INFLUENCE OF YEARS OF SWIM TRAINING ON SEPARATE THORACOABDOMINAL VOLUMES DURING BREATHING

Amanda Piaia Silvatti, Karine Jacon Sarro and Ricardo Machado Leite de Barros

Laboratory of Instrumentation for Biomechanics – College of Physical Education, Campinas State University – Campinas (SP), Brazil

The purpose of this study was to verify the influence of the years of swim training on the separate thoracoabdominal volume variation during breathing using a kinematic analysis. Fifteen male swimmers were analyzed during tidal volume and vital capacity maneuvers. From the 3D coordinates of 30 markers fixed at the trunk the volumes of 4 separate compartments of the trunk (superior thorax, inferior thorax, superior abdomen and inferior abdomen) were calculated in function of time. During tidal volume, the coefficient of variation of the volumes of the superior and inferior abdomen increased with the years of swim training ($p<0.05$). During vital capacity maneuver, the same result was found for the inferior abdomen. These results suggest that the years of swim training affect the separate thoracoabdominal volumes reflecting the increased utilization of the diaphragm.

KEY WORDS: trunk volumes, swimming, kinematical analysis.

INTRODUCTION:

Studies have shown an increase in lung volumes and respiratory capacities with swim training. Clanton et al. (1987) showed that 12 weeks of swim training increased vital capacity, total lung capacity and functional residual capacity in mature females. Courteix et al. (1997) affirmed that after one year of training, 1-second forced expiratory volume and maximal respiratory flows at 75, 50 and 25% of vital capacity had raised in prepubertal girls. Practice of yoga has also been reported to improve respiratory function; Chanavirut et al. (2006) suggested that yoga exercises improve respiratory breathing capacity by increasing chest wall expansion and forced expiratory lung volumes. Besides the alteration in lung volumes, yoga techniques may lead to the formation of specific breathing patterns with an increased abdominal motion (Barros et al., 2003). Since the higher lung capacities of swimmers have already been demonstrated and considering that swimming involves strenuous breathing efforts, the pattern of variation of the thoracoabdominal volumes could also be altered by this sport, indicating the effect of swim training on respiratory muscles. The kinematic analysis has been used to obtain the separate volumes of the thorax and abdomen from thoracoabdominal motion (Kenyon et al., 1997). The purpose of this study was to verify the influence of the years of swim training on the separate thoracoabdominal volume variation during breathing using a kinematic analysis. The knowledge of these changes could lead to the better understanding of the alterations in breathing mechanics caused by swim training.

METHOD:

Data Collection: A group of 15 male swimmers was studied. The criteria of inclusion were training aiming competitions for more than 3 years, at least three times a week or covering an average of over 30.000 meters/month in the period. The mean years of swim training among the subjects studied was 7.6 ± 3.9 years. The volunteers sat with abduction of the shoulders on a chair without back support. They were asked to breathe quietly in tidal volume during one minute (TV) and to perform 5 breathing cycles in vital capacity (VC).

Thirty spherical retro-reflective markers (ϕ=5mm) were attached to the trunk of the subjects (figure 1) and the three-dimensional coordinates of the markers were obtained with kinematical analysis system *Dvideow* (Figueroa *et al.*, 2003), with 6 digital video cameras (JVC-GR 9500) sampled at 60Hz.

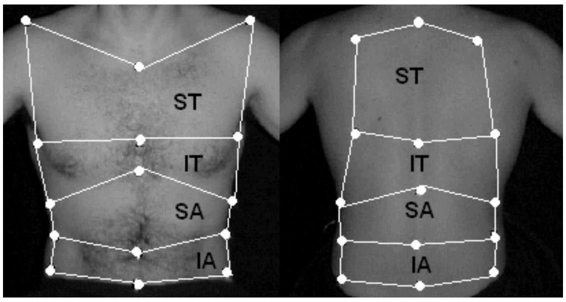

Figure 1: Representation of the trunk using external markers: model used to calculate the separate trunk volumes. Superior thorax (ST), inferior thorax (IT), superior abdomen (SA) and inferior abdomen (IA).

