THE ROLE OF THE SCALENE AND STERNOMASTOID MUSCLES IN BREATHING IN NORMAL SUBJECTS. AN ELECTROMYOGRAPHIC STUDY*

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INTRODUCTION

The activity of all the muscles which are generally thought to act as accessory muscles of inspiration has been examined electromyographically in normal men. The only ones which showed significant respiratory activity were the sternomastoid and the scaleni; these were investigated more fully. It is well known that these muscles are important accessory muscles of inspiration in dyspnoeic subjects, but their role in normal subjects has not apparently been examined hitherto.

METHODS

Apparatus. An Ediswan amplifier with inkwriter oscillographs was used. The surface electrodes used were shallow cups of silver coated with silver chloride. A 6 l. water-filled Kendrick spirometer was arranged to give a record of the respiration on the electromyograph paper.

The apparatus described by Campbell & Green (1953) for studying graded expiratory efforts was modified to allow inspiratory efforts also to be studied. This apparatus consists of a differential manometer in which any desired pressure can be maintained by the observer, and which is balanced by a voluntary inspiratory (or expiratory) effort made by the subject.

Subjects. Five healthy young men aged 18–27 were studied. The muscles on the right side only were examined.

Application of the surface electrodes. The skin was rubbed first with ether and then with Cambridge electrode jelly to reduce skin resistance. The cups of the electrodes were filled with electrode jelly and then fixed to the skin with collodion or adhesive plaster.

Placing of the electrodes

The sternomastoid. A pair of electrodes was placed 4·5 cm. apart along the length of the clavicular fibres of the muscle, just behind the fold of its sternal part. Usually the upper electrode was just below and behind the angle of the jaw and the lower electrode about 3 cm. above the clavicle. Preliminary experiments showed that there was no significant difference in activity between the sternal and clavicular heads.

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The scaleni. A pair of electrodes was placed 2–3 cm. apart in the lower anterior angle of the posterior triangle, just behind the clavicular fibres of the sternomastoid; the lower electrode was placed immediately above the clavicle. In this site the electrodes are over the scalenus medius and probably the lower fibres of the levator scapulae.

RESULTS

General Remarks

The main study was made with the subjects supine, as this was the only posture in which complete relaxation could be easily obtained. It is difficult to detect respiratory variation in the electromyogram against a background of postural activity. Even in the supine posture there was often considerable continuous activity unless care was taken to place and support the head in a comfortable position. The insertion of a mouthpiece also tended to cause continuous activity which increased when it was held firmly in the mouth, as when static inspiratory and expiratory efforts were being made.

The possible contribution of the platysma to the activity recorded at either of the sites examined was considered. The electrodes over the sternomastoid also lie over the platysma; as little respiratory activity is recorded in this situation the role of the platysma is insignificant. The greater activity commonly recorded over the scaleni may thus be attributed to these muscles and not to the platysma.

Skeletal movements

The slightest attempt by the subject to raise his head from the couch caused marked activity in both muscles. Elevation of the shoulder caused marked activity which was detected by the electrodes over the scaleni but not by those over the sternomastoid.

Observations in the supine position

Quiet breathing

Sternomastoid. There was no detectable activity in any of the subjects when they were relaxed and comfortable.

Scaleni. In three subjects there was no detectable activity. In the fourth there was continuous activity like that described above which could not be abolished by adjusting the position of the head and which showed no respiratory rhythm; he was examined again 6 months later with the same result. In the fifth subject there was considerable spontaneous activity; after reducing it as much as possible by attention to posture and comfort a respiratory rhythm persisted (Fig. 1).

Maximum inspiration and expiration

There was marked activity at both electrode sites in all subjects on maximum inspiration. On maximum expiration there was either no activity or only slight activity.

Graded inspiratory efforts performed at the resting respiratory level

There was a clearly discernible gradation in the intensity of the muscular activity over a range of pressures from −10 to −50 cm. H_2O (i.e. intra-pulmonary pressures 10–50 cm. H_2O below atmospheric). This gradation was obvious on simple inspection of the records.

