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The effect of posture and abdominal binding on respiratory pressures

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The effect of posture and abdominal binding on respiratory pressures. N. Koulouris, D.A. Mulvey, C.M. Laroche, J. Goldstone, J. Moxham, M. Green
ABSTRACT: We examined the effect of posture on the generation of respiratory pressures in 6 highly trained subjects. Transdiaphragmatic pressure was measured at FRC during bilateral percutaneous phrenic nerve stimulation (twitch Pdi) and maximal sniffs (sniff Pdi), with the abdomen bound and unbound. Maximum static inspiratory (PI_{max}) and expiratory (PE_{max}) mouth pressures were measured with the abdomen unbound. Three postures were examined: seated (Se), semi-supine (30s), and supine (Su). Changes of posture did not significantly alter twitch Pdi. By contrast, sniff Pdi and static mouth pressures were significantly reduced in the Su posture. Abdominal binding significantly increased twitch Pdi only. We conclude that voluntary respiratory manoeuvres requiring activation, recruitment and coordination of different muscle groups are performed better in the Se position. We suggest that posture be standardised for serial comparative measurements of voluntary respiratory pressures in a given subject.
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Muscle configuration and length alter with changes of posture, and may modify pressure generation by the respiratory muscles [1–4]. In clinical practice it is occasionally necessary to measure pressures in patients who are unable to assume a seated position, as on the intensive care unit. The aim of this study was to examine the effect of posture on the generation of respiratory pressures by voluntary and involuntary manoeuvres. Abdominal binding has previously been shown to increase transdiaphragmatic pressure (Pdi) generated by bilateral phrenic nerve stimulation [5]. We have also examined the effect of binding on Pdi generated by a sniff.

Methods

The study had the approval of the local Ethical Committee and subjects gave informed consent. We studied six healthy physiologists (5 male, 1 female, age range 30–45 years). Pressures were measured using Validyne MP45-1 differential pressure transducers (range±350 cmH_2O, Validyne Co, Northridge, CA). Oesophageal (Poes) and gastric (Pgas) pressures were measured with 10 cm balloons attached to 100 cm polyethylene catheters (PK Morgan, Rainham, Kent) and positioned in the standard manner [6]. Transdiaphragmatic pressure (Pdi) was derived by electronic subtraction (Pdi=Pgas-Poes) using Pdi at resting end-expiration as the zero reference point [7]. Two pairs of linearised magnetometer coils were used to indicate thoracoabdominal movements and to help identify functional residual capacity (FRC) [8]. Phrenic nerve stimulation was performed percutaneously with bipolar electrodes (Medelec Ltd, Old Woking, Surrey) and a constant voltage stimulator (Digitimer, Welwyn, Herts) [9, 10]. Square wave stimuli of 100 microsecond duration were applied with a frequency of 1 Hz at the posterior border of the sternomastoid [9]. Electrical contact was achieved with saline-soaked felt pads. The electromyogram (EMG) from both hemidiaphragms was recorded using surface electrodes placed in the 7th intercostal space and over the 8th rib after suitable preparation of the skin [11]. The EMG signals were integrated by a Neurolog EMG amplifier (Digitimer, Welwyn, Herts) and displayed on a Tektronix 5103N storage oscilloscope (Tektronix Inc, Oregon).

A rubber tube mouthpiece was used to obtain maximum static inspiratory (PI_{max}) and expiratory mouth pressures (PE_{max}) as maximal pressures were required [12]. All calibrated signals were recorded onto paper using a Mingograf 800 ink-jet recorder (Siemens-Elema, Sweden).

Protocol

All subjects were studied in three body postures: (a) seated (Se) in a high-backed chair, (b) semi-supine (30s) on a bed with the upper body tilted up 30°, (c) supine

(Su) on a bed without a pillow. Postures were adopted in random order. Static mouth pressures were measured on a separate occasion from sniffs and twitches. Sniff and twitch measurements were repeated after abdominal binding. This was carried out with the subject standing, using a tightly fitting corset extending from xiphoid to pubis and reinforced with a wooden board placed beneath [13]. The validity of Poes recorded in each posture was confirmed by the simultaneous measurement of sniff oesophageal and sniff mouth (Pmo) pressures [14]. Where necessary, the position of the oesophageal balloon was adjusted until the ratio sniff Poes/sniff Pmo was within 10% of unity [15, 16].

Supramaximal bilateral phrenic nerve stimulation was confirmed prior to making the definitive measurements. The stimulating voltage was raised progressively until no further increase in the size of the diaphragmatic M waves and twitch amplitude could be produced in a given posture. Pdi was then recorded at FRC for at least 30 twitches. This procedure was repeated three times in each posture. Five of those twitches which combined maximum M wave and mechanical amplitudes in each posture were selected for analysis.

