Effects of Added Resistive Loads to Inspiration on Submaximal Work Performance

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We can find very few studies on the physiological aspects involved in the use of respiratory protective devices (RPD) in Japan. To examine working conditions when workers wearing RPD, we need to obtain more physiological data on Japanese. As the first step of our purpose, we examine the effect of inspiratory resistance on physiological work load in young adults.

METHODS

The subjects were 7 male adults aged from 23 to 38 yrs old. Stainless steel mesh #325 was employed to make four different inspiratory resistances such as 0.6 (without mesh), 1.5, 2.5, and 3.1 cmH₂O/liter/sec called control, light, middle, and heavy load, respectively. Half facepiece mask was used for breathing. The subjects performed exercise at a load of 120 watts for seven minutes on a bicycle ergometer with electronic braking (Takei Kiki Kogyo Co. Ltd.). They take a rest on a bicycle ergometer for five and eight minutes before and after exercise, respectively.

A hot-wire-anemometer (Minato Medical Science Co.Ltd.) was placed on the inspiratory and expiratory limb, respectively, of the mask to measure each flow rate. A differential pressure transducer (Validyne MP-45) was employed to measure mouth pressure. Expired gas was led to O₂ and CO₂ analyzer (Nihon Denki Sanei Co.Ltd.) for breath by breath analysis. Each subject was instructed to operate a dial, numbered from 1 to 5, during experiment according to his sensation of the effect of the resistance on his inspiration. All signals were recorded on a digital data recorder and then transferred

to personal computer (NEC PC-9801VX) for breath by breath analysis.

RESULTS AND COMMENTS

There have been many studies in European countries as to effects of resistances on the work performance (Raven et al., 1979). However, most of these studies have focused only on respirator tolerance or physiological effects (Flook and Kelman, 1973). Therefore, the range of resistances used in the study was varied widely. From the point of view of an individual's fitness for respirator use, it is important to test an adequate range of resistances reflecting actual case in respirator use and to evaluate the physiologic and psychophysiologic consequences.

Japanese regulation of a initial resistance of RPD such as air purifying respirators limits to be below 0.8 cmH₂O measured at flow rate of 40 liters per minute (1.2 cmH₂O/liter/sec). Recently, the initial value of such RPD is around 0.6 cmH₂O/liter/sec as a result of development of filter paper and mask in itself. According to a survey of Japanese workplace, most of workers who wearing RPD change a filter paper at a resistance between 3.0 and 4.5 cmH₂O/liter/sec due to feeling difficulty of breathing. The range of the resistances used in this study was corresponding to that in the actual working circumstances.

Figure 1 shows the relationship between maximum inspiratory pressure (P_{imax}) and resistances. P_{imax} is the average of the values obtained for the last two minutes during exercise. P_{imax} increased linearly with increasing resistance. Figure 2 shows a example of changes in breathing pattern expressed

Fig. 1 The relationship between maximum inspiratory pressure (Pimax) and inspiratory resistances during exercise.

Fig. 2 Changes in breathing pattern expressed as % ratio to the control values when breathing against inspiratory resistances at rest and during exercise.

as % ratio to the control values when a subject was breathing against inspiratory resistances. There were individual differences in breathing pattern, however in general, we can say as follows; peak inspiratory flow rate (PIF) and mean inspiratory flow rate (MIF) decreased with increasing resistance or intramouth pressure. This caused the prolongation of inspiratory time (T_i) to keep tidal volume and shortening of expiratory time (T_e) to avoid a reduction of respiratory frequency (FQ). As a result of shortening of expiratory time, peak expiratory flow rate (PEF) increased and the ratio of inspiratory time per total duration in one breath (T_i/T_t) also increased. Four of seven subjects showed the reduction of inspiratory volume (V_i) caused by less tidal volume and/or less FQ.

The sum of sensation (SNS) was calculated. The scored number of sensation multiplied by the time period during which the score was kept was summed up, which was considered to express the degree

Fig. 3 The relationship between a parameter of subjective sensation (sum of SNS) and maximum inspiratory pressure during exercise.

of sensation of difficulty on breathing. Figure 3 shows the relationship between the sum of SNS and Pimax during exercise. The sum of SNS did not increase until Pimax increased up to around 5 cmH₂O/liter/sec, and then increased. This critical point of Pimax is corresponding to the resistance between light and middle load in this study.

It was concluded that breathing pattern might be affected even by a low resistance and that the workers who wearing RPD might start to feel the difficulty on their breathing much before they decid-

ed to change their filter paper.

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