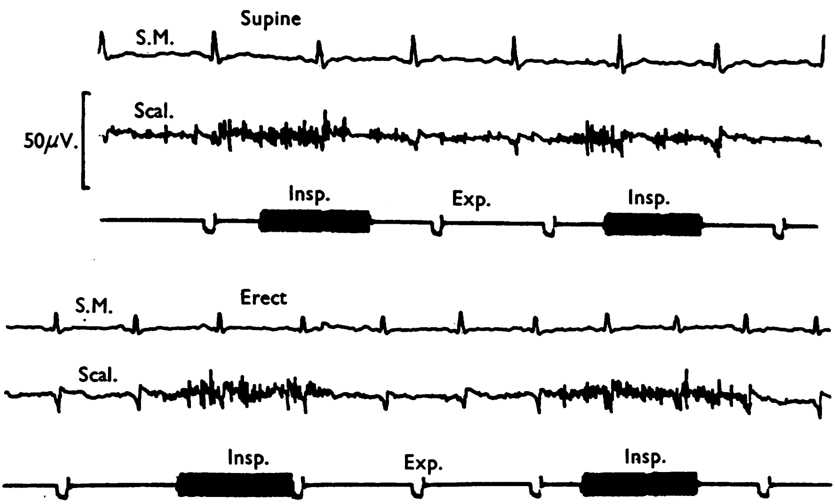

Fig. 1. Quiet breathing. Subject R. B. Electromyograms recorded from the sternomastoid (S.M.) and scalene muscles (Scal.). The phases of respiration were signalled by an observer. The onset of inspiration precedes the beginning of the signal. Time in sec. Regular deflexions represent the electrocardiogram. No activity in sternomastoids. Activity of scaleni present in both supine and erect posture. There is marked increase in activity with inspiration. Compare Fig. 3.

Graded expiratory efforts performed at the resting respiratory level

Sternomastoid. In three of the subjects slight muscular activity developed on making expiratory efforts in which the intra-pulmonary pressure rose to +40 cm. H_2O. The intensity of the activity was not related to that of the effort. In the other two subjects the presence of variable spontaneous activity prevented any conclusions being made.

Scaleni. During expiratory efforts resulting in intra-pulmonary pressures of +20 to 30 cm. H_2O spontaneous activity if present was suppressed. In no subject did fresh activity appear at these pressures. However, during efforts of +40 cm. H_2O and above, all subjects showed definite or marked activity (Fig. 2).

Increased pulmonary ventilation (*Fig.* 3)

The subjects rebreathed expired air from the spirometer with no CO_2 absorber in the circuit. As a result the ventilation rate increased to 50–80 l./min.; at this stage the subjects became too distressed to continue. As they became used to this procedure they were encouraged to increase the volume of their breathing voluntarily and they were then able to produce a steadily progressive increase to well over 100 l./min.

Sternomastoid. Activity towards the end of the phase of inspiration occurred in four of the subjects at minute volumes of 61·5, 75, 105, 41 l. respectively. In the fifth subject continuous activity appeared at 97·5 l./min. It is obvious on anatomical grounds that the tidal volume may be more important than the ventilation rate in determining the recruitment of the sternomastoid. The data are therefore given

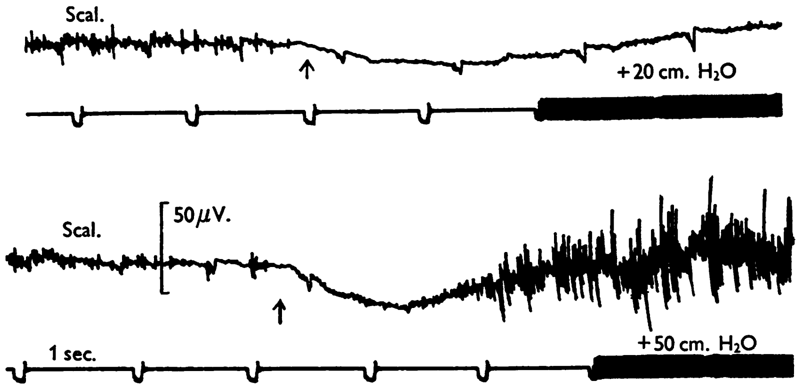

Fig. 2. Subject R. B., supine. Scal., the electromyogram recorded from the scalene muscles. Time in sec. The subject was breathing through a mouthpiece. At the arrow he began to make an expiratory effort. The signal marks the period of maintenance of the expiratory pressure indicated. This subject showed continuous irregular activity in the scalene muscles, as seen at the beginning of each record. An expiratory effort of +20 cm. H_2O (intra-pulmonary pressure 20 cm. H_2O above atmospheric) was associated with a decrease in background activity; an effort of +50 cm. H_2O was associated with a marked increase (see discussion).

