vital capacity (FVC), forced expiratory volume in one second (FEV1), maximum voluntary ventilation (MVV), saturation of oxygen (SpO2), respiratory rate (RR), pulse rate (PR)

Introduction
The last few decades have seen an increased popularity of the marathon running and have been used widely as a model to investigate the limits of physiological function. The physiological demands of marathon events are substantial, affecting multiple body systems, thus providing an excellent model to study the adaptive responses to extreme load and stress [1]. In healthy humans, the respiratory system is considered to have sufficient capacity to meet the endurance exercise demands on pulmonary ventilation and gas exchange. For exercise ventilation the subjects demands both maximal oxygen uptake ($\dot{V}O_{2max}$) and maximum cardiac output ($\dot{Q}$) [2, 3], and changes in intrathoracic pressure resulting from contractions of the respiratory muscles approximate 40–50% of their pressure-generating potential [4]. Respiratory muscle work is a critical determinant of the magnitude of inspiratory muscle fatigue [5, 6], and the cardiorespiratory demands of a typical marathon up to 75% $\dot{V}O_{2max}$ 7 are likely sufficient to compromise respiratory muscle contractile function via reductions in Ca^{2+} availability in the sarcolemma [8]. Accordingly, there is now a growing body of work suggesting that the respiratory demands of prolonged endurance exercise may compromise resting pulmonary

function, as well as attenuate the functional work capacity of the respiratory muscles, both of which might impact on health and endurance performance.

Several of the studies on pulmonary function following distance running-Maron *et al*. (marathon) [8], Ross *et al*. (marathon) [9] and Mahler and Loke (ultra-marathon) [10] made their assessments immediately after exercise, with follow-up measurements at 24 h post-race, by which time parameters had returned to baseline. Critically, both Mahler and Loke and Ross *et al.* made additional assessments at 2.5 h and 4 h post-race, respectively, by which point values had partially-recovered. Such a time-course of recovery (i.e., a transient decrease in function that recovers within a few hours), suggests that pulmonary function may have been influenced by a degree of respiratory muscle fatigue.

More recently, Vernillo *et al.* used the absolute distance and unique terrain of extreme-endurance exercise as an excellent model to assess the adaptive potential of the human respiratory system. The researchers assessed spirometry before, during and immediately after a 330-km mountain ultra-marathon [11]. The main findings were congruent with the existing data, i.e., significant post-race decreases in FVC (9.5%), FEV_1 (9.7%) and PEF (8.7%), but the ratios of FEV_1/FVC, and FEV_1/PEF were reasonably well-maintained pre-to-post race, thereby discounting lower- and upper-airway obstruction, respectively. There was a significant post-race reduction in the maximum voluntary ventilation in 12 seconds (MVV_{12}), which led the authors to attribute their findings, at least in part, to a fall in respiratory muscle endurance. Collectively, these studies suggest that marathon running is sufficient to induce substantial reductions in pulmonary function and which are likely to be influenced by aspects of respiratory muscle fatigue. The respiratory muscle fatigue has been evidenced by decrements in inspiratory and expiratory mouth pressures, FEV1, FVC and maximum voluntary ventilation [12, 13, 14, 15].

Stretching is defined as application of pressure to the muscular structures to increase the length of the muscle for improving the range, reducing fatigue and soreness. Stretching has been shown to reduce electromyographic median frequency fatigue of back extensor muscles and thereby enhanced coping with pain. Smaller decreases and more rapid return of strength after delayed onset muscle soreness (DOMS) were observed. The effectiveness of stretching protocols on the muscular systems are known and hence are given as cool down exercise for recovery from fatigue of the endurance run. These mostly comprise of the lower body stretches but the respiratory muscle fatigue is left to the time course recovery and is not given special effort to somehow reduce the respiratory fatigue and hence promoting better recovery. Various research studies demonstrated that just Intercostal stretching improved expired tidal volume, decreased the level of dyspnea level and increased chest expansion clinically which results in better gaseous exchange in human subjects (Leelarungrayub *et al*., 2009 [16, 17]. Bethune, 1975. Chest wall muscle stretch is performed actively by thoracic mobility exercises comprising thoracic rotation, Pectoral muscle stretch, Rhomboid muscle Stretch, lateral thoracic stretching, latissimus dorsi stretch, Serratus muscle stretch, Trapezius Stretch and the Anterior Chest Wall Strech. (Leelarungrayub *et al*, 2009 [18]. The external IC muscles which are helpful during inspiration showed a higher discharge activity during forcible inhalation. The increase in muscle activity of the IC muscles could lead to increase in lung volume and capacities. According to Puckree *et al*. (2002) [18], IC stretching is effective in improving breathing pattern and respiratory muscle activity among healthy conscious adults. However; none of the research studies examined the effect of Chest Wall Stretching on dynamic pulmonary function parameters among Healthy Marathon Runners. Therefore, the main purpose of the study was to observe the effect of Chest Wall Stretching on pulmonary function parameters like Forced Vital Capacity (FVC), Forced Expiratory volume in one second (FEV1), Maximum Voluntary Ventilation (MVV), Saturation of Oxygen (SpO2), Respiratory Rate (RR), Pulse Rate (PR) changes in 21k marathon runners.

