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DOES SPORTS BRA LIMIT RESPIRATORY FUNCTIONS DURING CONSTANT SPEED EXERCISE?

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ABSTRACT

The present study is aimed to investigate the effects of sports bra on respiratory functions at rest and during exercise. Sixteen healthy females voluntarily and repeatedly participated in 3 randomised trials of no bra (NB), casual bra (CB) and sports bra (SB). They accomplished standard resting spirometers (Static lung volumes included tidal volume (V_T), inspiratory capacity (IC), vital capacity (VC), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), respiratory rate (RR), minute ventilation ($\dot{V}E$); and dynamic lung volumes included forced expiratory volume in 1 second ($FEV_{1.0}$), forced vital capacity (FVC), proportion of forced expiratory volume in 1 second and forced vital capacity (%$FEV_{1.0}$/FVC), maximum voluntary ventilation (MVV), and peak expiratory flow (PEF)) before and immediately after putting on bras. Exercise was conducted on a motor-driven treadmill at constant speed of 4 mph continuously until heart rate reached 60, 70 and 80% of age-predicted maximal heart rate (MHR). Only parts of static lung volumes were detected during exercise in which data were collected. Data were compared at rest, 60, 70 and 80% MHR and every min of 5 min recovery period. Results showed that $FEV_{1.0}$, FVC and MVV were significantly decreased ($p<0.05$) when compared between pre- and immediate post- SB condition. During exercise, there were no significant differences of respiratory functions between bra conditions at 60, 70 and 80%MHR. In conclusion, sports bra exhibit only reductions in dynamic components. This effect disappeared as exercise was commenced. There was no limitation on respiratory function of either static or dynamic components during exercise. The present studies indicated that this brand (Wacoal WR1466) of commercial sports bra does not limit respiratory functions during exercise and may be appropriate for females with active lifestyle.

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KEYWORDS: sports bra, respiratory function, exercise

INTRODUCTION

Popularity of physical activities being performed in women may unpredictably induce adverse effects. Breasts, in particular, displace in either vertical or horizontal direction.[14] Breast discomfort, pain (mastalgia), and injury from extreme motion always occur in active women especially in large breast individuals.[4,14] In addition, such injuries retard exercise ability in active females. [4] External breast support, sports bra, has been introduced to create firm motion during physical exercise. [4,27] Previous studies suggested females to put on sports bra during exercise. On the other hands, too rigid sports bra specially designed for commercial purpose may limit respiratory functions.

Although sports bras have been demonstrated to be more efficient and safe for excess breast motion than other bras, only 13% of adolescent females[18] and 41% of women used sports bra during physical activity. [3] Previous evidence demonstrated that chest straps induced not only tightness and discomfort but also limit motion of thoracic apparatus for example decreased functional residual capacity (FRC)[25] with forced expiratory flow rate (FEFR).[13] This chest strapping negatively affects either resting lung volumes or exercise performance where rapid and shallow breathing were recognized. [22] On the other hand, Bowles and co-workers (2005) found that wearing sports bra during maximal treadmill exercise testing had no significant effect of restriction of respiratory function in healthy active female with small breast. Thus there is no consensus on the effectiveness of sports bra. It is hypothesized that manufactured sports bra may affect respiratory functions and exercise performance. The present study aimed to investigate the effect of wearing a sports bra on respiratory functions and exercise performance at rest, during and after exercise.

MATERIALS AND METHOD

Sixteen healthy active females, with B and C breast cup size, volunteered in this study. They were single and had regular menstrual cycle with no experience in any commercial sports bra. Inclusion criteria included those who were free from cardiorespiratory and musculoskeletal disorders. Testing procedures were approved by the Human Research Ethics Committee of Mahidol University. Health screening, physical activity level, bra size[18] (Wacoal Manufacture) and anthropometric data were identified a week prior to the test. Participants visited at the laboratory on three occasions with randomized exercises using three-bra conditions; no bra (NB), casual bra (CB, periodic bra), and sports bra (SB, WR1466, Wacoal Co. ltd.). For privacy and hygienic reasons, individual sports bra was assigned and only female investigators conducted the experiments in the confidential room. Data were collected at the same phase of menstrual cycle. According to standard method [20] , static lung volumes and capacities (tidal volume (V_T), inspiratory capacity (IC), vital capacity (VC), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), forced expiratory volume in 1 second ($FEV_{1.0}$), forced vital capacity (FVC), proportion of forced expiratory volume in 1 second and forced vital capacity ($FEV_{1.0}$/FVC), maximum voluntary ventilation (MVV), and peak expiratory flow (PEF)) were tested for 2 times of pre-bra (before putting bra on) and post-bra (immediately after putting bra on). Only some dynamic lung functions can be collected during exercise. These included minute ventilation ($\dot{V}_E$), tidal volume (V_T), respiratory rate (RR), heart rate (HR), blood pressure (BP), and subjective indicators of RPE and dyspnea scales. This study was conducted under standard procedure for example participants wore the same sportswear and visited the lab at the same time of the day over the three experimental conditions (NB, CB, and SB).