Table 1. *Sternomastoid activity during increased pulmonary ventilation: supine posture*

The respiratory rate per minute, tidal volume (T.V.) in litres and minute volume (M.V.) in litres per min. at which activity appeared are given for each subject. In the fifth and sixth columns the critical tidal volume (at which activity appeared) is expressed as a percentage of the subject's vital capacity (V.C.) and inspiratory capacity (Insp. capacity).

	Critical values			Critical tidal volume as percentage of	
Subject	Rate	T.V.	M.V.	V.C.	Insp. capacity
G. M.	22·5	2·7	61·5	60	80
G. Ho.	28·5	2·6	75	65	80
J. Da.	36	2·9	105	60–65	70–75
R. B.	30	3·2	97	55	70–75
G. Ha.	14	2·9	41	65–70	80–85

in more detail in Table 1; the tidal volume at which activity first appeared is also given as a percentage of the vital capacity and the inspiratory capacity. Three conclusions can be drawn from Table 1:

(i) At least 70% of the inspiratory capacity can be used as tidal volume by the normal subject without using the sternomastoid as a muscle of inspiration.

(ii) If the rate of breathing is increased to 30 per min. (as it was in subjects J. Da.

and R. B.) the maximum exercise level of ventilation can be attained without using the sternomastoid.

(iii) If 10 cm. H_2O/l. is assumed to be the elastance of the chest wall and lungs, all the subjects were able to exert a force equivalent to an inspiratory pressure of 20 cm. H_2O below atmospheric without using the sternomastoid. (The data of Rahn, Otis, Chadwick & Fenn (1946) give a value of about 14 cm. H_2O/l. for the elastance). The

