

CHANGE IN RESPIRATORY MUSCLE STRENGTH AND LUNG FUNCTION AFTER SPRINTS, MIDDLE AND LONG-DISTANCE RUNNING

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Abstract

Role of respiratory muscles in running is important as same as work of limbs. Because of fatigue in the respiratory muscle can impair exercise performance. So, it necessary to investigate respiratory muscle fatigue (RMF) after running. Hence, this study investigated RMF after sprints, middle and long distance running. 54 experienced male runners (18 sprinters (100 m, 400 m), 18 middle distance runners (800 m, 1,500 m) and 18 long distance runners (5,000 m, 10,000 m) participated in this study. Maximal inspiratory and expiratory pressure (MIP, MEP) and lung function parameter were recorded before and immediately after running. Whereas heart rate (HR) and respiratory rate (RR) were recorded during running. The results show that MIP were lower than baseline after running at all distances except 1,500 m but statistically not significantly different. MEP after 400 m and 5,000 m were significantly lower than baseline (-8.66% [p = 0.009] and -10.88% [p = 0.008]). FVC was significantly lower than baseline for 100 m, 800 m, 1,500 m and 10,000 m and FIVC was significantly lower than baseline for 100 m and 800 m. In addition, there was a significant correlation between percent change of MEP and RRmax during running ($R = 0.318$, $p = 0.021$). Hence, expiratory muscle fatigue (EMF) were found after 400, 5,000 m. EMF after 400m may be due to expiratory muscle has to perform as core muscle and respiratory muscle. While, EMF after 5,000 m may cause by a high respiratory rate during running. So, type of respiratory muscle training should be different for sprinters and long distance runners.

Keywords: Lung function, Respiratory muscle, Respiratory muscle fatigue, Runners, Sprinters

Introduction

The role of the respiratory muscles during exercise and the decrement of exercise performance due to respiratory muscle fatigue is well known (Derchak *et al.*, 2002; Aliverti, 2016; McConnell and Lomax, 2006; Romer *et al.*, 2006). Exercise performance can be limited at high respiratory muscle load. Accumulation of lactate stimulates “inspiratory muscle metaboreflex” causing limb fatigue by

activating limb vasoconstriction and reduced blood flow (Romer *et al.*, 2006). In addition, Suzuki (1992) found that respiratory muscle function has an influence upon perception of effort during exercise. When respiratory muscles work at a high level, the perception of effort is greater (McConnell, 2009). Studies tried to examine change of respiratory muscle function following exercise and to determine

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how intensity and duration of exercise affect respiratory muscle fatigue. Dempsey *et al.* (2006) reported that respiratory muscles have a high aerobic ability and naturally resist fatigue at low to moderate exercise intensities. Although they are sensitive to fatigue during high intensity exercise ($>80\%$ of $\text{VO}_{2\text{max}}$) with long duration (Vanhatalo *et al.*, 2011). In addition, respiratory muscle fatigue was observed following short duration exercise (<30 min) with maximal intensity ($>75\%$ $\text{VO}_{2\text{max}}$) (Coast *et al.*, 1990; Ozkaplan *et al.*, 2005). Moreover, Hodges and Gandevia (2000) found that diaphragm work as respiratory muscle and postural control muscle during repetitive upper limb movement. Diaphragm EMG activity was relate to upper limb movement at the movement frequency. So, rate of diaphragm activation may rely on speed of upper limb movement which may be different in each running distance. However, these studies were conducted in laboratory. Field study (observation), inspiratory muscle fatigue was shown in prolonged submaximal exercise for instance marathon (Loke *et al.*, 1982; Ross *et al.*, 2008) and short duration exercise as 400 m and 800 m running (Ohya *et al.*, 2016) but lack of the studies concerning expiratory muscle function and cardiovascular response in sprints, middle and long distance running. Moreover, there were no studies comparing change in respiratory muscle strength and cardiorespiratory response for 100 m, 400 m, 800 m, 1,500 m, 5,000 m and 10,000 m running. Thus, the purpose of this study is to investigate respiratory muscle fatigue and cardiorespiratory response in sprints, middle and long distance running. Respiratory muscle fatigue were presented by decrement of maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP). Cardiorespiratory response were presented by Heart rate (HR) and respiratory rate (RR) during running.