After 2 min of callisthenic warm up-static stretching and 3 min of 2 mph treadmill walking, exercise protocol at constant speed of 4 mph on an electrical treadmill until 80% maximum heart rate (MHR) was approached. Serial data collection at rest, 60%, 70%, and 80% of MHR, and 5 min recovery were collected.

Statistical analysis

All data were presented as mean ± SD. The *Kolmogorov–Smirnov test* (K–S test) was used for normal distribution testing. If all pulmonary function parameters are normal distribution, repeated measure was used for significant difference analysis, which was accepted at *p*-value less than 0.05. If a significant main effects achieved, Tukey's *post hoc* test will be applied to identify the difference couple.

RESULTS

General Characteristics of Subjects

General characteristics of all subjects in control (no bra), casual (CB), sports (SB) bras including anthropometric data. It showed the mean values and standard deviations of the total (n =16). The averages of age and height were 22.88 ±2.42 year and 161.25 ±6.06 cm, respectively. The averages of weight in NB, CB and SB conditions were 56.45 ±5.79, 56.29 ±5.60 and 56.44 ±5.24 kg respectively. Body mass index (BMI) in NB, CB and SB conditions were 21.70 ±1.77, 21.78 ±1.68 and 21.70 ±1.64 kg.m^{-2} respectively. The percentage of body fat mass in NB, CB and SB conditions were 22.91 ±2.75, 22.93 ±2.70 and 22.78 ±2.59 %, while the percentage of fat free mass in NB, CB and SB conditions were 28.03 ±1.67, 28.17 ±1.60 and 28.15 ±1.69% respectively. The waist in NB, CB and SB conditions were 74.38 ±6.40, 74.66 ±6.83 and 75.53 ±6.15 cm while the hip circumferences in NB, CB and SB conditions were 94.03 ±4.60, 94.88 ±5.02 and 94.34 ±5.19 cm respectively. Resting heart rate in NB, CB and SB conditions were 70.06 ±6.29, 71.63 ±8.10 and 71.33 ±9.67 bpm respectively. The above values were not significant differences (p>0.05) among three bras conditions. In addition, Tidal volumes (V_T) were 0.5 ±0.03, 0.63 ±0.07 and 0.48 ±0.04 liters in NB, CB and SB respectively. Respiratory rates (RR) were 16.79 ±0.87, 17.21 ±2.37 and 18.70 ±1.87 times/min in NB, CB and SB respectively. Minute ventilations ($\dot{V}E$) were 8.67 ±0.34, 8.08 ±0.46 and 9.06 ±0.76 liters/min in NB, CB and SB respectively. No significant differences of all resting variables among three conditions were found.

Table 1. General characteristics of female subjects in control (no bra, NB), casual (CB) and sports bras (SB) groups. Values are mean and SD.

Variables	NB (n = 16)	CB (n = 16)	SB (n = 16)
Weight (kg)	56.45 ±5.79	56.29 ±5.60	56.44 ±5.24
BMI ($kg.m^{-2}$)	21.70 ±1.77	21.78 ±1.68	21.70 ±1.64
Body fat (%)	22.91 ±2.75	22.93 ±2.70	22.78 ±2.59
Lean body mass (%)	28.03 ±1.67	28.15 ±1.69	28.17 ±1.60
Waist (cm)	74.38 ±6.40	74.66 ±6.83	75.53 ±6.15
Hip (cm)	94.88 ±5.02	94.34 ±5.19	94.03 ±4.60
Resting HR (bpm)	70.06 ±6.29	71.63 ±8.10	71.33 ±9.67
Resting RR (br/min)	16.79 ±0.87	17.21 ±2.37	18.70 ±1.87
Resting $\dot{V}E$ (L/min)	8.67 ±0.34	8.08 ±0.46	9.06 ±0.76
Resting V_T (L)	0.5 ±0.03	0.63 ±0.07	0.48 ±0.04

