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DOCUMENTATION OF RESPIRATORY PATTERNS. MOTOGRAPHY, IMAGE PROCESSING, KINESIOLOGY.

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ABSTRACT

A motographic device in combination with image analysis was used for the study of breathing patterns. The method allows for a vivid comprehension of group specific characteristics and individual peculiarities.

Keywords: Image analysis, kinesiology, motography, respiration.

INTRODUCTION

The specific use of muscles of the neck, the chest and abdomen, and of the diaphragm during inspiration is a controversially discussed problem. The difficulties arise from interdependencies of all the muscles with origin or insertion on the chest cage, and from other conditions such as elasticity of the lungs, body position and clothing. The anatomical approach, which considers mostly the bones and joints of the thorax and the origin and insertion of its muscles has been extended by physiologists, who used electromyography for the detection of excitation or who worked with electro-mechanical measurement devices for the registration of movements in respiratory studies (Sharp et al., 1975). Optical close-range sensing methods deserve special attention (Leder et al., 1990), because such a morphologic mapping corresponds to the attitudes of anatomists; it provides a vivid imagination and results in only modest annoyance, which may be essential for investigating greater groups. One of these methods, which to our knowledge has not been applied till now for studies on respiration, is the so-called motography, developed for occupational physiology (Baum, 1980, 1983). This paper is concerned with its application to the kinesiology of breathing.

EXPERIMENTAL SUBJECTS AND METHOD

The study was carried out on 8 young men, who had given their informed consent. The optical equipment consisted of two Yashica cameras with objectives 50 mm, 1:1.9, mounted onto an aluminum rail at a distance of 25 cm. The right camera was positioned directly in front of the person. The distance from the camera rear wall to the proband standing upright was 3 m. Red LEDs were attached to points of interest on the undressed persons (Fig. 1). As a reference frame, four LEDs were mounted at a distance of 30 cm on a rectangular tripod. The persons were asked for quiet breathing and for forced respiration (three or four respiratory cycles). This was repeated after the persons had turned 45° (half-profile) and 90° (profile). Exposures were made for 10 s in an dim or dark room (film speed 400 ASA). Additional pictures were taken with the proband supine or sitting.

Frontal image pairs were evaluated with a mirror stereoscope (Cartographic Engineering Ltd., England). Film negatives of the 'profile exposures' (right camera) were placed on a light box and viewed with a CCD camera (Hitachi) through a macro objective 90 mm, 1:2.5 (Tamron). The video signal was digitized with a framegrabber PIP 1024B (Matrox, Canada) and was evaluated with the image analysis software SIS (Münster), installed on a PC-AT/386 (Pyramid, Freiburg).

The black light tracks were separated from the bright background by simple thresholding, with the fixed reference LEDs used for linear calibration. Projected x and y values of the binary image were then automatically measured, corresponding to the z- (sagittal) and y- (vertical) axis in the body coordinate system.

RESULTS

Pictures of the persons during quiet breathing did not show any displacement of the LEDs other than caused by some swaying forth and back of the entire body. An other situation arises, if forced breathing was requested. Then, light tracks in forward and

