DETERMINATION OF BODY SEGMENT INERTIA PARAMETERS USING 3D HUMAN BODY SCANNER AND 3D CAD SOFTWARE

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INTRODUCTION: In the field of sports biomechanics, a human body is often treated as a linkage model to investigate various kinds of human movement. This modeling requires body segment inertia parameters (BSPs) such as masses, centers of mass, and moments of inertia. As the quality of motion capture system increases, more accurate BSPs are also needed to get accurate inverse dynamics results. Advanced technology has enabled us to obtain three-dimensional coordinates of the entire body surface. A 3D CAD software has also been able to be applied to measure the human body. It was hypothesized that BSPs with high accuracy could be determined by the combination of a 3D body scanner and a 3D CAD software. The purposes of this study are, first, to introduce a new method of measuring subject-specific BSPs and, second, to compare the BSPs from this study with those from an existing mathematical model in order to show that the proposed method can be used to produce more accurate BSPs.

METHOD: Subjects were 14 Japanese elite male distance runners (22.1±0.9 yr.). An optical body scanner (Hamamatsu Photonics K.K., Japan) was used to acquire three-dimensional surface coordinates of a standing body at 2.5mm height intervals. It took only 13 seconds to measure the coordinates with about 150,000 points over the entire body surface. The measured coordinates were then imported into a 3D CAD software (Dassault Systèmes SolidWorks Corp., USA) to produce a solid model that treats each segment as a rigid body. The procedure to produce the solid model and to calculate its BSPs is as follows.
1. A mesh was made from the point coordinates (Fig. 1 ①→②).
2. The mesh was smoothed (Fig. 1 ②→③).
3. A solid model was configured from the mesh (Fig. 1 ③→④).
4. The solid model of one body segment was cut out (Fig. 1 ④→⑦).
5. Its volume and the preliminary moments of inertia about its three principal axes were calculated by a modeling kernel.
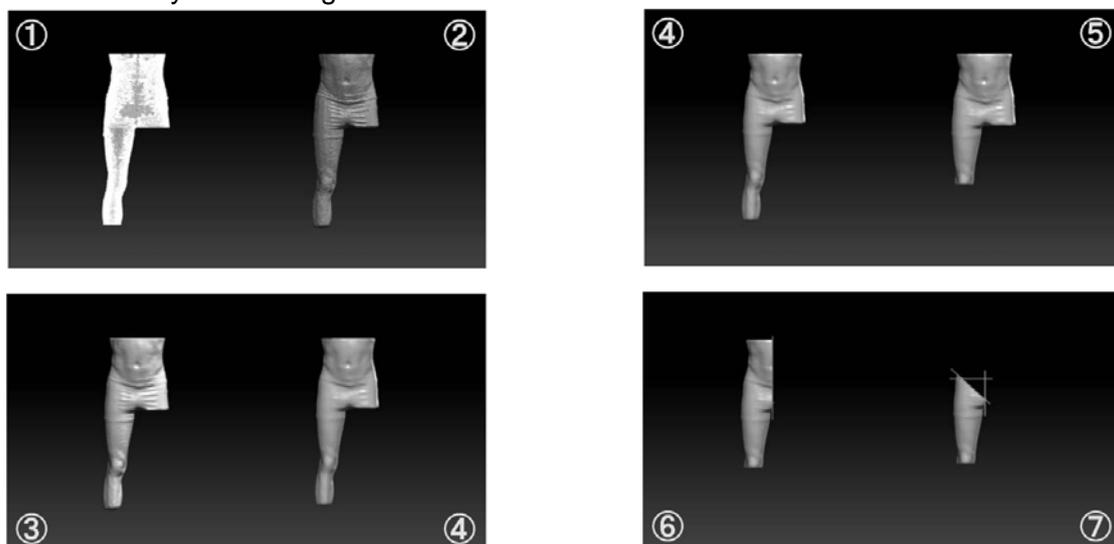

Fig. 1 Procedure for producing our solid model.

This procedure was repeated for each of the 14 segments (head, torso, upper arms, forearms, hands, thighs, shanks, and feet). Each segment density was assumed to be uniform. The optimal density set of the 14 segments for each subject was selected from the 26 density sets of cadavers (Dempster, 1955; Chandler et al., 1975). Subsequently, the density of each segment was adjusted in such a way that the sum of products of the calculated volume and the optimal density for each segment corresponds to the whole body mass. Finally, the mass, the center of mass, and the moments of inertia about the three principal axes for each segment were determined from the calculated volume, the preliminary moments of inertia, and the adjusted density.

RESULTS & DISCUSSION: We were able to construct a high shape fidelity body model by using the 3D body scanner and the 3D CAD software. Figure 2 illustrates our solid model and an exsisting elliptical-cylinder model. It shows that the solid model can reconstruct the body contour and shape faithfully. In contrast, the elliptical-cylinder model is too simplified to get an unevenness in details of a body part. To compare the two models, volumes of all 14 body segments were examined. When the elliptical-cylinder model was used, torso volume were 5% overvalued and the other body segments volume were 5-30% undervalued. Because the body shape is faithfully reproduced, our solid model has advantages over currently used elliptical-cylinder models for measuring subject-specific BSPs accurately. In addition, our new method is less demanding on subjects, less time-consuming for them like the photogrammetry.
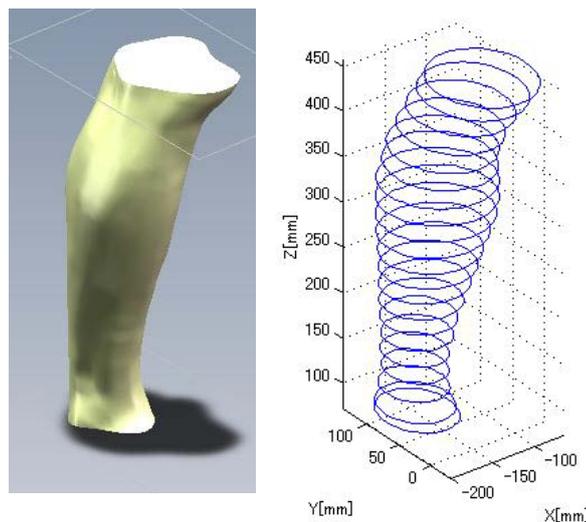

Fig. 2 Our solid model and a currently used elliptical-cylinder model.

CONCLUSION: This study proposed a new method of measuring subject-specific BSPs by using the 3D human body scanner and the 3D CAD. The measured values by our method have been thought more accurate than those measured by an existing elliptical-cylinder model.

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