Immediate effects of putting bra on lung volumes and capacities

The study was also aimed to explore the immediate effects of bras on both static and dynamic lung volumes and capacities. Therefore, only pre- and post-casual bra (CB) and pre- and post-sports bras (SB) were studied (Table 2). It was found that neither CB nor SB exerted changes in vital capacity (VC), inspiratory capacity (IC), tidal volume (V_T), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), respiratory rate (RR), minute ventilation ($\dot{V}E$), percent of forced expiratory volume in 1 second (%$FEV_{1.0}$) and peak expiratory flow (PEF). When compared between pre-CB and pre-SB, data revealed that FVC (L) and MVV (L/min) increased in SB than CB ($p<0.05$). In comparison between pre- and immediate post-SB, data showed that force expiratory volume in 1 second ($FEV_{1.0}$, L), force vital capacity (FVC, L) and maximum voluntary ventilation (MVV, L/min) were significantly decreased ($p<0.05$) whereas these characteristics were not found in CB. Subjective evaluation revealed that approximately 50% of subjects indicated uncomfortable feeling as sports bras were immediately putting on.

Table 2. Mean (±SEM) of immediate static and dynamic lung volumes and capacities responses to casual bra (CB) and sports bra (SB).

Condition	CB		SB	
	Pre-Bra	Immediate Post-Bra	Pre-Bra	Immediate Post-Bra
VC (L)	2.89 ±0.1	2.90 ±0.1	2.96 ±0.10	2.92 ±0.12
IC (L)	1.87 ±0.06	1.87 ±0.05	1.89 ±0.06	1.86 ±0.07
VT (L)	0.90 ±0.05	0.87 ±0.04	0.89 ±0.04	0.95 ±0.04
ERV (L)	1.02 ±0.08	1.03 ±0.09	1.09 ±0.07	1.05 ±0.08
IRV (L)	0.97 ±0.06	1.01 ±0.06	0.99 ±0.05	0.92 ±0.06
RR (br/min)	12.25 ±0.54	12.50 ±0.58	13.13 ±0.40	12.88 ±0.46
$\dot{V}E$ (L/min)	10.95 ±0.66	10.97 ±0.64	11.56 ±0.52	12.10 ±0.56
FEV_1 (L)	2.75 ±0.09	2.74 ±0.09	2.8 ±0.09	2.73 ±0.08$^{\infty}$
FVC (L)	3.05 ±0.10	3.06 ±0.10	3.13 ±0.09$^{\beta}$	3.07 ±0.09$^{\infty}$
%FEV_1/FVC	90.06 ±0.40	89.44 ±0.47	89.38 ±0.46	89.13 ±0.55
PEF (L/s)	6.36 ±0.30	6.27 ±0.29	6.46 ±0.28	6.26 ±0.22
MVV (L/min)	104.91 ±3.65	105.51 ±3.54	108.31 ±3.12$^{\beta}$	105.95 ±3.23$^{\infty}$

Abbreviations $^{\infty}$ represents significant difference between pre- and post- condition of the same group, $^{\beta}$ significant difference between pre-CB and pre-SB, and $^{\gamma}$ significant difference between post-CB and post-SB, at p<0.05.

Dynamic profiles of lung volumes and flows during exercises

Female subjects in the present study performed constant speed running at 4 mph with average durations at 60%, 70% and 80% of age-predicted MHR of 7.06 ±1.66, 12 ±2.82, 14.88 ±1.95 min (NB), 8.94 ±2.10, 15.07 ±3.95, 24.60 ±3.54 min (CB) and 8.13 ±1.98, 12.42 ±2.59, 20.78 ±3.70 min (SB) respectively. No significant difference of exercise durations was found among the groups.