The 3D coordinates were smoothed with a zero-phase forward and reverse Butterworth digital filter of 2nd order (cutoff 0.33 Hz). From the smoothed 3D coordinates of the markers the trunk was separated in 4 compartments, each one geometrically defined as a dodecahedron with 8 vertices. The compartments, based on the trunk anatomy, were defined as superior thorax (ST), inferior thorax (IT), superior abdomen (SA), and inferior abdomen (IA) (figure 1). The volume of each compartment was measured in liters and was calculated in function of time. Four volume curves were obtained for each subject and for each maneuver.

Data Analysis: From the volume curve the coefficient of variation was calculated, defined as the ratio of the standard deviation to the mean of the volume curve. The coefficient of variation was calculated for each compartment, for each subject, for both maneuvers, and was presented as a percentage of the total volume variation. Considering that percentages and proportions present a binomial distribution, the $\sin^{-1}$ transformation was applied to the coefficient of variation results. To verify the influence of the swim training on the pattern of variation of the thoracoabdominal volumes the correlation coefficient (r), the coefficient of determination (r^2) and the linear regression between the years of swim training and the coefficient of variation of the separate volumes ($p<0.05$) were calculated.

RESULTS:

The mean values (±standard deviation) of the coefficient of variation during the tidal volume were 6.0±2.1% for the ST, 7.2±2.2% for the IT, 8.2±2.2% for the SA and 8.2±2.6% for the IA. During the vital capacity maneuver it was found 11.7±1% for the ST, 16.8±1.5% for the IT, 18.7±1.7% for the SA and 17.1±2.8% for the IA.

Figure 2 shows the years of swim training versus the coefficient of variation of the separate volumes of each subject during tidal volume and vital capacity. During tidal volume the coefficient of variation of the volume of all the compartments tended to increase with the years of swim training. In vital capacity maneuvers the coefficient of variation tended to decrease in the ST and IT and to increase in SA and IA with the years of swim training.

Table 1 shows the correlation coefficient (r), the coefficient of determination (r^2), the F statistic and p value for the regression of the separate volumes in tidal volume and vital capacity maneuvers. The correlation coefficients were positive for all the compartments in tidal volume, indicating an increasing linear relationship between coefficient of variation and years of swim training for all compartments. During VC maneuvers, the correlation coefficients for ST and IT were negative, indicating a decreasing linear relationship; for SA it was near zero, indicating no linear relation between the variables; and for IA it was positive.

The linear regression was statistically significant considering the SA (p=0.031*) and IA (p=0.0298*) in tidal volume and the IA (p=0.0464*) in vital capacity maneuver, meaning that the variation of the volume of these compartments was dependent on the years of swim training.