Materials and Methods

54 male runners from nine athletic clubs (Athletics Association of Thailand, Thammasat University Athletics Club, Pathum Thani Province Sport Association, Royal Thai Naval Academy Athletics Club, Chulachomklao Military Academy Athletics Club, Nakornnont Sport Institute, Naval Ordnance Department Athletics Club, Sattahip Naval Base Athletics Club and Naval Rating School Athletics Club) participated in the current study. All participants had an experience in running at least one years, no experience in respiratory muscle training, no current injuries which limit running performance and no history of chest wall and respiratory system surgery, and all of them were

informed and signed the consent form that had been approved by the Thammasat University Ethics Committee No.078 /2561.

Protocol

Participants had to attend two visits, on the first visit to collect baseline information and to perform respiratory muscle strength test and lung function test, on the second visit to collect their running test. Heart rate (HR) and respiratory rate (RR) were recorded during running. Immediately after running, they had to repeat respiratory muscle strength test and lung function test.

Respiratory Muscle Strength Test

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured with a portable hand-held mouth pressure meter (Micro RPM, Micro Medical Ltd., Kent, UK). Following the technique of Black & Hyatt, 1969 (Black and Hyatt, 1969). The participants were encouraged to breath at maximal effort for 2-3 s, and verbal encouragement was given to help them perform maximally. A minimum of five and a maximum of ten technically satisfactory measurements were conducted, and the highest of three measurements with 5% variability or within a 5 cm H_2O difference was defined as maximum (Wen *et al.*, 1997).

Lung Function Test

Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), Forced inspiratory vital capacity (FIVC), force inspiratory volume in 1 sec (FIV_1) and maximum voluntary ventilation (MVV) were measured with a standard spirometer (Micro I, Micro Medical Ltd., Kent, UK). These maneuvers were performed following the ATS/ERS 1296 E. guidelines for standardization of spirometry (Miller *et al.*, 2005).

Heart Rate and Respiratory Rate Measurement

Heart rate (HR) and respiratory rate (RR) were measure by a Zephyr BioHarness (ZephyrTechnology, Auckland, New Zealand) during running. Zephyr BioHarness is a wireless chest-based wearable device, capable of real-time and long-distance recording of various physiological parameters including HR and RR (Nazari *et al.*, 2018). They had to wear this device at their lower chest all the time during warm-up period and running test.

Running Test

On the second occasion, they had to perform their own distance running test on standard synthetic athletics track. Sprinters perform starting position with block start. Middle and Long distance runners

perform starting position without block start. They demonstrated their regular warm-up program 15 to 45 min and rest before running with maximal effort. The warm-up and resting period were determined by runners depended on their personal routine which enhance their maximum performance. Running time should not exceed their best record by more than 10 percent as shown in Table 1.

Statistical Analysis

All results were express as Mean $\pm$ SD(CV). Kolmogorov-Smirnov test was used to confirm normal distribution for these data. Paired t-tests were used to statistically analyze the differences between pre and post of MIP, MEP, FEV1, FVC, FEV1/FVC, FIVC, FIV1, and MVV in every running distance. One-way ANOVA was used to compare average percent change of MIP, MEP and maximum heart rate (HRmax), minimum heart rate (HRmin), average heart rate (HRave), maximum respiratory rate (RRmax), minimum respiratory rate (RRmin), average respiratory rate (RRave) among six running distances. Moreover, Pearson's correlation test was used to analyze relationship between per cent change of MIP, MEP, and cardiorespiratory response (HRmax, HRmin, Hrave, RRmax, RRmin, RRave).

Results and Discussion

Participants characteristics including age, weight, height, experience, running time were shown in Table 1. Respiratory muscle fatigue were detected

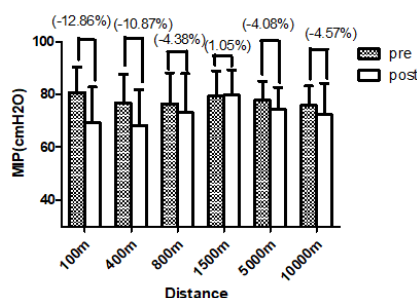


Figure 1 Mean $\pm$ SD of maximum inspiratory pressure (MIP) pre and post running of 100 m (pre = 80.78 $\pm$ 9.58, post = 69.33 $\pm$ 13.42), 400 m (pre = 76.78 $\pm$ 10.86, post = 68.22 $\pm$ 13.59), 800 m (pre = 76.44 $\pm$ 11.66, post = 73.22 $\pm$ 14.69), 1,500 m (pre = 79.44 $\pm$ 9.42, post = 79.67 $\pm$ 9.62), 5,000 m (pre = 77.78 $\pm$ 7.21, post = 74.33 $\pm$ 8.35), 10,000 m (pre = 75.89 $\pm$ 7.29, post = 72.33 $\pm$ 11.85). Values in brackets indicate mean percent difference of pre MIP compared to post MIP

by decrement of MIP, MEP and change of lung function values (FVC, FIVC, FEV1, FIV1, and MVV) after running. Cardiorespiratory response during running were detected by HR and RR.