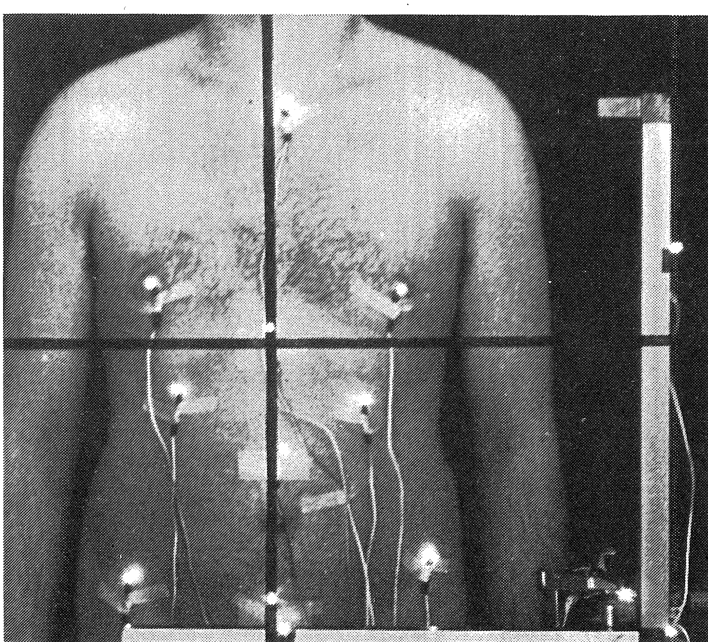


Figure 1. Anterior aspect of a young man during quiet breathing. LED positions: jugular groove, breast nipples, caudal end of xiphoid, costal arches in medial clavicular lines, 'upper' and 'lower' abdomen, i.e. halfway between xiphoid and navel, and between the latter and the symphysis. Further LEDs were mounted on the anterior upper iliac spines and on the tripod. The black cross was drawn on a transparent foil, which had been inserted into the camera to provide internal orientation.

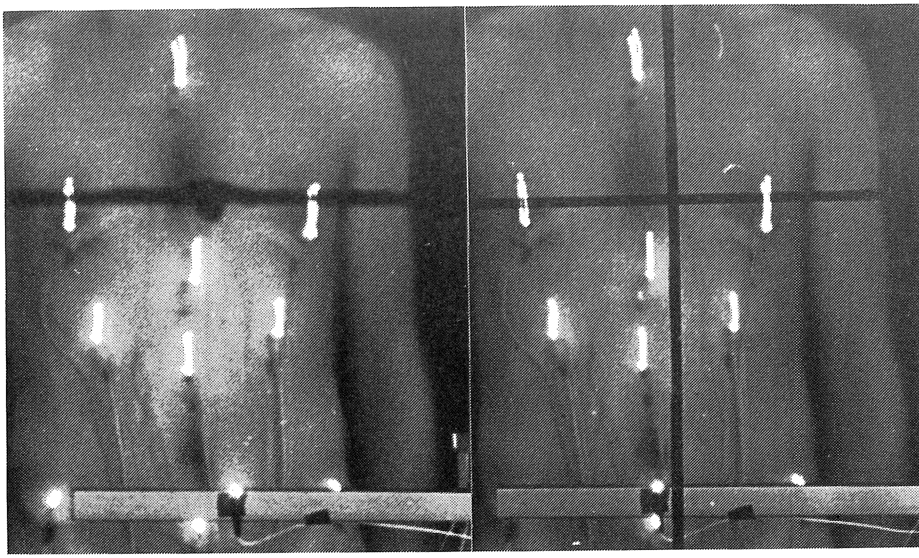


Figure 2. Forced breathing of a young man, stereo-images of anterior aspect.

