BREATHING PATTERNS IN YOUNG MALE ADULT CHINESE AND INDIANS.

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ABSTRACT

The movements of the rib cage (RC) and abdomen (ABD) bring about the necessary pressure changes that cause the flow of air into and out of the lungs. The pattern of breathing and the relative contributions of RC and ABD to ventilation changes with posture. In the course of our clinical practice, we have observed that Chinese subjects breathe differently from Indians. By the use of respiratory inductive phlethysmography (RIP), we studied the breathing patterns of a small group of young male adult Chinese and Indians in the sitting and supine position. We found that in all subjects, the supine position increased the ABD contribution to ventilation ($p = 0.009$). In the supine posture, the Chinese tended to breathe deeper and slower than the Indians. They also tended to be more irregular in the depth and timing of their breathing than their Indian counterparts (as assessed by the coefficients of variation). In 50% of the subjects (n=32), the volume/Motion coefficient (V/M) changed from the sitting to supine posture, necessitating a recalibration of the RIP. 19/32 of subjects were abdominal breathers in the supine posture and 27/32 were chest breathers in the sit position. As a group, the Chinese and Indians behaved like the subjects in the study by Sharp and colleagues (1).

SING MED J. 1988; 29: 570 – 574

INTRODUCTION

Ventilation in humans arises as a result of a change in the dimensions of the 'chest wall' which comprises not only the rib cage (RC) but also the diaphragm and abdomen (ABD). Konno and Mead (2) in 1967 showed that within limits, the chest wall can be likened to a system which moves with 2 degrees of freedom. Based on this finding, Sharp et al (1) in 1975 studied the breathing patterns in 81 normal subjects using magnetometers to measure displacements. They found that during quiet breathing most subjects were abdominal breathers in the supine position and thoracic breathers in the upright. Observations in our clinical practice and respiratory function laboratory have led us to believe that Chinese patients breathe differently from Indians. For example, liver palpation seems to be easier in Indians than Chinese and breathing seems more irregular in Chinese than Indians during helium rebreathing for determination of functional residual capacity (FRC). We therefore compared the breathing patterns of young adult Chinese with that of a similar group of Indians in both the sitting and supine positions using respiratory inductive phlethysmography (RIP).

METHODOLOGY AND SUBJECTS

Experiment I

We compared the resting breathing patterns of normal young age and height matched Chinese (n=8) and Indians (n=8), (Table 1). All subjects were non-smokers and had no history of asthma or other respiratory diseases.

Ventilation was measured non-invasively in both positions using respiratory inductance phlethysmography (Respitrace) with thoracic and abdominal belts. This was calibrated by the isovolume manoeuvre before both the sitting and supine measurements.

The subjects then breathed into a water spirometer (Warren Collins 6 litres) and tidal breathing was simultaneously recorded both with the water spirometer and the RIP for about 1 minute. Matched tidal breaths were then compared. A calibration factor was then computed by obtaining a mean of each matched breath ratio of RIP reading ($V_{T\ RIP}$) to spirometer reading ($V_{T.\ spiro}$) i.e. $V_{T\ RIP}/V_{T\ spiro}$. This calibration factor was then applied to the subsequent $V_{T\ RIP}$ readings to obtain volume. After calibration was completed, the subject remained seated comfortably in the chair with arms resting at the sides for a further 10 minutes. When the breathing pattern appeared regular on the RIP tracings, a 2 minute sample of tidal breathing was recorded. The data on tidal breathing was based on this record. At the end of this 2 minute recording the RIP was validated by asking the subject to breathe into the water spirometer again. The same calibration factor was then applied to the simultaneous RIP recordings and the volume obtained was then compared with actual spirometer reading. The mean of this validation ratio i.e RIP derived volume/spirometer volume was 1.06. Most of the validation ratios were within the range of 0.9 to 1.1 except for 5 (0.73, 0.88, 0.89, 1.17, 1.25 and 1.27)

The subject then assumed the supine position with a pilow to support the head. The isovolume manoeuvre was repeated to enable resetting the RIP gain when necessary. The spirometer and RIP calibration procedure was repeated in this posture and a new calibration factor ($V_{T\ RIP}/V_{T\ spiro}$) was obtained. A similar RIP recording was obtained in the supine posture as in the seated position following 10 minutes of rest and when the breathing pattern appeared regular on the RIP tracing. Validation was similarly done as in the sitting position and the mean value was 1.04. Almost all the validation ratios were within the range of 0.9 to 1.1 with the exception of 3 (0.82, 0.89 and 1.27). In 8 of the 16 subjects, the volume-motion (V/M)

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Table 1.
CHRACTERISTICS OF SUBJECTS IN EXPERIMENT I.