Respiratory Muscle Strength

MIP were lower than baseline immediately after 100 m, 400 m, 800 m, 5,000 m and 10,000 m running. Especially for 100 m and 400 m distances with -12.86% and -10.87% less than baseline but not enough to make a significant different (100 m $p = 0.088$, 400 m $p = 0.059$). Whereas, MIP after 1500 m was little higher than baseline. However, MEP after 400 m and 5000 m was significantly decreased compared to baseline (-8.66% [$p = 0.009$] and -10.88% [$p = 0.008$]). Mean percent change of MIP and MEP among six running distances were not significantly different. (%change MIP $p = 0.315$, %change MEP $p = 0.803$) as shown in Figures 1 and 2.

Lung Function

FVC was significantly lower than baseline immediately after 100 m, 800 m, 1,500 m, and 10,000 m running with P-values of 0.036, 0.02, 0.001, and 0.009, respectively. Moreover, FIVC was significantly lower than baseline for 100 m ($p = 0.036$) and 800 m ($p = 0.011$) distances. FEV1, FIV1, and MVV tended to be lower than baseline for all distances but were not statistically significantly different as shown in Table 2.

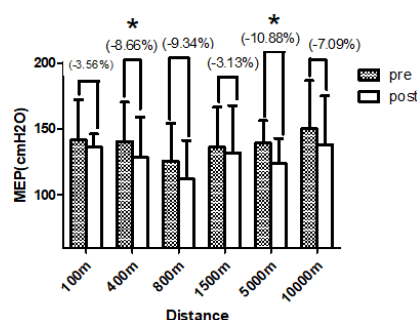


Figure 2 Mean $\pm$ SD of maximum expiratory pressure (MEP) pre and post running for 100 m (pre = 141.56 $\pm$ 30.48, post = 136.11 $\pm$ 29.27), 400 m (pre = 140.44 $\pm$ 29.86, post = 128.44 $\pm$ 30.96), 800 m (pre = 125.67 $\pm$ 28.48, post = 112 $\pm$ 29.01), 1,500 m (pre = 136.11 $\pm$ 30.33, post = 131.89 $\pm$ 35.78), 5,000 m (pre = 139.11 $\pm$ 17.07, post = 123.78 $\pm$ 19.08), 10,000 m (pre = 150.11 $\pm$ 36.43, post = 138.11 $\pm$ 11.85). * Statistically significant difference of MEP between pre and post running ($p < 0.05$). Values in brackets indicate mean percent difference of pre MEP compared to post MEP

Table 1. Participant characteristics shown as mean±SD

Distance (m)	N	Age (years)	Weight (kg)	Height (cm)	Experience (years)	Best record (Sec/Min)	Running test (Sec/Min)	%change of running time
100m	9	18.66±1.0	61.56±6.2	170.78±2.9	4.44±1.8	11.40±0.7s	11.59±0.97s	1.47±3.03
400 m	9	22.67±4.5	65.33±6.06	175.00±2.9	3.56±2.0	56.64±3.24s	58.42±2.16s	4.10±3.72
800 m	9	21.00±2.1	63.78±7.68	172.44±6.3	2.67±1.0	2.30±0.11m	2.37±0.12m	2.75±3.76
1,500 m	9	21.66±4.5	65.44±12.5	171.89±6.3	4.33±1.5	5.15±0.50m	5.48±0.57m	5.91±3.44
5,000 m	9	22.11±3.2	59.56±6.0	171.00±2.2	4.67±4.2	19.45±2.54m	19.56±1.89m	0.87±5.22
10,000 m	9	25.44±4.3	63.78±9.1	172.67±7.4	4.56±1.3	40.60±4.35m	42.22±3.88m	4.16±3.68

Table 2. Lung function parameters pre and post running. (Values are shown as mean ± SD(CV). FEV1: forced expiratory volume in 1 second, FVC: forced vital capacity, MVV: maximum voluntary ventilation, FIV1: forced inspiratory volume in 1 second, FIVC: forced inspiratory vital capacity.)

