Study of Influence Factor on Maximal Mouth Pressure Part II. —Influence of Trunk Flexion—

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Abstract. We studied the influence of posture on maximal mouth pressure in Part I. The study of Part II was aimed at determining the influence of trunk flexion on maximal mouth pressure. Nineteen healthy, young adult students from WCMA comprised a STANDING study group, and 27 healthy, young adult students from IUHW comprised a LYING study group (same subjects of Part I). Maximal expiratory mouth pressure (PE_{max}) and maximal inspiratory mouth pressure (PI_{max}) were measured at 0, 30, and 60 degrees of trunk flexion. Posture changes were significantly related to maximal mouth pressure values, and trunk flexion from the standing posture statistically influenced maximal mouth pressure. PE_{max} and PI_{max} in standing were enhanced with trunk flexion. Respiratory muscle strength changes with trunk flexion, because respiratory muscle tension occurs with the change in interabdominal pressure and the muscle length-tension relationship.

Key words: Maximal mouth pressure, PE_{max}, PI_{max}, Trunk flexion.

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INTRODUCTION

Maximal mouth pressure is one of the indices used in the field of physical therapy to evaluate respiratory muscle strength in patients^{1, 2)}. Measurement of maximal mouth pressure is generally used because it is a noninvasive and comparatively easy test and useful for screening^{3, 4)}. Positive mouth pressure upon exhalation is termed maximal expiratory mouth pressure (PE_{max}) and negative mouth pressure upon inhalation is termed maximal inspiratory mouth pressure (PI_{max})^{1, 3)}. Maximal mouth pressure values have been reported for young adults^{5, 6)}, the elderly^{5, 7-9)}, and patients with respiratory diseases^{10, 11)}, neuromuscular disease⁵⁾ and tetraplegia^{12, 13)}. Some factors that have been examined for their influence on

respiratory muscle strength are lung volume^{5, 9)}, aging^{5, 7)}, anthropometrics⁸⁾, lung function^{7, 14)} and physical activity¹⁵⁾. Controversy exists over whether PE_{max} and PI_{max} are accurate indicators of respiratory muscle strength, and many studies have been performed investigating factors that might influence PE_{max} and PI_{max} values. Of all the factors studied, only lung volume and aging appear to consistently influence maximal mouth pressure. We do know, however, that lung function parameters are affected by posture^{16, 17)}. Thus, in the study of part I, we investigated whether the influence of posture, lying, sitting, standing, or sitting with elbow on knee (the orthopneic position), influenced maximal mouth pressure values, and we concluded that postural influence resulted from the position of the diaphragm and the

length-tension relationship of other respiratory muscles being changed by posture and gravity.

We hypothesized that maximal mouth pressure would change according to the length of the diaphragm and that other respiratory muscles are affected by trunk flexion. Even in clinical practice, patients with chronic obstructive pulmonary disease flex the trunk and take the orthopneic position when they are fatigued after exercise. However the influence of trunk flexion on respiratory function measured by maximal mouth pressure has not yet been studied. Thus, the aim of this study was to elicit the influence of trunk flexion on maximal mouth pressure values.

METHODS

Subjects

Study subjects comprised 46 healthy young adult volunteers from two physical therapy schools (Waseda College of Medical Arts and Sciences, WCMAS; and the International University of Health and Welfare, IUHW, in Japan; all subjects of parts I and II were the same). It was confirmed beforehand that no participant suffered from cardiovascular, pulmonary, neuromuscular, or orthopedic disease. The WCMAS subjects were placed in a STANDING group (n=19), in which the influence of trunk flexion from the vertical standing position was studied. The IUHW subjects were placed in a LYING group (n=27) in which the influence of trunk flexion from the supine position was studied. Informed consent was obtained from all subjects before their participation.

Measurement of maximal mouth pressure (PEmax and PImax)

PEmax and PImax were measured with a KH-101 (CHEST, Ltd; Japan), which comprises a cylinder and pressure sensor. We used a silicon mouthpiece, also manufactured by CHEST, Ltd. The detailed method of the measurement of maximal mouth pressure and the setting of each of the groups is described in part I. We used only data collected at trunk flexion angles of 0° (vertical standing or lying), 30° and 60° in this study for the analysis of the influence of trunk flexion.