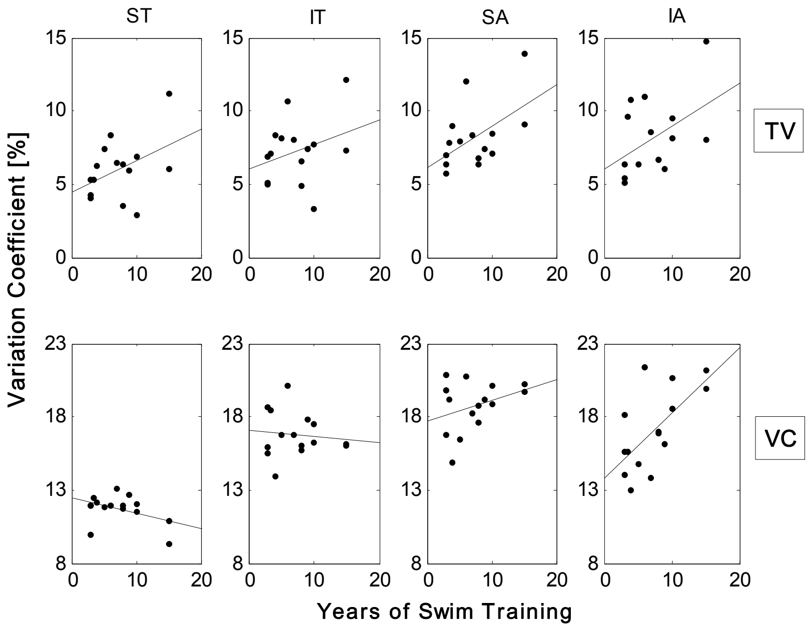

Figure 2: Years of swim training versus the coefficient of variation of the volumes of superior thorax (ST), inferior thorax (IT), superior abdomen (SA), and inferior abdomen (IA) during tidal volume (TV) and vital capacity (VC) maneuvers.

Table 1 – Correlation coefficient (r), coefficient of determination (r^2), F statistic and p values for the regression of the years of swim training and the volumes variation of superior thorax (ST), inferior thorax (IT), superior abdomen (SA), and inferior abdomen (IA) during tidal volume (TV) and vital capacity (VC) maneuvers.

Maneuvers	Compartment	r	r^2	F	p
TV	ST	0.4317	0.1864	2.9786	0.1080
TV	IT	0.3552	0.1262	1.8773	0.1938
TV	SA	0.5571	0.3104	5.8516	0.0310*
TV	IA	0.5604	0.3140	5.9499	0.0298*
VC	ST	-0.3831	0.1468	2.2600	0.1587
VC	IT	-0.2919	0.0852	1.2109	0.2911
VC	SA	0.1273	0.0162	0.2142	0.6511
VC	IA	0.5210	0.2714	4.8429	0.0464*

DISCUSSION:

The results showed that the volume variation of all the compartments increased with the years of swim training during tidal volume maneuvers. Gilbert et al. (1981) showed that relative motion of the rib cage and abdomen during quiet breathing is generally considered to reflect relative contributions of intercostal and diaphragmatic activity to ventilation. Thus the results achieved in this study suggest an increasing efficiency of the respiratory muscles, which could be related with the apnea required during the submerged phase of the swimming or with increase of the inspired air for the task during the stroke.

The increasing in the amplitude of breathing and the decreasing in breathing frequency, presented by yoga practitioners for example (Barros et al., 2003), can be related to increasing in the efficiency of breathing. The increased variation of the abdominal compartment of the trunk during tidal volume found in the more experienced swimmers could be explained by a long-lasting effect of swim training on the breathing pattern.

During vital capacity maneuvers there is an inversion of the influence of the years of training on the variation of the volumes of the ST and IT. The volume variation of the SA did not present dependence on years of swim training and that of the IA maintained its high positive correlation. These results suggest that the years of swim practice affect the pattern of variation of thoracoabdominal volumes when higher respiratory efforts are required, reflecting the increased utilization of the diaphragm. Previous works have already revealed that exercises (Kenyon et al., 1997) and Yoga practice (Barros et al., 2003) may lead to a increase in the abdominal variation during breathing. Sarro et al. (2006), comparing the correlation between motion of the ribs and the variation of the separate volumes of the trunk in swimmers and non-swimmers, found the highest difference in IA, where swimmers presented higher correlation values than non-swimmers.

Since the diaphragm is the main inspiratory muscle, respiratory exercises could be included in the session of the swim training aiming to increase even more the diaphragmatic efficiency.

It is important to analyze in future studies the possible consequences of these changes in breathing patterns developed in swimmers, since these changes can be related to the type of training and the main swim stile trained by the athlete. It is also interesting to investigate how long these changes remain, even when the athlete stops training.

CONCLUSION:

The results of this study suggest that the years of swim training affect the separate thoracoabdominal volumes during tidal volume and when higher respiratory efforts are required, reflecting the increased utilization of the diaphragm. Based on these findings, we believe that a respiratory training applied to swimmers could improve the development of the diaphragm, increasing their breathing capacity even more.

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