Only V_T, RR and $\dot{V}_E$ could be assessed during constant speed, of 4 mph, running. However, the above lung functions were compared at 60, 70 and 80% of age-predicted maximal heart rates. The present study shown that the longer exercise duration induced gradual physiologic strain which showed by increasing of cardiac responses up to 60 to 70 and 80% of age-predicted maximal heart rates (Figure 1). Patterns of changes V_T, RR were dissimilar in that V_T in all groups significantly increased from corresponding resting values (p<0.05) to 1.21 ±0.06, 1.12 ±0.04 and 1.14 ±0.06 L at 60%MHR in NB, CB and SB respectively and approached the plateaus response (Figure1A). No significant differences between group at all three workloads were detected. RR, on the other hands, significantly increased from corresponding resting values to 35.07 ±1.59, 37.98 ±1.65 and 37.98 ±1.89 br/min at 60%MHR in NB, CB and SB respectively (Figure1B). These exercising RR values showed further increased, but no significant differences between group at 60, 70 and 80%MHR. Similar pattern was observed in $\dot{V}_E$ where significantly increased from corresponding resting values (Figure 1C) to 42.53 ±2.46, 42.67 ±2.21 and 43.60 ±2.41 L/min at 60%MHR in NB, CB and SB respectively. These exercising $\dot{V}_E$ further increased, but no significant differences between group at 60, 70 and 80%MHR.

Table 3. Within-group comparisons of changes (mean ±SEM) in tidal volume (V_T in A), respiratory rate (RR in B) and minute ventilation ($\dot{V}E$ in C) of subjects at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 min. recovery period. Abbreviations *represents significant from initial (resting) value and ¶ significant from previous value All values are compared at p<0.05.

Condition	NB				CB				SB			
	V_T (L)	RR (bpm)	$\dot{V}E$ (l/min)	%$\dot{V}E$/MVV	V_T (L)	RR (bpm)	$\dot{V}E$ (l/min)	%$\dot{V}E$/MVV	V_T (L)	RR (bpm)	$\dot{V}E$ (l/min)	%$\dot{V}E$/MVV
Rest	0.51 ±0.03	16.06 ±0.85	8.35 ±0.34	8.18 ±0.45	0.61 ±0.06	16.44 ±1.97*	7.71 ±0.43	7.47 ±0.48	0.48 ±0.03	18.90 ±1.52	8.94 ±0.62	8.36 ±0.65
60%HRmax	1.21 ±0.06*	35.07 ±1.59*	42.53 ±2.46*	41.19 ±1.98*	1.12 ±0.04*	37.98 ±1.65*	42.67 ±2.21*	41.09 ±2.24*	1.14 ±0.06*	37.98 ±1.89*	43.60 ±2.41*	40.31 ±2.13*
70%HRmax	1.18 ±0.06*	41.31 ±2.56*¶	48.31 ±2.63*¶	46.43 ±1.76*¶	1.21 ±0.05*	40.56 ±1.84*¶	49.21 ±2.24*¶	48.45 ±2.63*¶	1.15 ±0.04*	42.67 ±2.32*¶	49.11 ±2.32*¶	42.74 ±3.77*
80%HRmax	1.23 ±0.07*¶	43.42 ±2.36*	51.92 ±3.33*¶	46.93 ±6.14*	1.15 ±0.04*	45.58 ±2.16*¶	51.67 ±2.23*¶	47.05 ±5.01*	1.14 ±0.03*	46.26 ±2.56*¶	53.33 ±3.22*¶	45.66 ±5.33*¶
r1	0.75 ±0.05*¶	30.00 ±2.22*¶	23.56 ±3.12*¶	21.76 ±3.29*¶	0.76 ±0.04*¶	29.93 ±2.47*¶	24.13 ±2.72*¶	23.35 ±2.35*¶	0.72 ±0.05*¶	27.77 ±1.66*¶	21.63 ±2.22*¶	20.52 ±2.45*¶
r2	0.64 ±0.04¶	24.69 ±1.56*¶	16.42 ±1.56*¶	15.27 ±1.88*¶	0.66 ±0.04¶	25.96 ±2.19*¶	18.49 ±2.57*¶	17.96 ±2.25*¶	0.61 ±0.03*¶	24.77 ±1.13*	16.98 ±1.27*¶	15.98 ±1.41*¶
r3	0.60 ±0.04¶	22.60 ±1.49*	13.84 ±0.88*¶	12.85 ±1.29*¶	0.61 ±0.04¶	24.67 ±1.61*	17.27 ±2.56*	16.78 ±2.22*	0.58 ±0.03*	23.69 ±1.12*¶	14.98 ±0.94*¶	14.13 ±1.05*¶
r4	0.60 ±0.04	22.58 ±1.50*	13.67 ±0.71*	12.65 ±1.18*	0.57 ±0.03	22.74 ±1.27*	14.55 ±1.75*	14.07 ±1.56*	0.56 ±0.03*	22.42 ±0.92	13.88 ±0.78*	13.00 ±0.80*
r5	0.63 ±0.06	21.33 ±1.87*	12.89 ±0.68*	11.87 ±1.04*	0.57 ±0.03	22.82 ±1.40*	13.81 ±0.82*	13.46 ±0.92*	0.55 ±0.03*¶	23.29 ±0.94	14.02 ±0.68*	13.05 ±0.62*