		100 m	400 m	800 m	1,500 m	5,000 m	10,000 m
FEV1(l)	pre	3.75±0.45(0.12)	3.79±0.48(0.13)	3.67±0.61(0.17)	3.55±0.32(0.09)	3.63±0.33(0.09)	3.91±0.46(0.12)
	post	3.76±0.34(0.09)	3.77±0.45(0.12)	3.60±0.64(0.18)	3.42±0.36(0.11)	3.62±0.36(0.10)	3.86±0.49(0.13)
FVC(l)	pre	4.11±0.41(0.10)	4.23±0.62(0.15)	4.06±0.71(0.17)	3.92±0.55(0.14)	4.17±0.32(0.08)	4.40±0.66(0.15)
	post	3.98±0.34(0.09)*	4.13±0.50(0.12)	3.79±0.63(0.17)*	3.67±0.57 (0.16)*	3.99±0.36(0.09)	4.26±0.71(0.17)*
MVV(l/min)	pre	140.66±17.04(0.12)	142.11±18.21(0.13)	137.78±23.24(0.17)	133.22±12.02(0.09)	136.11±12.51(0.09)	147.00±17.66(0.12)
	post	141.00±19.95(0.14)	141.44±17.06(0.12)	134.89±24.03(0.18)	128.22±13.56(0.11)	135.78±13.26(0.10)	144.78±18.35(0.13)
FIV1(l)	pre	3.96±0.48(0.12)	3.93±0.63(0.16)	3.50±0.84(0.24)	3.57±0.42(0.12)	3.80±0.31(0.08)	3.94±0.55(0.14)
	post	3.86±0.35(0.09)	3.98±0.38(0.10)	3.42±0.77(0.23)	3.60±0.52(0.15)	3.72±0.46(0.12)	3.90±0.62(0.16)
FIVC(l)	pre	4.06±0.44(0.11)	4.10±0.70(0.17)	3.88±0.64(0.16)	3.72±0.37(0.10)	3.91±0.29(0.07)	4.18±0.66(0.16)
	post	3.91±0.35*(0.09)	4.05±0.45(0.11)	3.60±0.67 (0.19)*	3.63±0.53(0.15)	3.87±0.44(0.11)	4.02±0.75(0.19)

* Statistically significant difference values between pre and post running ($p < 0.05$).

Table 3. Heart rate (beats per min) and respiratory rate (times per min) during running in six distances. (Values are shown as mean±SD (CV). (RRmin: minimum respiratory rate, RRmax: maximum respiratory rate, RRave: average respiratory rate, HRmin: minimum heart rate, HRmax: maximum heart rate, HRave: average heart rate.)

	100 m	400 m	800 m	1,500 m	5,000 m	10,000 m
RRmin	21.56±2.60(0.12)	16.63±3.59(0.22)	17.33±5.41(0.31)	13.22±5.84(0.44)	16.67±3.00(0.18)	14.13±2.17(0.14)
RRmax	23.78±2.86 (0.12)*	25.38±6.08 (0.24) *	33.00±8.18(0.25)	26.89±7.64 (0.28)*	40.11±3.89(0.10)	38.88±4.52(0.12)
RRave	22.75±2.59(0.11)	20.74±4.51 (0.22) *	25.56±5.57(0.22)	19.91±6.85 (0.34)*	28.23±4.06(0.14)	27.60±4.46(0.16)
HRmin	149.33±24.51(0.16)#	133.75±18.57(0.14)	116.89±26.12(0.22)	113.78±22.69(0.20)	114.00±17.78(0.16)	93.63±22.34(0.24)
HRmax	167.33±27.20(0.16)#	215.13±20.45(0.10)	223.44±13.17(0.06)	202.00±23.66(0.12)	198.56±16.42(0.08)	200.24±26.73(0.13)
HRave	156.06±24.61(0.16)	182.32±17.62(0.10)	184.68±18.38(0.10)	174.42±13.34(0.08)	180.21±5.94(0.03)	173.10±33.23(0.19)

* Statistically significant difference from 5000 m ($p < 0.05$). #Statistically significant difference from 800 m ($p < 0.05$).

Table 4. Correlation between percent change of expiratory muscle strength and cardiorespiratory response

		%change MEP	Maximum RR
%change MEP	Pearson Correlation	1	0.318*
	Sig. (2-tailed)		0.021
	N	54	54
Maximum RR	Pearson Correlation	0.318*	1
	Sig. (2-tailed)	0.021	
	N	54	54

* Correlation is significant at the level 0.05($p < 0.05$).