	Chinese			Indian		
Subject	**Age (yrs)**	**Height (cm)**	**Weight (kg)**	**Age (yrs)**	**Height (cm)**	**Weight (kg)**
1	24	174.2	72.9	27	174.8	59.5
2	27	177.2	56.0	26	178.0	62.7
3	23	168.9	63.2	23	167.6	72.7
4	22	177.8	77.3	24	177.2	80.9
5	27	180.0	80.0	23	179.0	70.0
6	23	170.2	56.7	23	169.0	58.0
7	22	161.3	56.1	22	163.0	55.9
8	23	178.0	70.0	23	178.0	70.0
mean	23.9	173.5	66.5	23.9	173.2	66.2

coefficients changed in the supine posture requiring recalibration. Vital capacity (VC) and expiratory reserve volume (E.R.V.) were also measured in both positions using the water spirometer. The RIP tracings were recorded with a Gould 2800s multichannel recorder. Values for minute ventilation (V_E), frequency of breathing (F_b), tidal volume (V_T), inspiratory time (T_I), expiratory time (T_E), mean breath duration (T_{TOT}) and mean inspiratory flow (V_T/T_I) were obtained in both positions. The relative contribution of RC was depicted as RC/SUM, the SUM being the sum of the amplitudes of the RC and ABD tracings with each breath.

Experiment II

The contributions of RC and ABD during resting breathing (tidal breathing) and the total lung capacity (TLC) manoeuvre in another group of young adult male Chinese (n=9) and Indians (n=7) were studied (Table 2). The RIP was calibrated with the isovolume manoeuvre and RC and ABD movements were subsequently measured (as in experiment I). The breathing loops thus obtained were displayed on a Philips Digital Storage Oscilloscope DM 3310. RC movements were represented on the Y axis and ABD on the X axis. The displays were then captured on Polaroids. In general the respiratory excursions were in form of loops moving in a counter-clockwise direction. The relative contributions of RC and ABD to a single breath were determined by estimating the slope of a line joining the points of 'zero flow' ie end-inspiratory and end-expiratory (or 'peak to trough', PT line). A slope of >45° meant that RC contributed more to ventilation than ABD. The shape and direction of the inspiratory limbs of the loops were also analysed to determine if either the RC and ABD led the other during inspiration. All subjects were asked to perform 2 breathing manoeuvres both in the sitting and supine positions: a) resting breathing b) TLC manoeuvre ie inspiration from FRC to TLC and passive (relaxed) expiration back to FRC. We thought that the act of voluntary deep breathing during abdominal palpation simulates the TLC manoeuvre.

All comparisons were done with unpaired Student's test and two-tailed analysis.

Table 2.
CHARACTERISTICS OF SUBJECTS IN EXPERIMENT II.

	Chinese			Indain		
Subject	**Age (yrs)**	**Height (cm)**	**Weight (kg)**	**Age (yrs)**	**Height (cm)**	**Weight (kg)**
1	23	186	84.6	27	174	78.0
2	22	169	54.4	26	173	66.0
3	28	165	62.2	35	173	87.8
4	28	170	70.8	27	174	61.2
5	24	155	59.6	25	170	61.0
6	22	183	76.6	22	161	50.9
7	27	170	54.0	22	168	70.0
8	21	168	66.2			
9	23	173	97.5			
mean	24.2	172.2	69.6	26	170	67.9

RESULTS AND COMMENTS

Experiment I: Resting breathing patterns and posture.
Findings: (Table 3)

Indices	Sitting (mean)	Supine (mean)	Probability*
1. V_E (mls)	7149	6592	>0.1
2. V_T (mls)	480	469	>0.1
3. F_B (min^{-1})	16	15	>0.1
4. T_I (sec)	1.5	1.6	>0.1
5. T_E (sec)	2.6	2.7	>0.1
6. V_T/T_I (mls/sec)	341.8	303.6	>0.1
7. T_I/T_{TOT}	0.37	0.38	>0.1
8. RC/SUM (%)	62.75	48.13	0.009

* = probability of significance of the difference between sitting and supine mean values.
TABLE 3. Mean values of the indices of breathing for both Chinese and Indians combined.