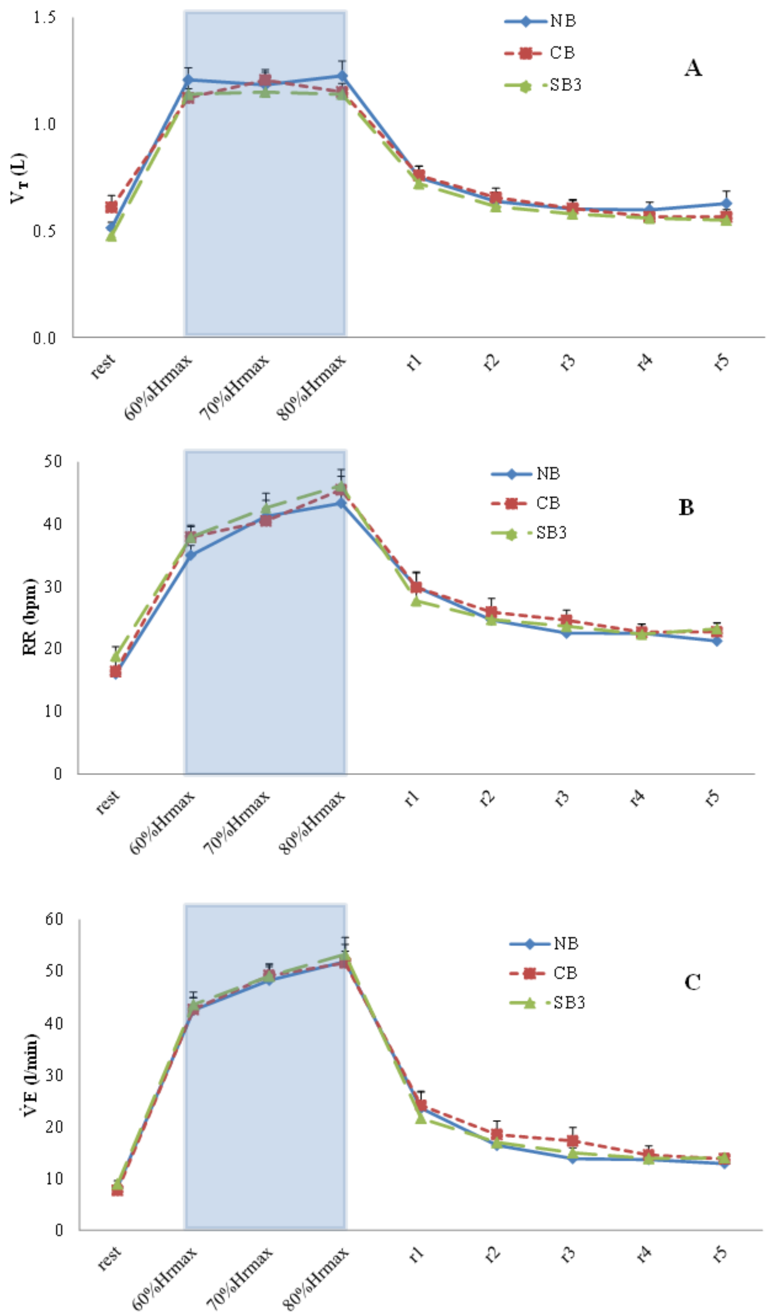

Figure 1. Between-groups comparisons of changes in tidal volume (V_T in A), respiratory rate (RR in B) and minute ventilation (VE in C) of subjects at rest, during exercise at 60%, 70% and 80% of age-predicted maximal heart rates (shaded area), and during 5 min. recovery period. Abbreviations: [a] represents significant between NB-CB, [b] significant between NB-SB and [c] significant between CB-SB. All values are compared at $p<0.05$.