Control of trunk flexion

We used a CYBEX6000 (CYBEX, Ltd)

dynamometer and a trunk attachment for control of trunk flexion in the STANDING group. Subjects' knees were positioned at a slight bend, and the pelvic and upper trunk were gently constrained with a belt and leaving the arm free to protect against motion of the thorax and abdomen. Subjects were monitored to ensure that strain did not occur during measurement of maximal mouth pressure. We used a reclining bed for control of trunk flexion in the LYING group. Subjects were not constrained, but were instructed not to rise from the bed. Subjects were positioned supine on the bed so that the crista iliaca aligned on a joint of the reclining bed joint for easy trunk flexion in any reclining angle.

Protocol

Subjects' physical characteristics were measured first, and after several practices, the PEmax and PImax were measured. The protocol of parts I and II were the same, and details are described in part I.

Statistical analysis

Data were analyzed at trunk flexion angles of 0° (vertical standing or lying), 30° and 60°. General characteristics of the STANDING and LYING group subjects were compared by non-paired t-test. All 15 measurements were considered based on the order of enforcement, and learning and fatigue effects were analyzed by two-way analysis of variance (ANOVA). Comparisons of each posture were analyzed by two-way ANOVA and Fisher's PLSD post hoc test was used for each of the different trunk angles. The criterion for statistical significance was $p < 0.05$.

RESULTS

Characteristics between groups and learning and fatigue effect

Age, height, weight and BMI did not differ statistically between the two groups. Sitting PEmax and sitting PImax also did not differ statistically between the two groups. The order of enforcement of the measurements was examined. Each value didn't change by the measurement order. Thus, learning and fatigue effects were not more influential than the influence of changing positions. The detailed characteristics of maximal mouth pressure and learning and fatigue effects are described in part I (Table 1, Fig. 1).

Fig. 1. Changing trunk flexion and maximal mouth pressure.

Influence of trunk flexion on maximal mouth pressure

Maximal mouth pressure data are shown in Fig. 1 a, b and in Table 1. In the STANDING group, both PEmax and PImax at 60° were significantly higher than PEmax and PImax at 0° and 30°, both values in this group changed significantly with trunk flexion. In the LYING group, however, no statistical change was observed in PEmax or PImax with trunk flexion. The difference in PEmax was significant at each angle in the STANDING group, and PImax at 0° differed significantly from PImax at 30° and PImax at 60°. The differences in PEmax and PImax in the LYING group were not significant between angles. Thus, in the STANDING group PEmax and PImax were significantly strong at 60° of trunk flexion and significantly weak at 0° of trunk flexion, but PEmax and PImax did not change with trunk flexion in the LYING group.

DISCUSSION

We measured maximal mouth pressure at various degrees of trunk flexion to determine the influence of trunk flexion on respiratory muscle strength. Maximal mouth pressure was changed by trunk flexion in standing, but was not changed by trunk flexion in lying. We considered the possibility that weaker inspiratory muscles do not keep the liver and the diaphragm from the pull of gravity and that

abdominal muscle activity differs between lying and standing postures^{18,19}. We deliberately studied healthy volunteers whose general characteristics did not differ greatly so that the individual differences in PEmax and PImax values would not be problematic in our study. Our sitting PEmax and PImax values were stronger than the sitting values reported by Kikuchi²⁰. The reason for the difference is probably because we used a mouthpiece made of silicon that did not leak air. Also, we did not set up an orifice that prevented glottal closing⁹ or influence of the buccinator muscle⁷ because we needed to prevent any change in lung volume caused by an orifice.