In this study a "sniff" was characterised by a short, vigorous inspiratory effort through the unoccluded nose from FRC [14, 17, 18]. Ten maximal sniffs were performed in each body posture. The five biggest sniffs were used for analysis.

The data were subjected to analysis of variance for repeated measures. This analysis was performed using the SPSS-X statistical computer package (SPSS Inc, Chicago).

Results

The within-subject coefficient of variation (COV) for twitch Pdi data selected for analysis was less than 7% in all subjects for all postures. For sniff Pdi data this COV was less than 8%.

In the unbound state, posture had different effects on the involuntary and voluntary manoeuvres. Posture did not significantly alter twitch Pdi although it tended to be less in the Se position (table 1) . Moving from Se to Su, twitch Poes tended to increase while Pgas decreased significantly (p=0.025). By contrast, sniff Pdi was significantly lower in the Su position (p=0.001, table 2) and this decrease was principally mediated by a significant reduction in sniff Pgas (p=0.001). Similarly both PI$_{max}$ and PE$_{max}$ were significantly lower when supine (p=0.03, table 3). For all manoeuvres, the values obtained in the 30s position were intermediate between Se and Su, and did not achieve statistical difference from either. (Figs 1, 2 and 3).

Binding the abdomen markedly increased twitch Pdi (p=0.001) and was mediated principally through an

Table 1. – Results of Pdi, Poes and Pgas during bilateral phrenic nerve stimulation

	Pdi		Poes		Pgas	
	Bound	Unbound	Bound	Unbound	Bound	Unbound
Su	3.52 (0.29)	2.96 (0.34)	2.20 (0.21)	2.34 (0.31)	1.34 (0.08)	0.61 (0.11)
30s	3.70 (0.36)	2.88 (0.32)	2.05 (0.18)	2.06 (0.21)	1.65 (0.19)	0.82 (0.11)
Se	3.63 (0.29)	2.59 (0.21)	1.90 (0.23)	1.58 (0.22)	1.72 (0.22)	1.00 (0.02)

(Su: supine; 30s=30° semi-supine, Se: seated) * 1 kPa=10.19 cmH$_2$O. Pdi: transdiaphragmatic pressure; Poes: oesophageal pressure; Pgas: gastric pressure; kPa*, mean±SE, n=6.

Table 2. – Results of Pdi, Poes and Pgas during a maximal sniff

	Pdi		Poes		Pgas	
	Bound	Unbound	Bound	Unbound	Bound	Unbound
Su	10.69 (0.79)	11.40 (0.89)	9.69 (0.74)	10.37 (1.00)	1.04 (0.15)	1.03 (0.49)
30s	11.82 (1.04)	11.77 (0.97)	10.14 (0.73)	10.74 (1.04)	1.68 (0.65)	1.03 (0.41)
Se	13.01 (0.78)	12.72 (1.15)	10.61 (0.70)	10.86 (0.89)	2.39 (0.35)	1.86 (0.70)

(Su: supine, 30s=30° semi-supine, Se: seated) * 1 kPa=10.19 cmH$_2$O. Symbols as table 1; kPa*, mean±SE, n=6.

increase in twitch Pgas (p=0.002). This increase was 40% Se, 29% 30s, and 21% Su.

Sniff Poes, Pgas and Pdi were unaltered by binding. Binding and posture were not found to interact significantly for either twitch or sniff Pdi.

Table 3. – Results of Maximum Static Mouth Pressures (kPa*, mean±SE, n=6)

	Inspiratory ($P_{I_{max}}$)	Expiratory ($P_{E_{max}}$)
Su	11.69 (1.43)	18.48 (2.05)
30s	12.55 (1.35)	18.64 (1.77)
Se	12.88 (1.68)	20.52 (2.01)

(Su: supine, 30s=30° semi-supine, Se: seated)
* 1 kPa=10.19 cmH_2O.