DISCUSSION

All resting variables were in normal ranges of Thai population. [30] Hip and waist circumferences, BMI and other variables indicated that they were in good shapes without overweight problem. Sports bras are considered as a chest wall restriction model. The present study did not measure how hard of compressive force from sports bra. However, subjective investigation from immediate putting on sports bra reviewed the comfortable feeling. Thus, compressive sports bra in the present study seems to be in the minimal range. It was reported that vigorous chest wall restrictions of over than 75 mmHg will cause deteriorations in lung function[12]

It is known that inspiration is an active process whereas expiration is the result of passive recoil of respiratory apparatus. [26] Chest wall restriction, up to 20% decreasing in VC, induced lower FVC, %FEV1.0, PEFR and FEF25-75%.[7] The present study indicated that resting respiratory function remains relatively preserved since there are no tachypnea, no changes in volumes and capacities. Immediate effect of sports bra affects only with dynamic lung function. Previous study indicated that this was caused by significant higher pressure in sports bra compared with casual bra[6] while static lung volumes remained unchanged. Induction of higher pressure can be transferred to the lung and tend to increase intrapleural pressure even at rest[15] which, during expiration, may high enough to cause early airway collapse known as an equal pressure point (EPP) of the airway[21]. It is simply explained there is a progressive increasing in dynamic airway resistance along the ascending tract and tends to diminish flow rates[21]. Our results corroborates with previous investigations which indicated reduction in flows[5] with constant static lung volumes.[16] These studies were performed in external rigid chest wall restriction models, plaster casts and straps, where reductions in pulmonary function were explained by diminution in chest wall compliance. Even though, there are reductions in some flow variables, sports bra is considerably allowed chest wall compliance.

Bras can be considered as a type of external chest wall wrapping which may or may not restrict either thoracic motion or lung functions. This may generally depend on elastic fabrics, style and direction of support. [2] Another focussed factor is the surface area covered by bras. Chest wall area is approximately 18% of whole body surface which is about 0.3 m^2 for a 165 cm, 63 kg woman with moderate cup size.[10, 23] Whereas sports bra covers, from costal margin to shoulder region, about 0.15-0.16 m^2 area. [29] With inappropriate bras, symptoms of inflammation of the costochondral joints include pain in the anterior chest, aching under the breast may be developed.[18] Therefore, unwise clothing options, as well as underwire bras, can damage the delicate thoracic anatomical structure of women.

Immediate effects of wearing sports bra, reductions only in few flow variables, were later found to be disappeared as exercise was commenced. It is quite clear that the immediate effect of sports bra has been overcome by the chemical drive within the body. During low to moderate exercise, increasing in V_T and RR are roughly in the proportion to intensity whereas at higher intensities, V_T reaches a plateau. This means the further increases in $\dot{V}_E$ are accomplished by increases in RR alone.[8] Our results covered all exercise intensities from light, moderate and high levels and indicated the similar breathing pattern. In details, increasing in V_T, at low-to-moderate exercise intensities might contribute for $\dot{V}_E$ by minimizing dead space volume/tidal volume (V_D/V_T) ratio.[9] Increasing in breathing frequency, on the other hand, will induce higher airways resistance which becomes higher during higher exercise intensity even in normal healthy subjects.[26] It was documented that airways resistance at certain parts of the lung became greater as man started cycling.[17] However, it may describe that pressure from sports bra or running speed was not high enough to the level which different affects respiratory response.

CONCLUSION

In conclusion, sports bra exerts no limitation during exercise on respiratory function of either static or dynamic component. Only limitation is found as an immediately effect of bra on resting lung volumes and capacities. Interestingly, this immediate effect disappears during exercise. Thus, there is no main effect of bras on respiratory functions during exercise. No matter whether it is a type of sports bra or not, lung volumes and capacities remain in normal ranges. With friendly fabric elasticity, this conclusion is made only for bras in the study. Further investigations will be made for effects of sports bras on cardiac and thermoregulatory functions.

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