Cook et al.⁹ did not observe a short learning effect, but they observed a long learning effect in certain subjects. Wen et al.⁴ reported in a retrospective analysis that the late testing data were stronger than the early testing data in a series of 367 measurements of maximal mouth pressure. We wished to avoid this learning effect, so we performed our measurements after detailed explanation and several practices involving all of the each subjects. All low values were checked against the order of measurements (Part I, Fig. 1), but we found no pattern that would indicate that low values were obtained early in the series of measurements. Thus, we concluded that the learning effect was not more influential than the influence of trunk flexion.

Table 1. PEmax and PImax measurements*

	Standing group		Lying group	
	PEmax	PImax	PEmax	PImax
0 degrees	163.5 ± 26.5	164.2 ± 33.3	177.1 ± 22.5	156.2 ± 32.6
30 degrees	171.7 ± 23.2	176.5 ± 24.4	179.0 ± 22.0	159.2 ± 32.1
60 degrees	179.8 ± 19.3	179.2 ± 25.3	178.7 ± 23.0	158.7 ± 34.7

*Mean ± SD cmH₂O Values are shown. **Fig. 2.** Reinforcement of PEmax and reinforcement of PImax by trunk flexion from the standing position.

Maximal mouth pressure may be increased by action of the abdominal muscles. Upon exhalation with effort, the abdominal muscles (the transversus abdominis, abdominal oblique, and rectus abdominis) are activated¹⁸⁾. With trunk flexion, the rectus abdominis is able to move ventrally and dorsally because the muscle origin and insertion become closed and relaxed. Contraction of the abdominal muscles (including the rectus abdominis and transversus abdominis) pulls the abdominal wall dorsally, increasing the interabdominal pressure at the beginning of the expiratory phase. At the beginning of the inspiratory phase, rectus abdominis contraction pulls the abdominal wall (including other abdominal muscles) dorsally, decreasing the interabdominal pressure ventrally (Fig. 2). The viscera, which is enclosed by the

thorax and pelvis, increases interabdominal pressure with trunk flexion. PEmax increases because expanding the abdominal wall (the viscera is pushed out by the diaphragm contracting and falling) improves the length-tension relationship of the abdominal muscles. The increased interabdominal pressure which occurs with trunk flexion augments this mechanical advantage. The diaphragm is lifted by the increase in interabdominal pressure, improving the length-tension relationship of the rectus abdominis, and consequently, PImax is strengthened. This is the mechanism for optimal, inspiration and expiration. In this study, both PEmax and PImax were increased by trunk flexion from the standing position, but not in the lying position. It may be that in the lying position, the change in PImax is only

Fig. 3. Reinforcement of PEmax and compensation of PImax by trunk flexion from standing. In the standing position, PEmax is decreased, but it is compensated by trunk flexion. Furthermore, PImax is reinforced to above the level in the sitting by trunk flexion.

slight because the diaphragm does not lift the intrathorax due to the weight of viscera; i.e., with trunk flexion in the lying position, the decreased gravity “advantage” neutralizes the increased trunk flexion “advantage”. Our overall observations (Part I and II) were that PEmax in the standing position is decreased in comparison to PEmax in the sitting position, but when the trunk is flexed from vertical standing, PEmax is recaptured and PImax increases. Thus, it appears that trunk flexion compensates for decreased PEmax and reinforces PImax (Fig. 3). This causes us to consider the possibility that exercise for chronic lung failure could be effective if trunk flexion is included in the exercise routine. There may be a particular advantage in cases of severe chronic obstructive pulmonary disease in which the diaphragm is flattened by marked lung expansion.

We observed influence of posture on maximal mouth pressure and postulate that this influence is connected with activity of the rectus abdominis and transversus abdominis. However, we didn't measure intragastric pressure, position of diaphragm, and especially activation of muscle EMGs. The observation of which are needed to prove this hypothesis.

CONCLUSION

We studied the relationship between trunk flexion and respiratory muscles by measurement of maximal mouth pressure. Changing trunk flexion influenced respiratory muscles and both PEmax and PImax were significantly strong at 60° of trunk flexion in standing only. We believe the causes of the influence of respiratory muscle strength through trunk flexion are participation of the respiratory muscles, especially the transversus and rectus abdominis.

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