1) In all subjects, changing from the sitting to supine position did not affect any of the indices of breathing (ie V_T, T_I, T_E, T_{TOT}, F_b, V_T/T_I, T_I/T_{TOT}) except the relative contribution of RC/ABD. As expected, the abdominal displacement increased its contribution to ventilation, Sitting RC/SUM (62.75%) vs Supine RC/SUM (48.13%) (p=0.009). The reduced abdominal contribution in the seated posture may be due to abdominal muscle contraction. This may act to prevent the loss of geometric advantage of the diaphragm that would tend to occur as a result of the inspiratory effect of abdominal hydrostatic pressure on the diaphragm in the upright position. An alternative explanation (offered by Mead and Goldman) for the fall in the RC/SUM ratio in the supine position is the relationship of the anterior diaphragm fibres to the chest wall (1). In the seated position, the anterior fibres are closely apposed to the inner aspect of the rib cage such that diaphragmatic contraction would lift up (and expand) the lower rib cage. The diaphragm-abdomen is thus effectively coupled with the rib cage. Thus in the upright posture, RC displacement is due both to direct RC inspiratory muscle action as well as diaphragmatic action. In the supine posture however, the anterior fibres of the diaphragm fall away from the RC thus uncoupling the diaphragm from the RC. Diaphragm action would thus not translate into RC displacement and may indeed impede it (Figure 1). An analysis of the individual RC/SUM values

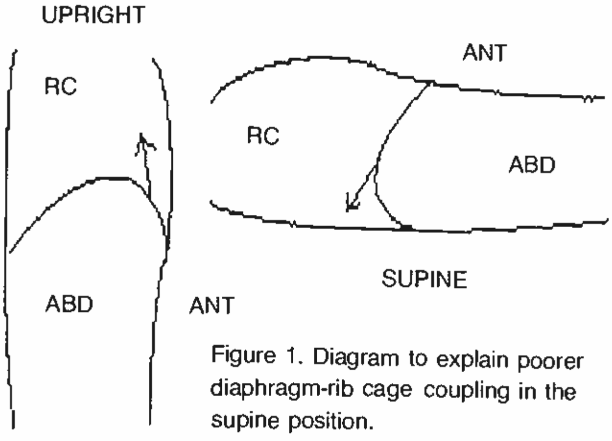

Figure 1. Diagram to explain poorer diaphragm-rib cage coupling in the supine position.

showed that in the sitting position, 6/8 Chinese and 5/8 Indians were chest breathers (RC/SUM > 50%) while in the supine position, 4/8 Chinese and 5/8 Indians were abdominal breathers (RC/SUM < 50%).

2) The Chinese tended to breathe deeper (ie larger V_T) than the Indians especially in the supine position and this was mainly due to an increased V_T/T_I rather than T_I.

In the sitting position, Chinese V_T was not significantly greater than Indian V_T, (p=0.198 n.s., Table 4). In the supine position however, Chinese V_T was significantly greater than Inidan V_T (P=0.033) and Chinese V_T/T_I was greater than Indian V_T/T_I (p=0.08). There was no significant difference between Chinese T_I and Indian T_I (p>0.1). However, when V_T was expressed as %VC (correcting for size), the trends and significance disappeared.

Indices	Chinese sitting*	Chinese supine*	Indian sitting*	Indian supine*
V_T	552.5	577.8	406.6	359.4
	+/−236.5	+/−208.9	+/−159.6	+/−128.6
T_I	1.68	1.78	1.31	1.46
	+/−1.02	+/−0.85	+/−0.25	+/−0.4
T_E	3.21	3.38	2.04	2.07
	+/−1.59	+/−1.44	+/−0.35	+/−0.40
V_T/T_I	377.9	355.6	305.8	251.6
	+/−190	+/−130.6	+/−86	+/−64.3

* = mean values +/− 1 Std. deviation
TABLE 4. Mean values of some indices of breathing for both Chinese and Indians in the sitting and supine positions (see text for probabilities of comparisions)

3) The Chinese tended to have greater variability in their breathing than the Indians especially in the supine posture ie more irregular in depth (V_T) and timing (T_E) as assessed by the coefficients of variation (COV). In both sitting and supine postures combined, Chinese $T_{E\,(COV)}$ (16.84 ±9.67 [±1 SD]) was more than Indian $T_{E\,(COV)}$ (9.49 ±8.83) (p=0.038) and Chinese $V_{T\,(COV)}$ (20.26 ±9.59) was more than Indian $V_{T\,(COV)}$ (15.43 ±4.77) (p=0.09). In the supine posture, Chinese $T_{E\,(COV)}$ (16.44 ±7.05) was greater than Indians $T_{E\,(COV)}$ (8.96 ±8.43) (p=0.09).

