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BODY SEGMENT INERTIAL PROPERTIES OF ELITE ATHLETES IN VARIOUS COMPETITIVE EVENTS

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SUMMARY
We calculated the body segment inertial parameters (BSPs) for elite athletes in various competitive events by using an optical 3D body scanner and a 3D-CAD. Their BSPs differed among their competitive events and between sexes. These differences may be due to not only the volume of muscles but also due to the region of muscle hypertrophy.

INTRODUCTION
Segment inertial properties such as the mass, center of mass, and principal moments of inertia (body segment inertial parameters: BSPs) are necessary information for analyzing human movement, especially in kinetic analysis. These BSPs are affected by morphology of each individual. In particular, when we analyze a movement of elite athletes, their peculiar morphology may affect the accuracy of the analysis.

The purposes of this study were to calculate the body segment inertial parameters for elite athletes of various competitive events and to clarify the effects of the morphological differences induced by characteristics of their competitive event on the body segment inertial properties.

METHODS
Subjects were 245 Japanese elite athletes including Olympians (Male: n=122, 25.7±3.8yr., 176.0±7.9cm, 73.9±16.8kg. Female: n=123, 25.1±4.6yr., 164.1±7.9cm, 58.6±13.2kg). They are highly trained and at international level athletes. Therefore, their morphology is thought to reflect the characteristics of their competitive events.

Using an optical 3D body scanner (Bodyline Scanner C8300, Hamamatsu Photonics K.K., Japan) with four laser diodes and CCDs, we measured the three-dimensional position coordinates of point groups on the body surface of subjects in their standing position at height intervals of 2.5mm. These coordinates were imported into 3D-CAD software (SolidWorks, SolidWorks Japan K.K., Japan), and a solid model of the body was made from the configuration formed by the point groups. The solid model was divided into the following 14 or 15 segments after Ae et al. (1992) [1]: Head, whole torso (which was furthermore divided into upper torso and lower torso), upper arms, forearms, hands, thighs, shanks and feet. For each segment, the volume, center of volume, and preliminary principal moments of inertia with a density of 1g/cm^3 were calculated by the modeling kernel. The procedure to produce the solid model and to calculate its preliminary BSPs is as follows.

1) A mesh was made from the point coordinates (Figure1 a → b).
2) The mesh was smoothed (Figure1 b → c).
3) A solid model was configured from the mesh (Figure1 c → d).
4) The solid model of one body segment was cut out (Figure1 d →e → f).
5) Its volume and the preliminary moments of inertia about its three principal axes were calculated by a modeling kernel.

Segment density was assumed to be uniform within a segment and to be equivalent to the averaged density of several athletes derived from MRI. The mass, center of mass, and principal moments of inertia were determined for each segment from the volume, preliminary principal moments of inertia, and the density.

RESULTS AND DISCUSSION
Figure2 shows comparison of percent mass of thigh among various competitive events in descending order from the left. The thigh percent mass was larger in the events such as speed skating and cycling track in which the role of lower limb is much more important than upper limb. Female tended to be in high rank. On the other hand, percent mass

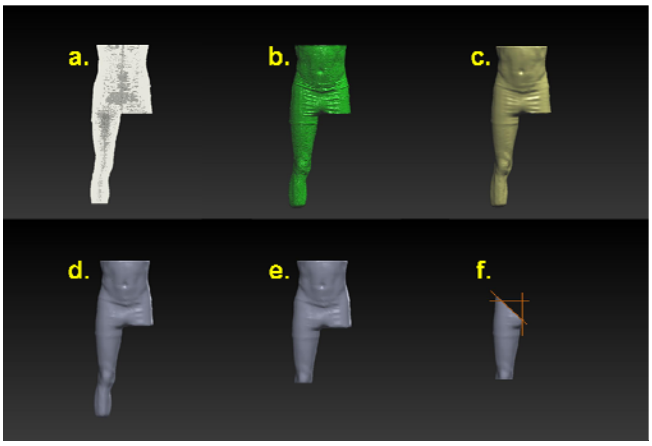

Figure1: Procedure for producing a solid model for each segment

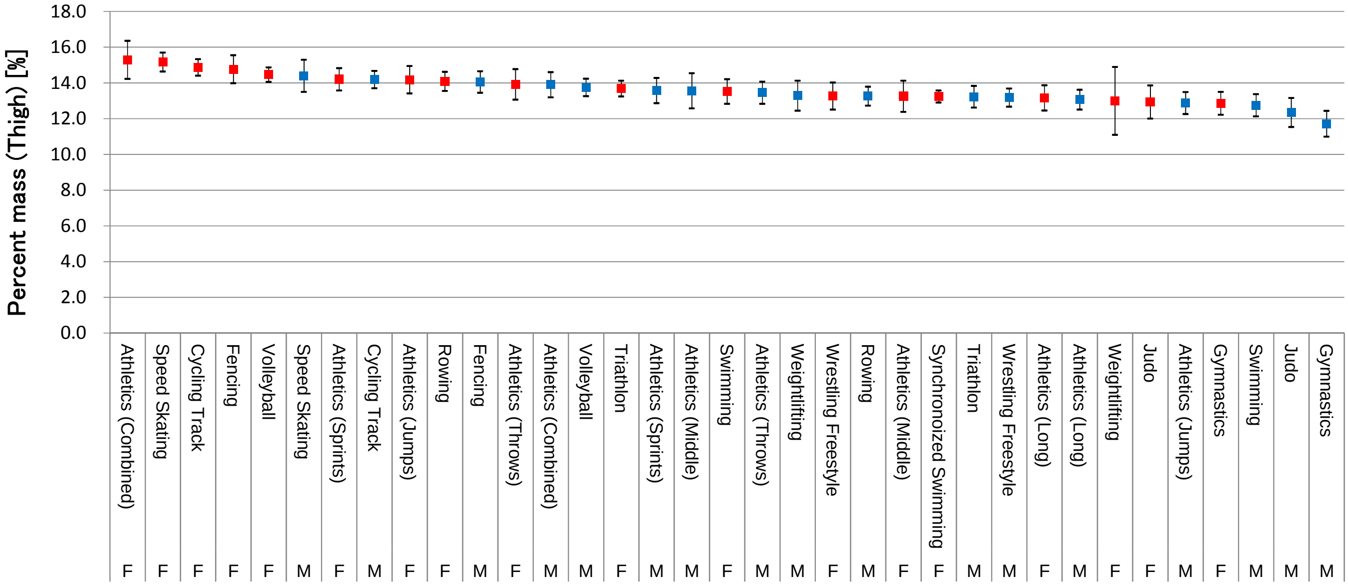

Figure2: Comparison of percent mass of thigh among athletes in various competitive events. M: male; F: female

of upper arm was larger in the events such as swimming and throws of athletics. And male tended to be in high lank. These results reflect the morphological differences among the competitive events and between sexes. The ratios of radius of gyration to segment length were also different among the events and between sexes in many segments. Both the percent mass and the radius of gyration was normalized value (Percent mass is a percent to the whole body mass and radius of gyration is a square root of moment of inertia divided by mass). These were different among the events and between sexes in spite of normalized value. This indicates that the differences in BSPs are not only due to the differences in total muscle volume within a segment but also due to the region of muscle hypertrophy and its mass distribution.

CONCLUSIONS

In addition to body size, the region of muscle hypertrophy is a factor that affects BSPs. Therefore, we should know the BSPs for athletes involved in each competitive event in order to obtain more accurate motion analysis results.

REFERENCES

1. Ae M, et al., Biomechanism 11: 23-33, 199