Materials and methodology

Study design was Quasi-Experimental study design. Study was conducted on 8th edition of Shaheed Marathon 21k Runners. Sampling method used was convenient sampling done on a sample size of 45 subjects. Elite Normal healthy 21k runners of age group 25-45 years, both male and female with normal BMI were included in the study. Subjects with any respiratory, cardiac, musculoskeletal and neurological pathologies with 5k and 10k runners were excluded

Outcome Measure: Pulmonary Function Test Equipment (FVC, FEV_1, MVV), Pulse-Oximeter – (RR, PR, SaO_2).

Procedure

After obtaining ethical clearance from the committee subjects were selected on the inclusion and exclusion criteria by convenient sampling method. An informed consent was obtained from the subjects. Each subject was explained in detail the functioning of the equipments used and the purpose of the study and its non-invasive nature. The recordings of each individual PRE and IMMEDIATE after RUN assessment of their pulmonary function was done using the SPIROVIT SP-1 SCHILLER PFT Equipment for FVC, FEV_1, MVV values and Vital Parameters PR RR and SaO_2 was done by the Olex Portable PULSE OXIMETER. After their 21k run they were randomly assigned into three groups,

Group A- Chest Wall Stretching and Conventional Stretching

Group B- Chest Mobility Exercises and Conventional Stretching

Conventional Stretch included 30seconds Passive Stretch to the Hamstrings, Quadriceps, Hip Adductors, Illiopsoas, Glutei, Dorsiflexors and Plantarflexors.

Chest Wall Stretching included 30 seconds Pectoral muscle stretch, Rhomboid muscle Stretch, lateral thoracic stretching, latissimus dorsi stretch, Serratus muscle stretch, Trapezius Stretch and the Anterior Chest Wall Stretch.

Chest Mobility Exercises included 5 repetitions of the simple anterior, lateral, rotatory chest movements, lateral neck movements.

Post stretch Assessment of Group A, B, C for their pulmonary function was done using the SPIROVIT SP-1 SCHILLER PFT Equipment for FVC, FEV_1, MVV values and Vital Parameters PR RR and SaO_2 was done by the Olex Portable pulse oximeter.

Data was analyzed using appropriate statistical measures with student's t-test by SPSS software.

Result

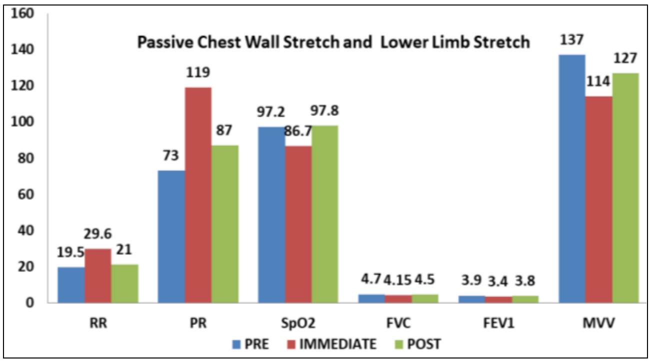
Statistical analysis was carried out utilizing SPSS software. Paired't' test and anova was utilized to analyze the data. The result were concluded to be statistically significant with $p<0.0001$.

Respiratory rate was calculated using post intervention data in both the groups. The mean value of respiratory rate in group A was 27±1.6 and in group B 24±2.9. Pulse rate was calculated using post intervention data in both the groups. The mean value of Pulse rate in group A was 87±5.5and in group B 93±2.4. SpO2 was calculated using post intervention data in both the groups. The mean value of SpO2 in group A was 97.6±1.3 and in group B 97.7±1.6. Functional vital capacity was calculated using post intervention data in both the groups. The mean value of FVC in group A was 4.5±0.15 and in group B 3.4±0.3. Forced expiratory value in 1sec. was calculated using post intervention data in both the groups. The mean value of Forced expiratory value in 1sec in group A was 3.8±0.19 and in group B 2.6±0.30. Maximum Voluntary Ventilation was calculated using post intervention data in both the groups. The mean value of MVV in group A was 127±22.12 and in group B 103±19.2.