4) The Chinese also tended to have longer expiratory pauses than the Indians especially when supine. In the sitting position, Chinese T_E was greater than Indian T_E (p=0.079). In the supine position, Chinese T_E was significantly greater than Indian T_E (p=0.037). Chinese F_b (13.5 ±5.7) was comparatively lower than Indian F_b (16.6 ±3.5) (p>0.1).

5) The effect of the supine posture on the control sitting values was similar in both Chinese and Indians ie supine : sitting ratio (Chinese) vs supine : sitting ratio (Indian) showed no significance in all parameters. Therefore, posture affected the Chinese and Indians similarly.

Conclusions of Experiment I.
1. As a group, the Chinese and Indians behaved similarly to the subjects in Sharp's study in that the ABD contribution increased in the supine posture.
2. The Chinese tended to breathe slower, deeper and more variably (both in depth and timing) especially in the supine position.
3. Changing from the sitting to supine position affected the Chinese and Indians similarly.
4. The V/M coefficients changed in 50% of all subjects on changing from the sitting to supine postures requiring recalibration of RIP.

Experiment II.

Findings:

1) V/M coefficients.

As in Experiment I, the V/M coefficients changed with postural change in 8 out of 16 subjects.

2) During tidal breathing.

Sitting position:

RC displacement was greater than ABD displacement (ie PT >45°) in all subjects whereas in Experiment I, 11/16 subjects were chest breathers.

Supine position:

In all subjects, shifting to the supine position consistently caused a decrease in the RC displacement relative to the ABD. In 3/7 Indians and 7/9 Chinese ($p > 0.1$), the relative reduction of RC was so great that the abdominal displacement was predominant (ie PT <45°). In Experiment I, 5/8 Indians and 4/8 Chinese had greater abdominal displacements in the supine position.

3) Loops.

In all subjects in both sitting and supine positions, there was some degree of looping and generally in the counter-clockwise direction. However, in the supine position, in 5 out of 8 Chinese the initial part of the inspiratory limb was almost horizontal indicating predominantly (if not solely) abdominal displacement with hardly any RC displacement. (see Figure 2).

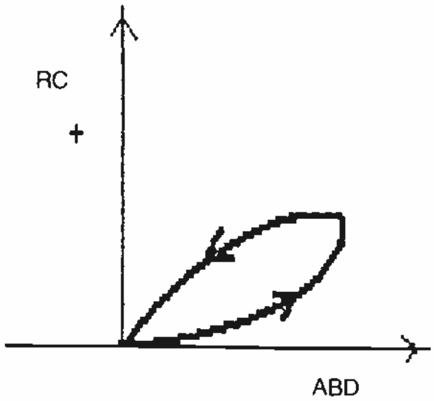

Figure 2. Diagram showing a typical loop of a Chinese subject during quiet breathing at supine position.

4) During TLC manoeuvre.

In all subjects in both positions, the RC displacement was greater than the ABD displacement (ie PT >45°, mean = 92°). In all subjects the RC:ABD ratio decreased (but was still >1) when shifting from sitting to supine.

Sitting position:

In 44% of all subjects (4/7 Indians, 3/9 Chinese, $p > 0.1$) the RC dominace was so great that the PT angles were >90° ie RC displacement was solely responsible for ventilation, with ABD displacement being negative (or paradoxical) (Figure 3). Another 4/9 Chinese had PT angles of close to 90° ie almost vertical loops. This need not mean that the diaphragm was inactive or ineffective. It could be that the abdomen was contracted (thus reducing the ABD displacement or even having negative displacement) to give the diaphragm a geometric advantage in displacing the RC through its anterior fibres (Figure 4). Altogether, 4/7 Indians and 7/9 Chinese ($p > 0.3$) had PT angles 90° or more. There was no significance in the difference between the mean PT angles of the Chinese (88°) and Indians (95°) ($p > 0.1$).

