INITIAL EXPIRATORY ACTIVITY AS A TEST OF RESPIRATORY CENTER FUNCTION

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Ideas on the functional organization of the respiratory center and, in particular, of that part of it which is generally regarded as the central pattern regulator, have been substantially modified [4]. In particular, in addition to the concept of central inspiratory activity, reflecting the output signal of "output" bulbospinal inspiratory neurons (CIA), the term "central expiratory activity" (CEA), linked with the hypothetical function of expiratory neurons, has been introduced. For the noninvasive recording of CIA, the jump of negative oral pressure rising during short-term occlusion of the inspiratory channel for 0.1 sec ($P_{0.1}$) or the maximal rate (1st derivative) of rise of the negative oral pressure (dP/dt_I) at the beginning of inspiration, are used for the noninvasive recording of CIA. Both these parameters, according to some authorities [5], reflect rapid isometric contraction of the inspiratory muscles: initial inspiratory activity. However, to evaluate the process developing in the respiratory system at the end of inspiration, the corresponding parameter has not yet been used. As such a parameter the maximal rate of rise of the positive oral pressure on the boundary between inspiration and expiration could be used (dP/dt_E). To test this possibility we studied the time course of respiratory variables and undertook correlation analysis of connections between the parameters dP/dt_I, dP/dt_E, and volume and time parameters of the respiratory act in man at rest and during hyperpnea, induced by muscular effort, and also with additional resistive resistance to breathing.

EXPERIMENTAL METHOD

Altogether, 13 healthy men aged 25 to 45 years took part in the investigation. They did work of stepwise increasing intensity (by 30 W every 3 min) on a "Monark" bicycle ergometer, with pedal rotation speed of 60 rpm. At rest, and also during average (110 W) and heavy (215 W) work, the tidal air (V_T), the duration of inspiration and expiration (T_I, T_E), the mean inspiratory and expiratory flow rates ($\dot{V}_I$, $\dot{V}_E$) and the minute ventilation ($\dot{V}$) were recorded by a spirographic method. In addition, peak values of the inspiratory and expiratory oral pressure (P_{mI}, P_{mE}) and the first derivatives of their rates of rise were recorded by means of an electromanometer, connected to the breathing mask, and a differentiating circuit, at the beginning of inspiration were standard in magnitude and it was in fact the rate of change of pressure that was recorded, the breathing mask was equipped with inspiratory and expiratory valves, which opened when the oral pressure fell to -1 cm water and rose to $+1$ cm water, respectively. Thus the parameter dP/dt_I reflected the rate of fall of oral pressure before opening of the inspiratory valve, whereas dP/dt_E reflected the rate of rise of this pressure before opening of the expiratory valve. The recording part of the apparatus was calibrated with the aid of a device simulating pressure drops, whose characteristics corresponded to those observed in the investigation. These parameters were recorded during breathing for 5 min against additional aerodynamic (resistive) resistance, which was created by introducing perforated diaphragms into the inspiratory and expiratory channels, and which amounted to 12, 16, 20, or 40 cm water (liters/sec).

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TABLE 1. Effect of Muscular Work on Respiratory Parameters ($M \pm m$)

Parameter	Load, W		
	0 (rest)	110	215
dP/dt_I, mm water·sec^{-1}	140±11	489±71	1127±114
dP/dT_E, mm water·sec^{-1}	102±6	308±38	787±93
P_{mI}, cm water	2,3±0,2	4,6±0,4	9,2±1,3
P_{mE}, cm water	1,5±0,1	3,2±0,2	6,5±0,5
$\dot{V}_I$, ml/sec	425±21	1153±50	2437±112
$\dot{V}_E$, ml/sec	270±17	923±41	2067±114
$\dot{V}_T$, ml	1000±113	2008±140	2310±110

Legend. Changes in all parameters during work compared with resting conditions are statistically significant ($p < 0.01$).

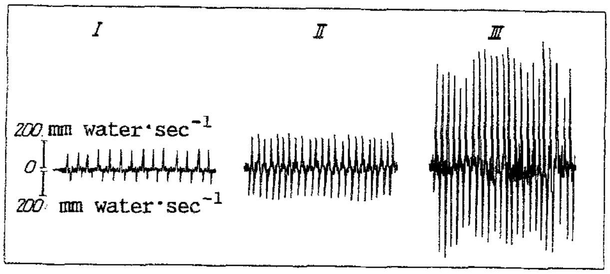

Fig. 1. Trace of differential pressure inside the mask at rest (I) and during muscular work with a power of 110 W (II) and 215 W (III). Peaks upward from isoelectric line correspond to dP/dt_I, those downward to dP/dt_E.

