THE EFFECT OF SHOULDER POSITION DIFFERENCE OF STREAMLINE POSTURE IN COMPETITIVE SWIMMERS

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The objective of this study was to investigate the movements of the centers of buoyancy and mass and the change in the distance between the two centers because of the elevation of the shoulder joints. The total length increased by 5.7 cm on an average because of the elevation of the shoulder joints. The positions of the center of mass with respect to the heels were 103.4 ± 4.0 cm during depression and 104.2 ± 4.1 cm during elevation. The center of buoyancy shifted toward the head more during elevation (105.9 ± 4.2 cm) than during depression (105.1 ± 4.1 cm) during neutral buoyancy. Also, the distance between the centers of buoyancy and mass was smaller during elevation (1.60 ± 0.20 cm) than during depression (1.66 ± 0.21 cm) with 1% significance. This study suggests a possible effect of the shoulder position on maintaining a horizontal position.

KEY WORDS: scapula, elevation, depression, center of buoyancy.

INTRODUCTION: Swimming is an exercise performed with one's body lying horizontally in water. A swimmer is subject to resistances due to pressure, waves, and friction. In particular, the pressure resistance has the largest effect. The pressure resistance stems from the pressure difference between the swimmer's front and rear. The key is to maintain a horizontal position along the direction of motion. In other words, the factors for maintaining a horizontal position are the relationship between the buoyant and gravitational forces as well as the positional relationship between the centers of buoyancy and mass.

To date, we have developed a system for real-time measurement of the distance between the two centers with change in lung volume in order to compare swimming performances (Watanabe et al., 2014[a], 2014[b]). The subjects of this study were swimmers having highly flexible shoulder joints. We measured the buoyant force, the motion of the center of mass during respiration and the change in the distance between the buoyant and gravitational centers during elevation and depression of the shoulder joints in a streamline position. Furthermore, we investigated the effect of flexibility of the shoulder joints in a horizontal position in water.

METHODS: The subjects were nine male collegiate swimmers. The subjects had an age of 19.7 ± 0.83 years, a height of 170.8 ± 5.0 cm, and a weight of 66.4 ± 4.9 kg. The center of mass was measured on the ground. Each test subject held breath after inspiration and remained immobile for three s. While in the streamline posture, the distance from the subject's foot (lateral malleolus) to the subject's hand (center of the fist) is designated as x, and the distance from the subject's foot to the subject's CoM is designated as y. Calculations were made using the following equation, where the weight ($F1_{CoM}$ + $F2_{CoM}$) and force ($F1_{CoM}$) vertically act on the hand: $y = F1_{CoM} \cdot x/(F1_{CoM} + F2_{CoM})$ (1)

The total length of the streamline position was measured during depression and elevation of the shoulder joints (see, figure 1).

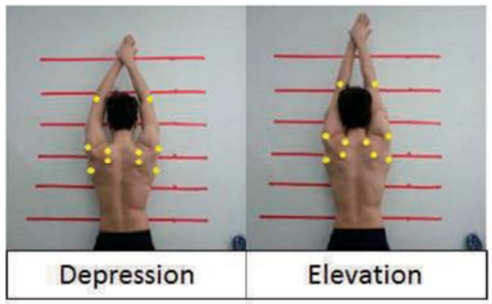

Figure 1: The difference of the position of the shoulder joint.

Similar to the measurements of the center of mass, measurement was made during depression and elevation of the shoulder joints. The method was to measure the total length of the streamline position for both cases on the ground. Then, the distance between F1 (force on the fingers) and F2 (force on the toes) was matched. The fingers and toes of the subjects were fixed by hanging grips on the F1 sensor and fixing devices on the F2 sensor, respectively. The ventilation volume was measured by installing a measuring device on the tip of a snorkel. The test lasted for 60 s with six cycles of inhalation and exhalation of 5 s duration each. The test was set to start with inhalation. If we assume that a subject remains still in the water, the buoyancy force (B) can be calculated: $B = -(F1_{CoM} + F2_{CoM}) - F1_{CoB} - F2_{CoB}$ (2)

The CoB from the foot area (z) can be calculated by inserting equations (1) and (2) into the following formula: $z = \left((F1_{CoB} \cdot x) + \left((F1_{CoM} + F2_{CoM}) \cdot y\right)\right) / (F1_{CoM} + F2_{CoM})$ (3)

Hence, the CoB/CoM distance in a swimmer's underwater horizontal posture (d) can be calculated: $d = z - y$ (4)

RESULTS: 1. The change in total length and position of center of mass: The total lengths during depression and elevation of the shoulder joints were 204.8 ± 7.7 cm and 210.4 ± 6.7 cm, respectively. The stretch of the total length because of the elevation of the shoulder joints was 5.7 cm. The average positions of the centers of mass with respect to the heels during depression and elevation were 103.4 ± 4.0 cm and 104.2 ± 4.1 cm, respectively.

2. Change in buoyancy because of the change in ventilation volume: Figure 2 shows the change in buoyancy because of the change in ventilation volume (left: during depression, right: during elevation).