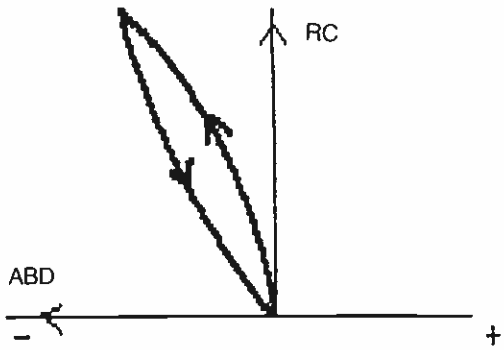

Figure 3. Diagram showing a typical loop of a Chinese subject with 'paradoxical' breathing during TLC manoeuvre

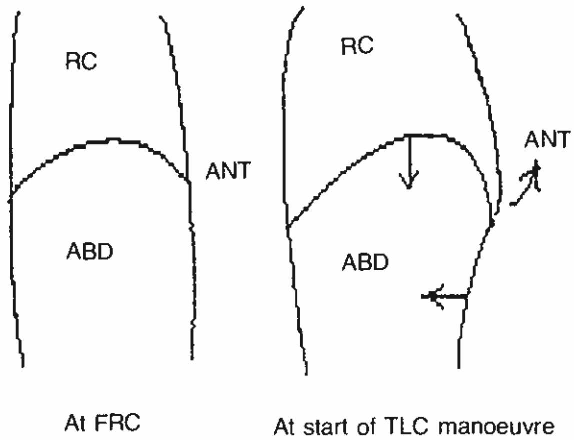

Figure 4. Diagram to show geometric advantage due to abdominal muscle contraction during TLC manoeuvre.

Supine position:

In all who had paradox, this disappeared in the supine position but RC displacement remained predominant. It is possible that abdominal muscle contraction was no longer necessary to give the geometric advantage to the diaphragm now that abdominal hydrostatic pressure had taken over the role. In this position too, there was no significant difference between the mean PT angles of the Chinese (70°) and Indians (72°) ($p > 0.1$).

5) Loops.

In general both Indians and Chinese had minimal looping in the sitting position. In the supine position, the Chinese had noticeably more looping (or 'opening up' of the loops). This meant that there was more 'phase lag' between the RC and ABD displacements.

Conclusions of Experiment II.

1) In general as a group, both Chinese and Indians behaved somewhat alike during quiet breathing and the TLC manoeuvre. In the supine position the ABD again contributed more to ventilation during quiet breathing (as in experiment I). During the TLC manoeuvre, the RC predominated both in the sitting and supine position although the relative contribution of RC was decreased in the supine position. There was no significantly difference in the breathing pattern of the Indians as compared to the Chinese during TLC manoeurvre.

2) Paradoxical breathing was seen in the sitting position during TLC manoeuvre (3/9 Chinese, 4/7 Indians). In another 4 Chinese, this manoeuvre was performed principally with RC displacement alone. These observations were similarly seen in the study by Sharp and colleagues (1).

SUMMARY.

In summary, our experiments have shown the following:

1. Resting ventilation can be fairly accurately studied with respiratory inductive phlethysmography. The calibration remained stabled during the 15 minute study provided the subject's position did not change.

2. In 50% of the subjects (16/32), the volume/motion coefficients changed from the sitting to supine position. Therefore recalibration is an essential step in any study using RIP if there is a change of posture.

3. As a group, the breathing patterns of the Chinese and Indians were similar to the group studied by Sharp i.e. the abdominal contribution to ventilation was greater in the supine position during quiet breathing. In all subjects, the change in position from sitting to supine significantly affected only the relative contribution of RC and ABD. In the sitting position, RC predominated (RC/SUM = 62.75%) whereas ABD contributed more in the supine position (RC/SUM = 48.13%). No significant effects were seen on the other parameters (Table 3).

4. The Chinese when compared to the Indians, tended to breathe slower, deeper and more variably (both in depth and timing) especially in the supine position (experiment I). In the supine position, 5/8 Chinese initiated their tidal breaths with their abdomen (experiment II) with hardly any contribution by their RC. This pattern of breathing was not seen in the Indians. Paradoxical breathing was seen during the TLC maneouvre in both Chinese and Indians in the sitting position. Whereas resting breathing occured predominantly through abdominal displacement (in the supine position), a voluntary manoeuvre like the TLC manoeuvre resulted mainly through RC displacement both in sitting and supine position (ie the PT angles were >45°).

5. Our clinical impression that the Chinese breathe differently than the Indians was partly correct (finding no. 4 above). However, during the TLC manoeuvre in the supine position (? during abdominal palpation), there was no significant difference in the breathing patterns between the Chinese and Indians. Perhaps a larger study encompassing a wider age group may show the difference that we sought for.

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