Heart Rate (HR) and Respiratory Rate (RR) During Running

The study measured minimum, maximum and average of respiratory rate (RR) and heart rate (HR) during running as shown in Table 3. We found that RRmax and RRave were highest during 5,000 m running. RRmax of 5,000 m significant difference from 100 m, 400 m, and 1,500 m ($p < 0.001$). RRave of 5,000 m significant difference from 400 m ($p = 0.02$) and 1,500 m (0.007). The minimum range of

RR was 14-21 times per min and the lowest RRmin was found in 1,500 m which significant different from 100 m ($p = 0.01$). Whereas, HRmax and HRave were highest during 800 m. HRmax of 800 m significant difference from 100 m. ($p < 0.001$). HRave were not significant difference among 6 distances. The minimum range of HR was 93-149 beats per min. The HRmin was highest in 100 m and significant difference from 800 m (0.046) and 10,000 m ($p < 0.001$) as shown in Table 3.

Correlation Between Change of Respiratory Muscle Strength and Cardiorespiratory Response

We measure the correlation among percent change of maximum expiratory pressure (%change MEP), percent change of maximum inspiratory pressure (%change MIP), Minimum, Maximum and Average heart rate (HR) and respiratory rate (RR). We found that there was a significant correlation between %change MEP and RRmax during running ($R = 0.318$, $p = 0.021$) ($p < 0.05$) as shown in Table 4.

Discussion

This study found that MIP were lower than baseline after running at all distances except 1,500 m but statistically not significantly different. However, MEP after 400 m and 5,000 m running were significantly lower than baseline ($p < 0.05$). In addition, FVC was significantly lower than baseline for 100 m, 800 m, 1,500 m, and 10,000 m and FIVC was significantly lower than baseline for 100 m and 800 m ($p < 0.05$). The interested finding is the significant correlation between %change MEP and RRmax during running ($p < 0.05$). The RRmax and RRAve were highest during 5,000 m running and significant different from 400 m and 1,500 m running. Hence, expiratory muscle fatigue (EMF) was found in 400 m running and 5,000 m running and there were a significant relation between EMF and RRmax during running.

In previous studies, a reduction of inspiratory muscle strength was found after short exercises such as 400 m and 800 m (Ohya *et al.*, 2016) and prolonged exercises as marathon and ultra-marathon (Chevrolet *et al.*, 1993; Ker and Schultz, 1996; Ross *et al.*, 2008). In this study, we found a reduction of inspiratory muscle strength for almost running distances (except 1,500 m distance). Numerous studies reported inspiratory muscle fatigue after short duration exercise. Inspiratory muscle fatigue was found for 400 m, 800 m running (Ohya *et al.*, 2016) and 100 m, 200 m front crawl swimming (Lomax and McConnell, 2003; Brown and Kilding, 2011). Ohya *et al.* (2016) revealed that the diaphragm must control postural stability during sudden voluntary movement of the limbs with the result of inspiratory muscle fatigue after short-duration running exercise. Moreover, the reduction of FVC was found in 100 m, 800 m, 1,500 m, and 10,000 m. and FIVC was found in 100 m, 800 m. running distance. The reduction of both parameters might be due to fatigue of the diaphragm in accordance with the previous finding that weakness of the diaphragm can cause lower FVC values (Dubé and Dres, 2016). Surprisingly, the highest

reduction was observed after 100 m running but not enough to make it statistically significantly different. We cannot clearly explain this result but we assume that it might have been caused by their young age, body mass and inexperience. Most of them were young and slim. They had a few years of training. Klusiewicz *et al.* (2014) found that MIP indicate a stronger dependence on body size and lean body mass in athlete. Moreover, the higher body mass index values were most likely attributable to increases in active tissue due to years of training (Klusiewicz *et al.*, 2014). So, it might cause highly reduction in MIP after 100 m running.

Interestingly, the reduction of expiratory muscle strength was significant for 400 m and 5,000 m ($p < 0.05$). In previous research, reduction of expiratory muscle strength was uncertain after marathon. Some studies found no change of MEP (Hill *et al.*, 1999; Ross *et al.*, 2008). Generally, expiratory muscles are not used at rest but become active in response to exercise (Aliverti, 2016) and contraction of expiratory muscles becomes harder when exercise intensity is high (McKenzie, 2012). Moreover, the metaboreflex which causes vasoconstriction in limb blood flow and decreased exercise performance has been demonstrated in expiratory muscles (Derchak *et al.*, 2002; Verges *et al.*, 2007). Verges *et al.*, 2007 found a significant correlation between the decrement in maximal expiratory mouth pressure (MEP) after resistive breathing and the reduction in running distance ($r^2 = 0.528$, $p = 0.007$). In summary, expiratory muscle fatigue impairs exercise performance similar to inspiratory muscle fatigue. According to our findings, expiratory muscle fatigue apparently happens in 400 m and 5,000 m running.