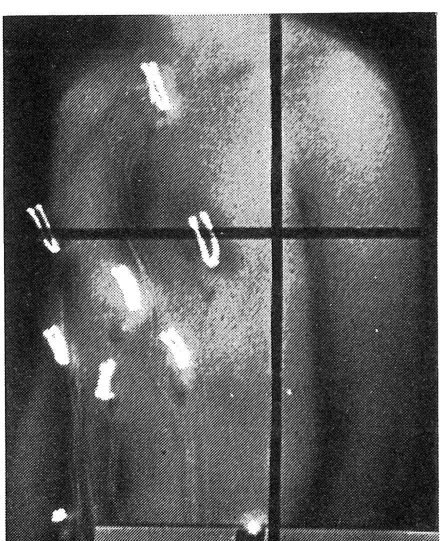
3 

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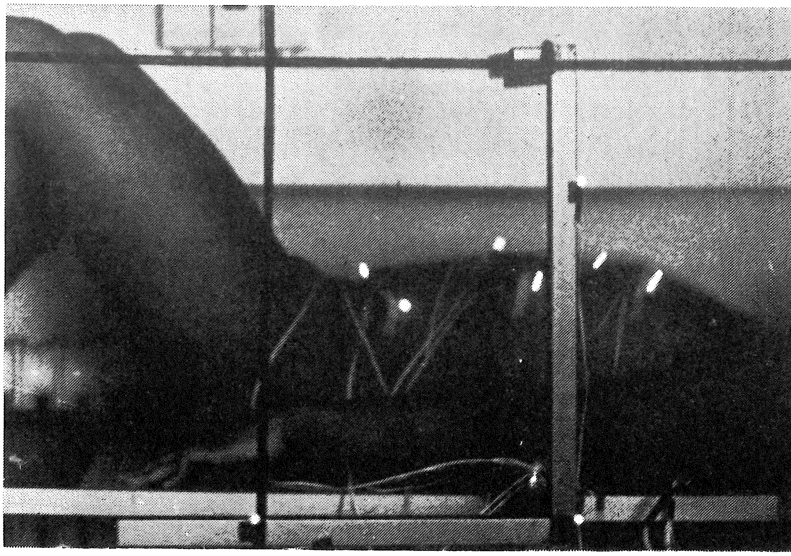
Figure 3. Forced breathing of a young man (25 y.), turned for 45°.

Figure 4. Forced respiration of an elder man (63 y.), lateral aspect (90°).



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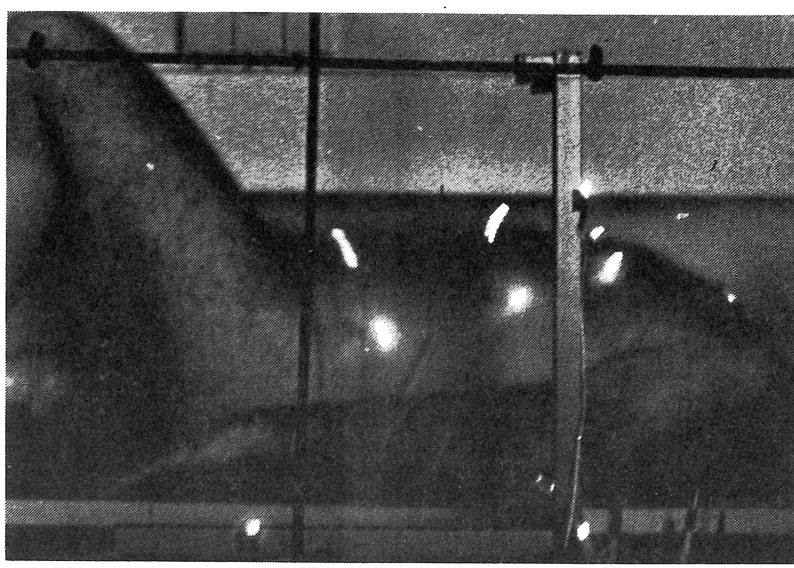

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Figure 5. Profile exposure of a younger man in supine position; forced breathing.

Figure 6. Profile view of an elder man. Supine position, forced breathing. Observe the comparatively large excursion of the abdomen, especially with the legs flexed.

upward direction could be observed on the chest cage (cf. Fig. 2). Modest protrusions of the abdominal wall were likewise recorded. The oblique aspect of the curved paths is especially instructive ('half-profile', Fig. 3).
Profile exposures were well suited for the two-dimensional quantitative evaluation (Fig. 4, Tab. 1). The projections of the light traces in the vertical plane indicate quite different patterns of inspiration. Some persons show longer tracks at the jugular end of the breast bone than at the lower rib cage. In other subjects, an inverse relation can be observed. The differences correspond to the so-called 'upper' and 'lower' chest breathing. The movement of the abdominal wall during deep respiration indicates the importance of the diaphragm. Because the latter has a component to elevate the lower ribs (Gray, 1901, Grassino and Goldman, 1986), its contraction may, at least partly, cause the 'lower' chest respiration.
The activity of the diaphragm is more apparent, if the tonus of the abdominal wall has been lowered in supine position. The light traces at the upper and lower abdominal wall were remarkable, though varying among individuals, during deep or even quiet breathing (Figs. 5,6).

Table 1. Projections of light tracks on the z- and y-axis (cm). Lateral view of eight subjects. Measurements with image analysis on negatives from the right camera.