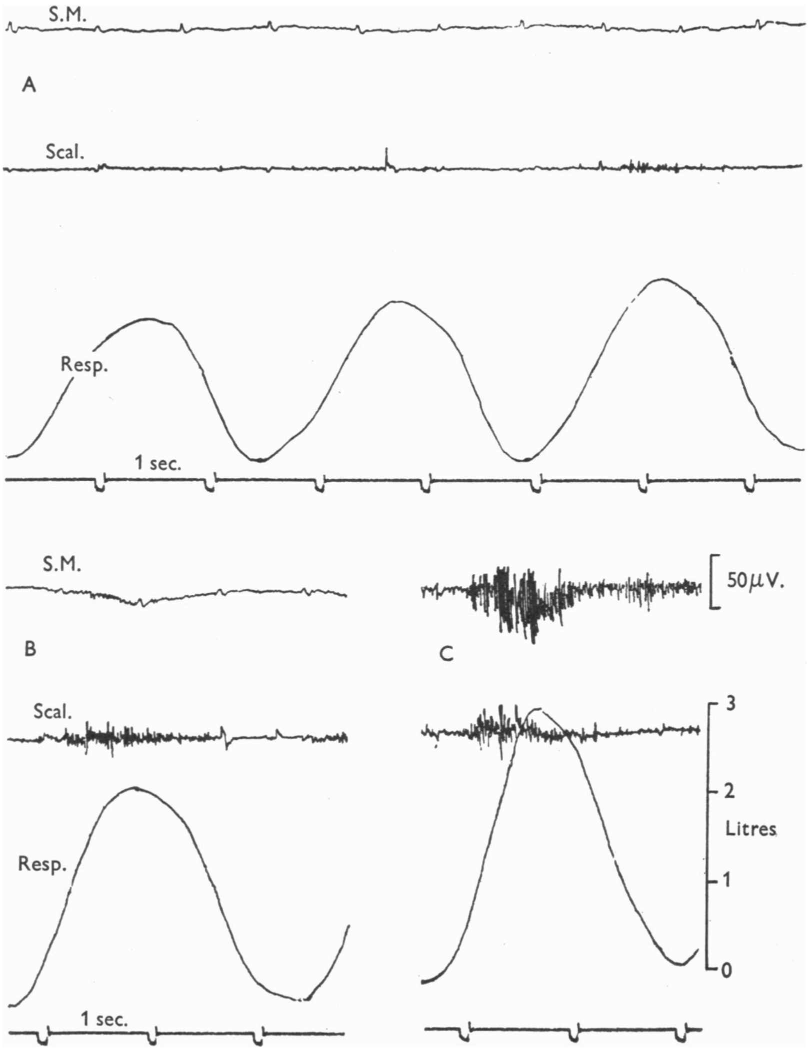

Fig. 3. Subject G. M., supine. Electromyograms recorded from the sternomastoid (S.M.) and scalene (Scal.) muscles. Resp. = the record of respiration (inspiration upwards). Time in sec. The subject re-breathed expired air from a 6 l. spirometer. A shows the onset of inspiratory activity in the scaleni. B and C show the development of activity in the sternomastoid. At the beginning of A the ventilation rate was 42 l./min. and at the end it was 52 l./min. In B the ventilation rate was 60 l./min. and, in C, 78 l./min.

muscular activity recorded during static voluntary inspiratory efforts of −10 cm. H_2O is difficult to account for. The explanation may be that the accessory muscles are always more readily employed in voluntary inspiratory efforts, possibly because the ordinary muscles such as the diaphragm and intercostals are not subject to sufficiently exact voluntary control.

Scaleni. Table 2 sets out the rate and depth of breathing at which activity appeared in the three subjects who showed no activity (spontaneous or rhythmic) during quiet breathing. It is clear that activity develops earlier in the scaleni.

Table 2. *Activity of scaleni during increased pulmonary ventilation*

The respiratory rate per minute, tidal volume (T.V.) in litres and minute volume (M.V) in litres per min. at which activity appeared are given for three subjects. In the fifth and sixth columns the critical tidal volume (at which activity appeared) is expressed as a percentage of the subject's vital capacity (V.C.) and inspiratory capacity (Insp. capacity).

	Critical values			Critical tidal volume as percentage of	
Subject	Rate	T.V.	M.V.	V.C.	Insp. capacity
G. M.	27	1·6	42	30	40–45
J. Da.	26	2·6	68	55–60	65
G. Ha.	15	2·1	31·5	45–50	60

No definite expiratory activity was detected in either muscle in any subject until the ventilation rate was so great that the significance of the activity was doubtful. This is because severe efforts or general distress often cause widespread slight contraction of many muscles, some of which are not associated with the movement which the subject is performing.

The effects of posture

In four subjects (one of whom was not included in the series of experiments described above) records were taken of quiet breathing and increased pulmonary ventilation in the erect posture.

Sternomastoid. Although there was a tendency for irregular activity to appear in the erect posture it could always be abolished, and no subject showed constant rhythmic activity. Table 3 gives the rate and depth of breathing at which activity appeared during increased pulmonary ventilation. The data suggest that the sternomastoid is more readily used in the erect than in the supine posture, but too much emphasis must not be placed on the values recorded. They probably underestimate

Table 3. *Sternomastoid activity during increased pulmonary ventilation: erect posture*

This table gives the tidal volume (T.V.) in litres, respiratory rate per minute and minute volume (M.V.) in litres per min. at which activity appeared in the sternomastoid muscle during progressively increasing pulmonary ventilation in the erect posture.

Subject	T.V.	Rate	Minute volume
R. B.	1·4	22	31
M. Ch.	2·1	24	51
G. M.	2·7	27	73
G. Ha.	1·9	25	48

the threshold of recruitment because it is difficult, even for trained subjects, in the erect posture with a mouthpiece, to relax and allow their breathing to be increased by CO_2 accumulation. Previous experience with subjects R. B. and M. Ch. suggests that they are both capable of greater minute volumes than G. M. before using their accessory muscles of inspiration.