A new interesting finding is the reduction of MEP after 400 m running. There were no previous studies that mentioned expiratory muscle fatigue after short running distance. We assume that the expiratory muscles have to perform as a respiratory muscle and core stability muscle same as the diaphragm during short duration exercise. (Grillner *et al.*, 1978; Ohya *et al.*, 2016) and this leads to the development of expiratory muscle fatigue. However, further research is required to support this idea by measured muscle activation and muscle oxygen saturation of expiratory muscle during short duration exercise.

On the other hand, the reduction of MEP after 5,000 m running may cause by high respiratory rate during running. RRmax and RRAve were highest in 5,000 m running and there was a significant correlation between percent change of maximum expiratory pressure (MEP) and RRmax during running ($p < 0.05$). Thus, respiratory rate during running is a factor which can induce expiratory

muscle fatigue. Respiratory rate (RR), respiratory frequency (f_R) or breathing rate (BR) is a critical vital sign that provides early detection of respiratory compromise (Eisenberg *et al.*, 2018) and strongly correlates to rate perceived exertion (RPE) more than other physiological variables (Nicolò *et al.*, 2017). Sugiura *et al.* (2013) found that expiratory muscle fatigue regulate the respiratory response by inducing shallow and fast breathing to increase the ventilation volume during medium-intensity exercise. In conclusion, fatigue of expiratory muscles after short distance running may due to expiratory muscles has to perform as a respiratory muscle and core stability muscle during running. Whereas, fatigue of expiratory muscles after long distance running may due to expiratory muscles have to contract consistency and repetitively throughout running.

In the present study, there were two limitations. Firstly, it lacks investigation of some physiological parameters, e.g., blood lactate, oxygen uptake, muscle activation during running. Secondly, the number of participants in each group was too small which prevented statistically meaningful results for some parameters.

Practical Application

Previous study found that expiratory muscle fatigue impaired running performance (Verges *et al.*, 2007). Nevertheless, there were very little research investigate about effect of expiratory muscle training in runners. There were only a study by Bernard *et al.* (2019) which investigated the effect of expiratory muscle training on 5,000 m running in college students and the study found that expiratory muscle training can improve running performance similar to aerobic exercise (Bernard *et al.*, 2019). Thus, expiratory muscle training can improve running performance. However, there is another factor we choose concern about expiratory muscle training is type of respiratory muscle training; resistance training, endurance training. Resistance training can be performed by applying external loads during breathing such as flow resistive load, pressure threshold loading. Endurance training can be performed by using voluntary isocapnic hyperpnoea (VIH) which require subject perform voluntary ventilation at target level during 30 min. According to our finding, respiratory muscle has to work consistency and repetitively during 5,000 m running. Moreover, high respiratory rate can induce expiratory muscle fatigue. So, endurance training is seem to be suitable for 5,000 m runner to develop respiratory muscle endurance capacity. On the other hands, respiratory muscle work during short period

is different. It has to perform as ventilator and core stabilizer. Therefore, resistance training is seem to appropriate for 400 m runner to improve respiratory muscle strength and to prevent respiratory muscle fatigue during running.

Conclusions

Reduction of inspiratory and expiratory muscle strength was found after almost distance running but statistically significant reduction was only found in expiratory muscle strength after 400 m and 5,000 m. Fatigue of expiratory muscles after short distance running may cause by expiratory muscles has to perform as a respiratory muscle and core stability muscle during running. Whereas, fatigue of expiratory muscles after long distance running may due to high respiratory rate during running. According to the different of expiratory muscle function between short and long distance running, type of respiratory muscle training should be different for sprinters and long distance runners. Resistive respiratory muscle training is seem to appropriate for short distance running while respiratory muscle endurance training is seem to suitable for long distance running. However, the present study lacks investigation of some physiological parameters, e.g., blood lactate, oxygen uptake, muscle activation during running and the number of participants in each group was too small. So, further research should investigate more depth in another physiological parameters with more numbers of participant.

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