LED / Person		Fossa jugularis	Papilla mammaria	Processus xiphoideus	Arcus costalis	'Upper Abdomen'	Spina iliaca ant.sup.	'Lower Abdomen'
1	z	3.00	6.55	7.36	8.32	5.86	2.73	3.00
	y	5.73	7.11	5.63	4.84	4.55	1.48	2.37
2	z	2.86	3.00	2.18	1.91	1.91	1.50	1.77
	y	2.27	2.47	2.47	2.67	2.67	1.09	2.37
3	z	3.41	4.36	3.68	4.23	5.18	3.41	5.59
	y	2.22	3.38	2.64	2.64	2.43	1.58	2.64
4	z	-.--	3.96	2.59	3.95	3.82	-.--	2.05
	y	-.--	2.96	2.37	3.16	2.67	-.--	0.99
5	z	3.41	5.05	3.68	4.09	3.14	2.45	-.--
	y	3.75	5.24	4.25	3.26	3.16	1.28	-.--
6	z	4.64	5.18	3.82	4.64	3.00	-.--	-.--
	y	4.05	4.55	3.16	3.56	3.36	-.--	-.--
7	z	4.09	4.09	3.27	3.27	2.59	-.--	-.--
	y	2.27	2.77	2.27	2.57	1.78	-.--	-.--
8	z	3.14	5.18	4.36	4.64	2.45	2.18	2.32
	y	4.45	5.93	4.05	3.66	2.96	1.98	2.08

DISCUSSION

In comparison to other applications of motography with infrared or other light of special bandwidth (Baum, 1980, 1983), the exposure technique was simplified using red LEDs in a dim or dark room. The method does not reveal any elevation of light marks during quiet breathing. This lack of any visible alteration of the chest cage corresponds to what may be expected, if the diaphragm is considered as the principal breathing muscle. The chest cage expansion of 1.2 cm, found with physiological methods during inspiration (Wade, 1954), could likewise be caused by diaphragmatic breathing: the costal parts of these muscles can have elevating and widening components for the lower chest cage (Grassino and Goldman, 1986, Gray, 1901, Sharp et al., 1975). It should be admitted that the study of quiet respiration is limited not only by the at most small changes of the body surface but also by some swaying of the trunk of the upright standing persons. This drawback can be avoided in a supine or sitting position (Figs. 5,6).

Then, however, the tonus of the abdominal wall may be altered. As a consequence, men exhibit generally longer light traces at the abdominal wall in supine position than when upright. Although the combination of motography with stereoscopy in fact provides a vivid impression of movements of the body wall during deep respiration, the evaluation of the kinesiologic findings with methods of image analysis also is significant, even if it is restricted to the monocular view. Only such a quantitative documentation gives an objective information and allows for descriptive and explorative statistics.

The measurements of the light traces in the vertical projection show particularly well the different possibilities to increase the thoracic volume. Most probably, these represent peculiarities of the individuals, because most conditions of the study were quite similar, while others, like body position and clothing, could influence the pattern correspondingly. The eight men could be collected into one group with upper and into a second one with lower chest respiration; the latter may essentially be due to the activity of the diaphragm, as already mentioned. The longer tracks in supine position once more give a hint towards the general importance of the diaphragm, producing abdominal breathing at a lower tonus of the abdominal muscles in supine and chest breathing at a higher one in upright persons. The abdominal breathing of supine and the costal breathing of upright persons is known from extensive studies with electro-mechanical devices (Sharp et al., 1975). The authors suppose, in correspondence to Mead and Goldman (not published), smaller cephalad force components of the diaphragm, if persons are supine instead of upright. Differences in muscle tension of the abdominal wall were not considered. We investigated undressed persons, a possible drawback of our procedure, to compare our results with this physiological study. For the application in clinical studies now in progress, however, it seems to be adequate to expose only the chest and the upper abdomen of patients. Under such conditions, motography may have its place in the evaluation of respiratory movements on account of its vividness and the possibility to realize individual motion patterns.

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