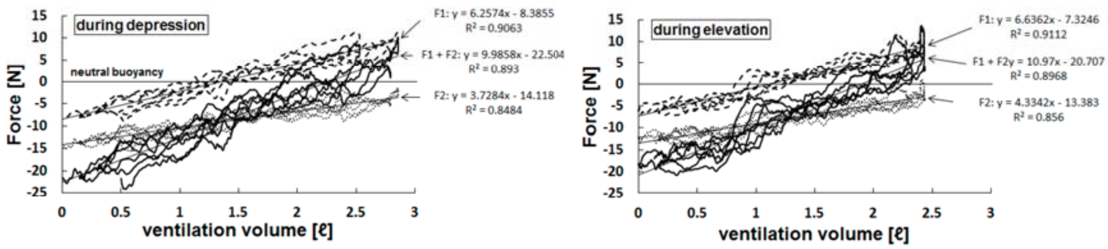

Figure 2: Change in buoyancy because of the change in ventilation volume.

3. Position of the center of buoyancy and the distance between the centers of buoyancy and mass: For all subjects, the positions of the center of buoyancy during neutral buoyancy shifted toward the head more during elevation (105.9 ± 4.2 cm) than during depression (105.1 ± 4.1 cm). The distances between the centers of buoyancy and mass in neutral buoyancy were lower during depression (1.66 ± 0.21 cm) than during elevation (1.60 ± 0.20 cm) with a significance of 1 % (see, figure 3).

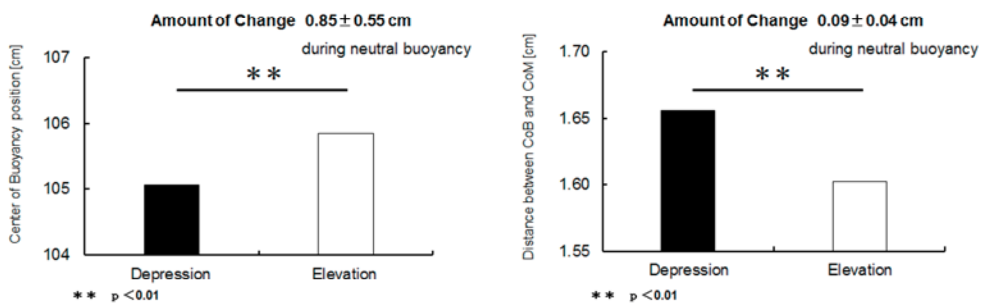

Figure 3: Comparioson of the center of buoyancy position (left), and the distance between center of buoyancy and mass (right).

4. Ventilation volume during neutral buoyancy and maximum ventilation volume:
The ventilation volume during neutral buoyancy was 2.41 ± 0.38 ℓ (± 0.38) during depression and 2.16 ± 0.32 ℓ during elevation with a significant difference (1 % significance). Furthermore, seven out of the nine subjects showed higher maximum ventilation volumes during elevation.

DISCUSSION: Between depression and elevation, we observed a difference in the forces on the hands and on the feet during neutral buoyancy. From the perspective of respiration, there was a difference between depression and elevation in the ventilation volume during neutral buoyancy. Because the lung capacity is basically constant, the difference of ventilation volume is likely because of the residual volume. Respiration is achieved by motions of the diaphragm and rib cage. It is probable that the rib cage is affected by the motion of the shoulder joints, thus changing the residual volume (see, figure 4).

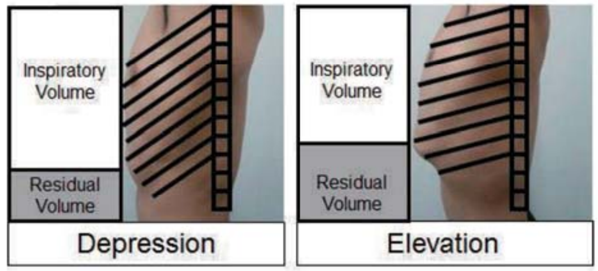

Figure 4: Differences of motion of the rib cage, and lung internal structure.

In contrast, from the perspective of physical characteristics, it is probable that the increase in the total length of the streamline position because of the elevation of the scapulae increases the torque on the hands, moves the center of mass toward the head, and decreases the buoyant torque (see, figure 5).

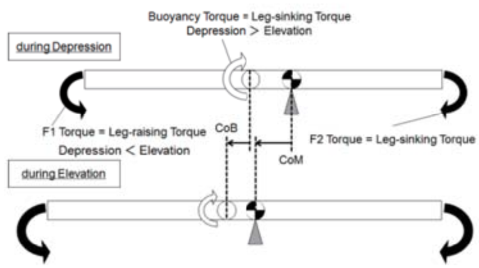

Figure 5: Schematic view of the body torques change due to the change of the total length.

CONCLUSION: We observed that the positions of centers of mass and buoyancy both shifted toward the head because of the elevation of shoulder joints. However, the change in the position of the center of mass was larger than that in the position of buoyancy, shortening the distance between the two centers. This study revealed that, in a streamline position with full immersion and with neutral buoyancy, the distance between the centers of mass and buoyancy during elevation was significantly shorter than during depression.

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