EXPERIMENTAL RESULTS

As will be clear from Table 1, under conditions of working hyperpnea the inspiratory and expiratory pressure drops in the respiratory passages (P_{mI}, P_{mE}) and, in particular, their initial rates (dP/dt_I and dP/dt_E), increased stepwise, and the magnitude of the increase in the two last parameters was absolutely identical with an increase in the intensity of work. This is also clear from Fig. 1.

In accordance with the intensity of work, the inspiratory and expiratory flow rates in the respiratory passages ($\dot{V}_I$, $\dot{V}_E$) increased. However, it is important to note that the depth of respiration increased only up to a value of about half of the vital capacity: the further increase of ventilation, in accordance with the known law, was achieved through the quickening of the respiration rate.

Different relations were found under the conditions of additional resistance to respiration (Table 2). All gradations of resistive load were associated with an increase in the parameters dP/dt_I and dP/dt_E. Peak inspiratory and expiratory pressures in the respiratory passages rose by an even greater degree. However, the corresponding flow rates and also the respiratory volumes showed a tendency to fall with an increase in the additional resistance.

The close correlation (Table 3) of the initial rate of rise of expiratory pressure (dP/dt_E) with the corresponding inspiratory parameter (dP/dt_I) which, in turn, reflects CIA, is evidence of its direct relationship to activity of the respiratory center. Since it is considered that the switching from inspiration to expiration and subsequent development of the expiratory phase depend to a greater or lesser degree on the inspiratory phase [4], there are good reasons to connect the parameter dP/dt_E with activity of a central respiratory mechanism.

Admittedly, this interpretation of the parameter under examination is complicated by the following state of affairs. First, expiration at rest takes place on account of the elastic pull of the lungs, and for that reason expiratory activity under conditions of eupnea ought not to be exhibited. Evidently during quiet breathing (and also to some extent, during forced breathing) the parameter dP/dt_E reflects the pressure jump due, not to contraction of the expiratory, but to relaxation of the inspiratory

TABLE 2. Effect of Resistive Resistances on Respiratory Parameters ($M \pm m$)

Parameter	Additional resistance to respiration, cm water/(liters/sec)				
	0	12	16	20	40
dP/dt_I, mm water·sec^{-1}	140±11	169±10	188±21*	267±25**	292±27**
dP/dt_E, mm water·sec^{-1}	102±6	121±7*	141±10**	174±14**	213±21**
P_{mI}, cm water	2,3±0,2	34,4±0,3**	5,1±0,5**	6,8±0,6**	8,7±0,7**
P_{mE}, cm water	1,5±0,1	2,2±0,2**	2,9±0,2**	3,6±0,3**	4,6±0,3**
$\bar{V}_I$, ml/sec	425±21	357±19	340±17**	324±18**	287±16**
$\bar{V}_E$, ml/sec	270±17	254±13	246±16	231±15	213±18*
V_T, ml	1000±113	900±113	885±114	869±111	854±109

Legend. *$p < 0.05$, **$p < 0.01$) Levels of statistical significance of changes compared with breathing without resistance.

TABLE 3. Correlation between Initial Expiratory Activity (dP/dt_E) and Parameter of Initial Inspiratory Activity (dP/dt_I) and Breathing Pattern

Parameter	Coeff. of correlation
dP/dt_I	0,99*
P_{mI}	0,99*
P_{mE}	0,99*
V_T	0,94
T_I	—0,99*
T_E	—0,95

Legend. *$p < 0.05$.

muscles, signifying the cessation of inspiration. The more marked the inspiratory activity, the deeper its subsequent fall must be. Hence there is a definite parallel between the parameters dP/dt_I and dP/dt_E. On the other hand, we know that after the end of inspiration activity of the inspiratory muscles does not disappear, but steadily weakens throughout the so-called postinspiratory phase. The functions of special postinspiratory neurons are ascribed to this phase [3, 6], and its precedes true, active expiration, which is linked with excitation of the expiratory bulbospinal neurons (although not necessarily accompanied by contraction of expiratory muscles). The rate of fall of activity of the inspiratory muscles must naturally have a direct, and the duration of the postinspiratory phase a reverse effect on the dynamics of pressure in the air passages and, consequently, on the parameter dP/dt_E also. However, it is difficult at present to judge the importance of the processes we have examined for the magnitude of initial expiratory activity.

Thus the concept of "initial expiratory activity" used in this paper is still conventional in character. The parameters dP/dt_E, which we have used for the first time, undoubtedly reflects the switch from inspiration to expiration, and it is thus linked, although indirectly, with activity of the central respiratory mechanism. Further research, we must assume, will produce a final solution to the problem of whether this parameter can be used for the noninvasive study of activity of the respiratory center in man and in animals under various conditions.

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