Table 1: Comparison of Pre, Immediate and Post Passive Chest Wall Stretch and Lower Limb Stretch (Group A)

Measurement	Pre Mean ±SD	Immediate Mean ±SD	Post Mean ±SD	P value
RR	19.5±2.5	29.6±1.4	21±1.16	<0.0001
Pulse rate	73±6.9	119±7.9	87±5.5	<0.0001
SpO2	97.2±5.5	86.7±3.3	97.8±1.3	<0.0001
FVC (L)	4.7±0.1	4.15±0.20	4.5±0.15	<0.0001
FEV1	3.9±0.3	3.4±0.2	3.8±0.1	0.0007
MVV	137±21.8	114±23.4	127±22.1	<0.0001

On comparison of pre-post chest wall stretch and lower limb stretch in 21k marathon runner using student 't' test, p value was 0.0001, which was statistically significant.

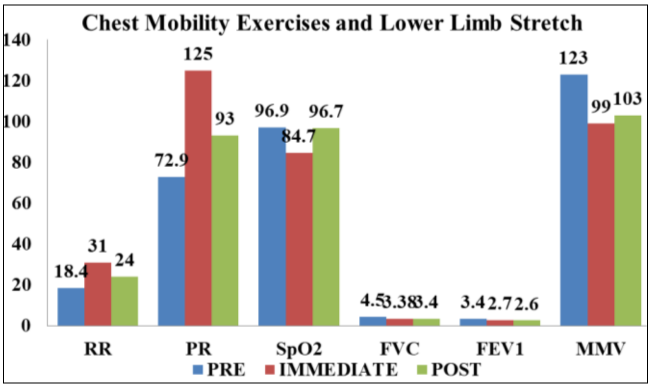


Graph 1: there was statistical significant difference in pre-test and post-test value on comparison of chest wall stretch and lower limb stretch in 21k marathon runner

Table 2: Comparison Pre, Immediate and Post Chest Mobility Exercises and Lower Limb Stretch

Measurement	Pre Mean ±SD	Immediate Mean ±SD	Post Mean ±SD	P value
RR	18.4±1.8	31±1.5	24±2.9	<0.0001
Pulse rate	72.9±5.6	125±5.5	93±2.4	<0.0001
SpO2	96.9±1.5	84.7±2.4	96.7±1.16	<0.0001
FVC (L)	4.5±0.2	3.38±0.33	3.4±0.35	0.0009
FEV1	3.4±0.9	2.7±0.36	2.6±0.30	0.03
MVV	123±16.8	99±20	103±19.2	0.001

On comparison of pre-post chest mobility exercises and lower limb stretch in 21k marathon runner using student 't' test, p value was 0.0001, which was statistically significant.

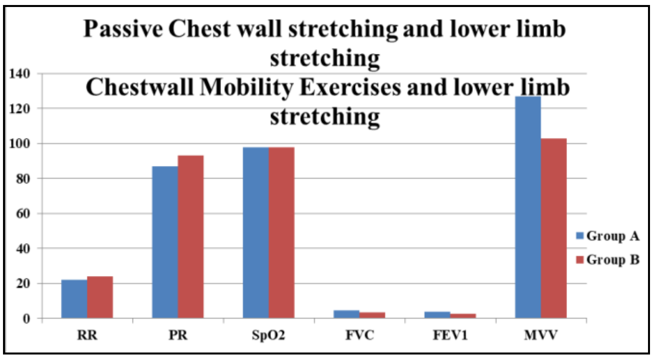


Graph 2: there was statistical significance difference in pre-test, immediate test and post-test values in comparison of chest wall mobility exercises and lower limb stretch in 21k marathon runner.

Table 3: Comparison of Passive Chest Wall Stretching and Lower Limb Stretching Versus Chest Mobility Exercises and Lower Limb Stretching.

Measurement	PCWS Mean ±SD	LL Mean ±SD	t value	Mean difference	P value
RR	21±1.6	24±2.9	2.49	-2.8	<0.0082
Pulse rate	87±5.5	93±2.4	3.41	-6.3	<0.0001
SpO2	97.8±1.3	96.7±1.6	1.98	-1.1	<0.0001
FVC (L)	4.5±0.15	3.4±0.3	8.8	1.07	0.0001
FEV1	3.8±0.19	2.6±0.30	11.8	1.19	0.03
MVV	127±22.12	103±19.2	2.08	24.1	0.001

On comparison of passive chest wall stretching and lower limb stretching versus chest wall mobility exercises and lower limb stretching 21k marathon runner using student 't' test, p value was 0.0001, which was statistically significant.



