TRUNK SURFACE DEFORMATION AND VOLUME MEASUREMENT DURING RESPIRATION USING A LIGHT PROJECTION SYSTEM

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This paper aim to measure trunk surface deformation and volume variation during respiration based on realistic 3D data obtained by means of a light projection system. For volume measurement, the trunk was represented as a polyhedron using QHULL method and the polyhedron volume was calculated for each instant of the respiratory cycle. Trunk surface deformation was obtained by means of contour maps and it variation during respiratory movement. The method was tested in one male health subject. Comparing the volume variation curve with the contour maps, it is possible to evaluate how the subject trunk deforms in order to produce this volume variation. In conclusion, the proposed method was able to measure trunk volumes and surface deformation during the respiration.

KEY WORDS: biomechanics, breathing, contour maps, torso.

INTRODUCTION: The use of body scan systems to obtain 3D models of the human body has increased. This fact occurs because these systems are capable of generating 3D models that should faithfully reproduce the studied object and allows the direct and accurate measurement of variables such as circumferences, diameters, splitting volumes, areas, among others.

Measurements of body dimensions and surface have been widely used on ergonomic design and anthropometry (Allen, Curless, & Popović, 2004), plastic surgery (Bolton, Cash, & Persing, 2001) and in virtual animation (Magnenat, Seo, & Cordier, 2003). Those measurement are also an important tool for the analysis of human body in sport field by the accurate estimating of anthropometric body segment parameters (Wicke, Dumas & Costigan, 2009).

Most of body scan systems are capable to obtain 3D models and to measure accurate body dimensions only on static position (Wang, Gallagher, Thornton, Yu, Horlick & Pi-Sunyer, 2006). In particular in sport field, it is crucial to measure not only body dimension but how it deforms during the movement. As an application example of how important is to measure body deformation in sports could be the swimming case. During the swimming practice, the drag force is directly affected by the body shape change that could influence the athlete performance. A step towards this direction, this paper intent to measure trunk surface deformation and volume variation during breathing based on realistic 3D data obtained by means of a light projection system.

METHODS: The measurement of trunk volume and surface deformation during respiration propose in this study was applied on realistic 3D data obtained by means of the light projection system proposed by Lodovico, Cerveri, Ferrigno & Barros (2010). The projected light system uses four digital video cameras (JVC 9500), one pair of cameras registering the anterior trunk surface and one pair registering the posterior trunk surface (acquisition frequency of 30Hz). For each pair of cameras one multimedia projector was used to project a dense grid of circular markers on the body surface. The video stream is segmented to obtain 2D coordinates of the projected markers and a labeling process establishes the correspondence between markers on the different image projections. The 3D coordinates of the labeled markers were obtained by using the camera calibration parameters by means of a Direct Linear Transformation method (Abdel-Aziz & Karara, 1971). From 3D data, the triangulation method proposed by Barber, Dobkin & Huhdanpaa (2006), know as Qhull was used for enclose the trunk volume and represent it as a polyhedron. Polygonal lines were defined around the polyhedron and the volume was calculated by using equation 1:

$$Volume = \int_{H0}^{H} A(h)dh \cong \sum A(hi)\Delta hi$$

where, A is the area of the polygon generated by the polygonal line on h high, e Δh is the distance between 2 consecutive polygonal lines.

For trunk deformation measurement, contour maps were defined for the anterior and posterior surface on each instant of time of the respiratory cycle. The volume measurement accuracy and the reproducibility were obtained by the comparison between plastic trunk model volume obtained by water displacement and the volume obtained by our method. In order to exemplify the proposed method, one respiratory cycle of a male health subject was analyzed. The participant was sitting down with the arms on a waist and he was encouraged to execute maximal consecutive inhale and exhale cycle while the anterior and posterior trunk surface movements was recorded. Ethical approval was received from the University of Campinas Ethics Committee prior to data collection. For data analysis, volume and deformation data was normalized in function of the respiratory cycle. All procedures described above are implemented in MatLab ® R2009a.

RESULTS AND DISCUSSION: The upper portion of Figure 1 shows time course of trunk volume variation during the respiratory cycle. The trunk volume variation during the cycle was 1,87 liters. The lower portion of Figure 1 represent the contour maps for the anterior and posterior trunk surface in 0%, 25%, 50% and 100% of the respiratory cycle. Each line of the contour maps represents a level curve and the color intensity represent the curve elevation in respect to the X-Y plane. Thus, in the anterior maps the lines with color insensitive near to blue represent the highest elevation in respect to the X-Y plane, and the curves intensity color near from red the lowest elevations. The trunk volume variation during respiration showed a coherent signal with the respiratory cycle phases. Comparing the volume variation curve with the contour maps, it is possible to evaluate how the subject trunk shape change in order to produce this volume variation. On the maps of the anterior and posterior trunk surface, level curves with maximum values are shifted to the thorax region at 25% and 50% of the respiratory cycle. Both moments of the cycle correspond to maximal inspiration phase where the trunk was the largest volume. Furthermore, this increased displacement curves for the thorax region was symmetry performed when comparing the right and left sides of the trunk. The result of the volume accuracy measurement by the proposed method relative to the real value was 2.9% (SD 0.08 liters).