Scaleni. In two subjects there was well-marked rhythmic inspiratory activity in the erect posture. In the third subject there was considerable irregular activity which with adjustment of the posture of the shoulders showed slight rhythmicity. In the fourth subject (G. M.) there was either no activity or slight irregular activity which became rhythmic at a minute volume of 50 l./min. ($27 \times 1{\cdot}9$ l.).

DISCUSSION

Scalene muscles. On anatomical grounds the three scaleni would appear to have the same fundamental actions. The scalenus medius was probably the main contributor to the records obtained from the electrode site used in this study. It is possible that the levator scapulae or the omo-hyoid also contributed to the electromyogram, but it is unlikely that the considerable respiratory activity recorded arose in these muscles. To settle this point it would have been desirable to explore the region with needle electrodes. This procedure was considered to be unjustifiable because of the risks of damaging the major nerves and blood vessels present in this region of the neck.

The importance of the scaleni as muscles of inspiration is variously assessed by different authorities. Some regard them as ordinary muscles of inspiration equal in importance to the intercostals. Others class them as accessory muscles of inspiration equal in importance to the sternomastoid. The findings in the present study show that in fact the scaleni may be active in normal subjects even during quiet breathing, but that the sternomastoid is only employed at very high levels of ventilation. Weddell, Feinstein & Pattle (1944) observed inspiratory contraction of the scaleni during quiet breathing. Schill (1942) observed by palpation that in patients with heart or lung disease the scaleni are used at an earlier stage of dyspnoea than the sternomastoids.

These observations, however, do not establish the importance of the scaleni in pulmonary ventilation. Duchenne (1867) observed that costosuperior breathing continued in a patient who had lost most of his scaleni. Joly & Vincent (1937) found that scalenotomy performed in patients with pulmonary tuberculosis did not reduce the amplitude of the rib movements in breaths of normal depth (whereas paralysis of the intercostals did). Giauni (1936) observed that although scalenotomy caused an immediate decrease in vital capacity, considerable recovery occurred later and in some cases there was a complete return to normal. R. Fick (1923) calculated that the scaleni are only potentially one fifth as important as the intercostals.

The findings of considerable activity during moderately severe voluntary expiratory efforts (Fig. 2) suggests the possibility that the scaleni may be of importance in these circumstances and in such procedures as coughing or straining. Their action under these conditions may be to fix the upper ribs and prevent the thoracic cage from being pulled downwards by the abdominal muscles, or it may be to provide support for the apex of the lung to prevent it from bulging upwards. Recordings taken during coughing and straining did in fact show considerable activity, but electromyograms taken at any site in the trunk show activity during these procedures. The technique of graded voluntary efforts was used to distinguish muscular contraction of importance from the minor generalized activity which occurs in violent efforts.

Sternomastoid muscles. The importance of the sternomastoids in dyspnoea is a commonplace clinical observation. The present study shows how surprisingly slight is their respiratory activity in normal subjects. It appears that they become important when the respiratory level is elevated and the ordinary muscles of inspiration are operating at much reduced mechanical advantage. Cournand, Brock, Rappaport & Richards (1936) suggested that a spastic state of the accessory muscles of inspiration might be a contributory cause of dyspnoea in patients with pulmonary fibrosis. This suggestion was based on the observation that some patients who are unduly dyspnoeic in relation to the assessment of their ventilatory function and the tension of their blood gases, show over-activity of these muscles.

Duchenne recounted the case of a young man with a high cervical transection of the spinal cord who breathed for some weeks apparently by means of his sternomastoids alone. He was very cyanosed and when he was given artificial respiration contraction of the sternomastoids ceased. On stopping the artificial respiration the contraction only returned when he again became very cyanosed.

SUMMARY

1. The respiratory activity of the scalene and sternomastoid muscles has been examined electromyographically in five healthy young men.

2. The scaleni were readily employed as muscles of inspiration and in some of the subjects they were active during quiet breathing, especially in the erect posture.

3. The scaleni also showed considerable activity during moderately severe expiratory efforts. They may be of importance in such actions as coughing or straining.

4. The sternomastoids only showed activity during very deep breaths, and all the subjects were able to attain high ventilation rates without using them.

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