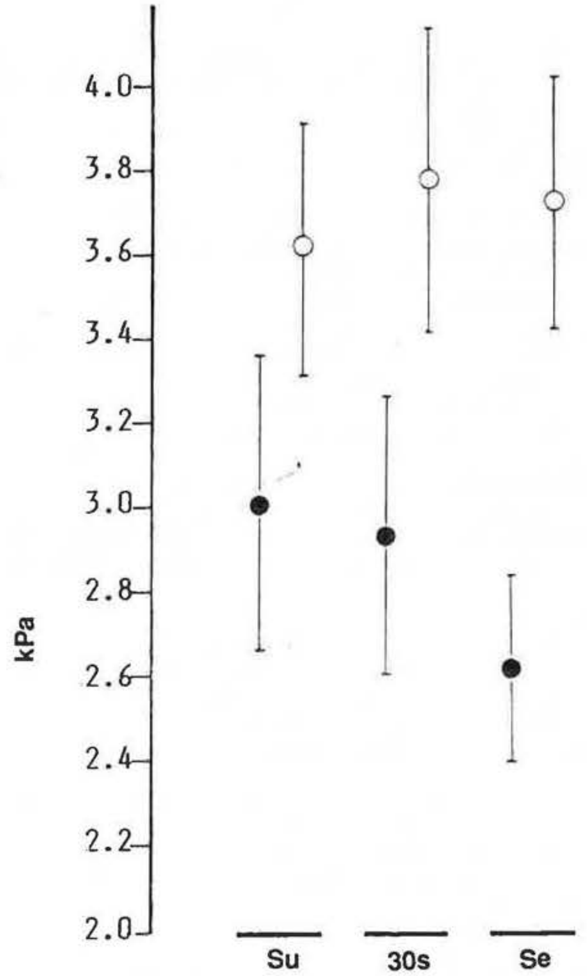

Fig 1. – Results of twitch Pdi in 6 subjects semi-supine (mean±SE, o : bound, ● : unbound in the seated (SE), 30° semisupine (30s) and supine (Su) postures. Analysis of variance showed a significant difference between bound and unbound values (p=0.001).

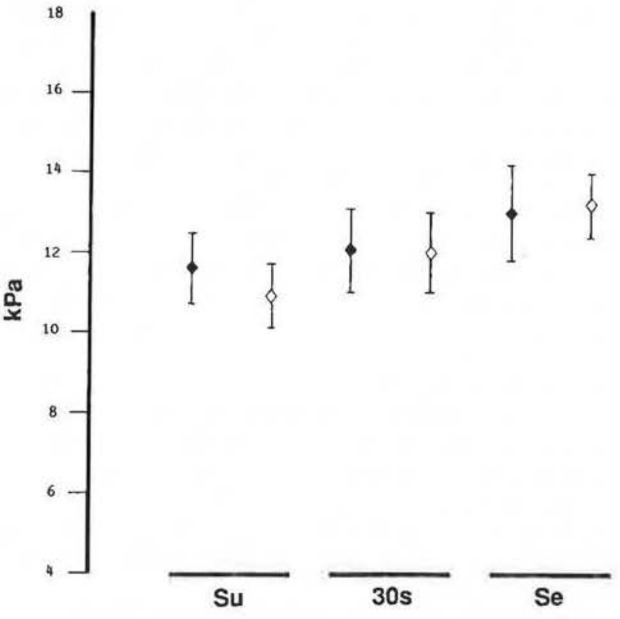

Fig 2. – Results of sniff Pdi in 6 subjects (mean±se, ◇: bound, ◆ : unbound) in the seated (Se), 30° semi-supine (30s) and supine (Su) postures. Analysis of variance showed a significant difference between postures (p=0.001).

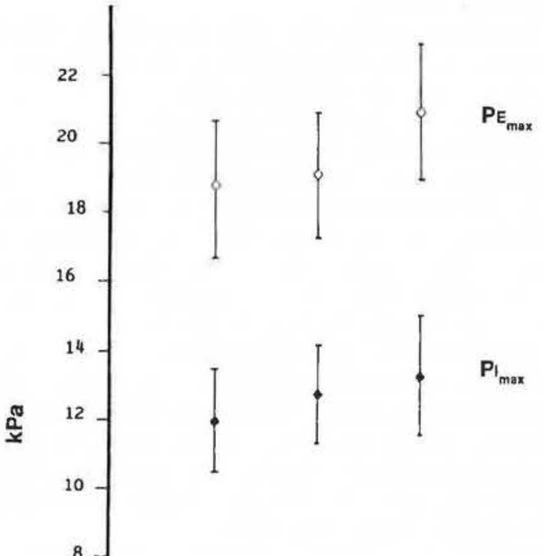

Fig 3. – Results of $P_{E_{max}}$ and $P_{I_{max}}$ in 6 subjects (mean±SE) with the abdomen unbound. Analysis of variance showed a significant difference between postures (p=0.03).

Discussion

The present study has examined the influence of posture and abdominal binding on the generation of respiratory pressures and indicated a differential effect of these factors on voluntary and involuntary manoeuvres.