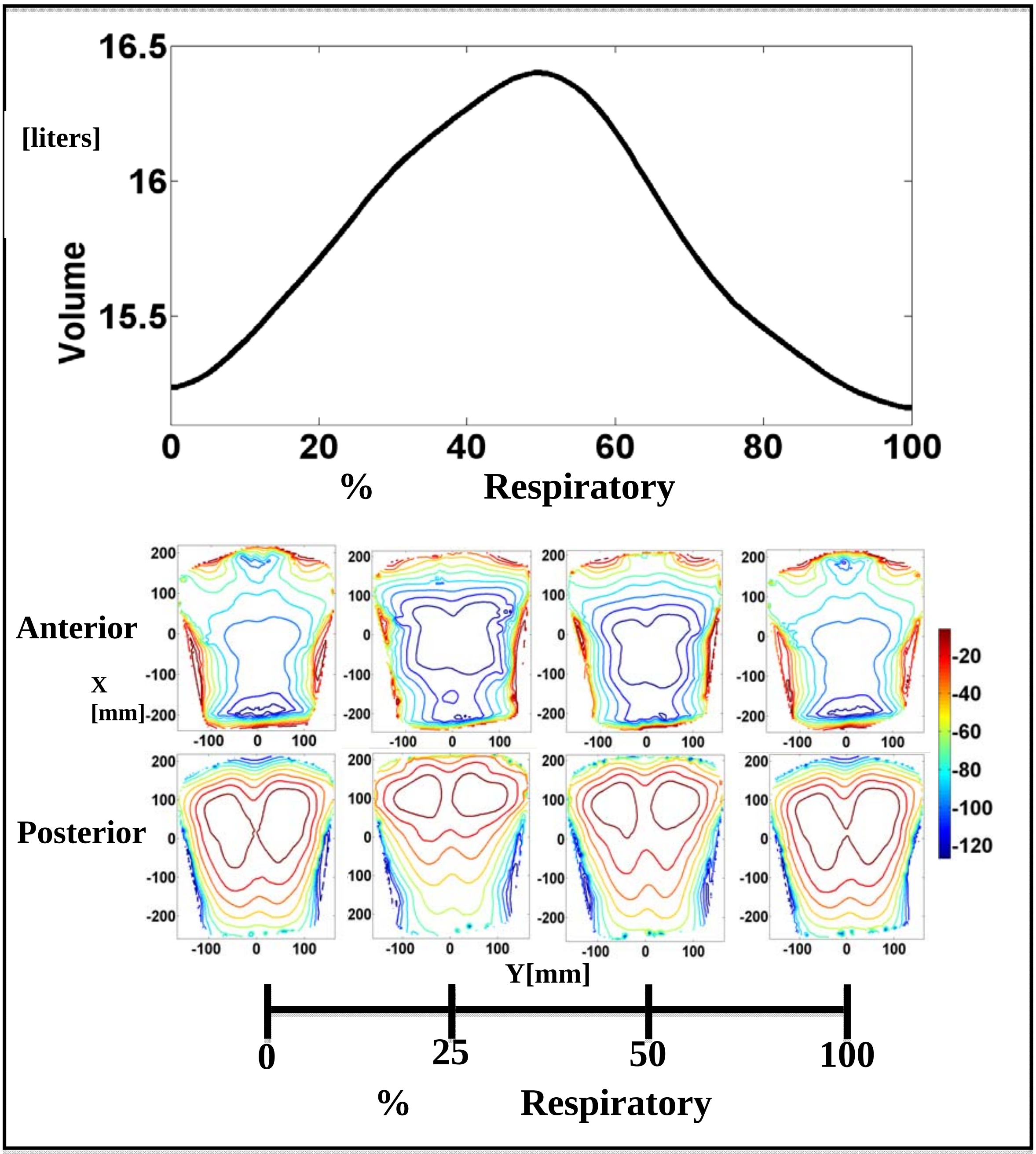

Figure 1: Time course of trunk volume variation during the respiratory cycle and contour maps (at 0%, 25%, 50%,100%) of the anterior and posterior surface.

CONCLUSION: The proposed method was able to measure trunk volumes and surface deformation during the respiratory cycle performed by the subject. The method proposed for measure trunk surface deformation and volume variation during respiration provides a reliable tool for direct and accurate measurement of body dimensions, an important technology advanced at sport field. A several applications of the proposed method on others body segments and on a group of subjects needs to be conducted in order evaluate its applicability.

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