Graph 3: there was statistical significance difference in post-test value are comparison of of passive stretch wall stretching and lower limb stretching versus chest wall mobility exercises and lower limb stretching in 21k marathon runner.

Discussion

The results in the present study indicates that Passive Chest Wall Stretching is significantly effective in improving the Ventilatory Parameters thus, reducing the acute effects of respiratory fatigue, of the Marathon Runners in comparison to Conventional Lower limb Streching. Significant changes in pulmonary function parameters with FVC, MVV, SpO2, RR and PR (p=<0.0001) was seen showing increase in their ventilatory volumes. FEV1 (p=0.03) showed significant improvements in individual groups too.

Respiratory rate

There was a significant difference in between both the groups for the values of respiratory rate. Comparing the mean difference it can be concluded that the respiratory rate recovered better in Group A than Group B with as the respiratory muscles were stretched. A similar study performed on healthy adults by Puckree *et al.* (2002) [19] studied the effect of IC stretch on third and the eighth IC space in which they proved there was decrease in breathing frequency, the rate of respiration lessened as the Intercostal stretch was performed. The full thoracic expansion due to Chestwall Stretching more space for overall lung expansion thus reducing the dead space during perfusion[18]. Hence, it can be incorporated as one of the Therapeutic Stretching maneuvers after endurance running.

Pulse rate

The pulse rate recovery was statistically significant in both the groups but better for the Group A than Group B being statistically significant (p <0.0001), thus the Group A responded haemodynamically better with chest wall stretching than conventional stretching. This recovery could be accountable to increase in the cardiac output up to 14-16% being directed to the respiratory muscles than the locomotor muscles as found by Harms *et al*. in his study Effects of respiratory muscle work on cardiac output and its distribution during maximal exercise. Thus recovering the pulse rate better than the Group B[3].

Saturation of oxygen

Comparing the mean difference it can be concluded that the Post-exercise oxygenation improved as alveolar ventilation improved with respiratory muscles stretching significantly (p<0.0001), of Group A over Group B. similar effects were observed by Chang A *et al*. in his study on Ventilatory effects of neurophysiological facilitation and passive movement in patients with neurological injury concluded increase in the satuaration of oxygen due to sensory stimulation. The increase expansion with chest wall stretching helped improve intra-thoracic lung volume which contributed to improvement in flow rate percentage. This may contribute to the increase in ventilatory capacity such as tidal volume, minute ventilation and oxygen status [19].

Forced vital capacity, forced expiratory volume (one sec), maximum voluntary ventilation

There was a significant difference in between both the groups for the values of FVC, FEV1 and MVV (0.0001, 0.03, 0.001). Comparing the mean difference it can be concluded that the Forced Vital Capacity recovered better in Group A than Group B. The reductions in the ventilatory parameters immediately post marathon of FVC, FEV1 and MVV were accountable to respiratory muscle fatigue post marathon running. The improvement in respiratory outcome measures after stretching maneuver that involves the application of manual or mechanical force to elongate or lengthen the structures could be due to increase in shoulder quadrant muscles lengthening, and intercostal muscle lengthening. According to the theory of Laplace’s law suggests that the length of muscle relates to the maximal force of either diaphragm or intercostal muscles, which affect ventilation in the lung. Chest mobilizations help to increase chest wall mobility, flexibility, and thoracic compliance, so improved mobility allows an individual to breathe more effectively and deeply [20].

Puckree T *et al*. in their study IC stretch alter breathing pattern and respiratory muscle activity in conscious adults found similar results on the static and dynamic parameters of FVC, FEV1 and MVV as this study, they reported that applying manual techniques such as IC stretch may produce a suitable amount of plastic deformation of connective tissue to enhance mobility at joints [18].

The goal of Functional Streching is to comfortably and efficiently make the athlete recover as much mucus as possible from the haemodynamicaly elevated parameters due to respiratory fatigue and the muscular fatigue. The addition of chest wall stretching alongwith conventional stretching helped the athletes recover better and earlier than otherwise would require more time and energy being expended and hence proved to be an effective form of stretching procedure which should be involved as cool down protocol after each long distance running.

Limitation of the study

1. Study duration was short.
2. Recovery parameters after one hour could have been recorded

Recommendations for future study

1. Study duration can be increased
2. Recovery respiratoy and haemodynamic parameters can be studied over a longer period of time.

Conclusion

This study concludes that Chest Wall Stretching with Lower limb Streching is significantly effective in improving the Ventilatory Parameters thus, reducing the acute effects of respiratory fatigue, of the 21k Marathon Runners in comparison to Chest wall Mobility Exercises and Lower limb Streching hence it should be incorporated in the Therapeutic Stretching maneuvers after each endurance running.

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