Diaphragm length increases when supine and should confer an advantage in pressure generation in this posture [1–4]. Our data for twitch Pdi show an increase when moving from seated to supine, and although statistical significance is not achieved this may be due to our small number of subjects. Alternatively, the similarity of twitch Pdi obtained in the different postures may suggest that mechanisms additional to the length-tension relationship must influence pressure generation. An attractive hypothesis to explain the stability of twitch Pdi is that the velocity of contraction decreases as the initial length of the diaphragm decreases [19, 20]. It has been shown that the velocity of contraction of diaphragmatic fibres is directly dependent on the rate of abdominal wall displacement [21]. Tonic contraction of abdominal wall musculature occurs with moving upright, and would reduce the rate of displacement constraining the diaphragmatic fibres to contract at reduced velocity [22]. This view is supported by work indicating that there is an inverse relationship between velocity of diaphragmatic contraction and abdominal impedance [23].

Binding the abdomen increased twitch Pdi as previously reported [5]. Posture had no influence upon the bound twitch Pdi. The diaphragm is at least mechanical advantage in the unbound Se position, and binding the abdomen produces the greater numerical increase in twitch Pdi in this position.

Contrasting results are obtained with the voluntary manoeuvres. Maximal sniff Pdi is significantly lower in the Su posture, an observation not previously reported. During the sniff manoeuvre many muscles are recruited to generate maximal pressure gradients across the diaphragm. This is emphasised in the study of GOLDMAN *et al.* [18] who measured sniff Pdi in tetraplegic patients with intact phrenic nerves. The Pdi obtained in these patients never achieved normal values, even when diaphragmatic function was optimised by posture or abdominal binding. We hypothesise that activation [24], coordination [25], and recruitment [26] of both the diaphragm and non-diaphragmatic muscles are submaximal in the supine posture. Binding the abdomen of normal subjects would not improve the function of non-diaphragmatic muscles. Additionally our subjects reported that the discomfort of abdominal binding inhibited their performance of maximal sniffs.

Similarly, PI_{max} and PE_{max} are significantly lower in the Su position. We feel that these volitional manoeuvres are subject to the limitations discussed above for the unbound sniff.

Other factors are reported as influencing the ability of the respiratory muscles to generate pressure during postural changes; *e.g.* elastance of the diaphragm, amount of fibre shortening achieved, compliance and mechanical coupling of rib cage and abdominal compartments [3, 4, 10, 23, 27, 28]. To what extent these factors interact, or exert influence upon pressure generation is not known, and cannot be deduced from our data.

In the clinical setting, we observe that subjects are most comfortable when phrenic nerve stimulation is performed in the 30s position. The results of this study show that the reproducibility of twitch Pdi is unaltered by posture. When patients or normal subjects were studied, it was much easier to locate the phrenic nerves and maintain stimulus maximality in this posture [29]. Any advantage of abdominal binding in producing higher twitch Pdi pressures is offset by patient discomfort and increased breathlessness, and binding does not improve reproducibility. It is therefore suggested that stimulation is most convenient in the unbound semi-supine posture, keeping in mind that patients with a weak or paralysed diaphragm may be severely orthopnoeic when totally supine.

We conclude that (a) twitch Pdi is unaltered by posture, (b) pressures generated by voluntary manoeuvres are significantly reduced in the Su posture, (c) abdominal binding increases twitch but not sniff Pdi. We suggest that posture be standardised for serial comparative measurements of maximal sniff Pdi, PI_{max} and PE_{max}.

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Effets de la position et du serrage abdominal sur les pressions respiratoires. N. Koulouris, D.A. Mulvey, C.M. Laroche, J. Goldstone, J. Moxham, M. Green.

RÉSUMÉ: Nous avons étudié l'éffet de la position sur la production de pressions respiratoires chez 6 sujets largement entraînés. La pression transdiaphragmatique a été mesurée à la CRF pendant une stimulation bilatérale du nerf phrénique par voie percutanée (twitch Pdi) et pendant des reniflements maximaux (sniff Pdi), alors que l'abdomen était ou non bandé. Les pressions buccales inspiratoires statiques maximales (PI_{max}) et expiratoires (PE_{max}) ont été mesurées, l'abdomen étant dégagé. Trois positions ont été examinées: la position assise (Se), la position semi-couchée (30s) et la position couchée (Su). Les modifications de position n'ont pas entraîné de changement significatif de la twitch Pdi. Par contre, sniff Pdi et les pressions buccales statiques sont significativement diminuées en position couchée. Le fait d'enserrer l'abdomen a augmenté significativement uniquement la twitch Pdi. Nous concluons que des manoeuvres respiratoires volontaires, exigeant l'activation, le recrutement et la coordination de différents groupes musculaires, sont mieux réalisées en position assise. Nous suggérons que la position soit standardisée pour les mesures comparatives en série des pressions respiratoires volontaires chez un sujet donné.

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