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► **To cite this version:**

Thomas Robert, Paul Leborgne, Georges Beurier, Raphaël Dumas. Personalized body segment inertia parameters using 3D body scanner images. 15th International Symposium on 3-D Analysis of Human Movement, Jul 2018, Manchester, France. 2 p. <hal-02109074v2>

HAL Id: hal-02109074

<https://hal.science/hal-02109074v2>

Submitted on 14 Apr 2021

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HAL Authorization

Thursday July 5th 2018

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Personalized body segment inertia parameters using 3D body scanner images

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Introduction

Personalized values of Body Segment Inertia Parameters (BSIP) are necessary to perform dynamic analysis of human movement (e.g. trajectory of the whole body centre of mass trajectory for stability analysis, joint torques / muscular forces estimations, etc.). BSIPs are usually estimated using regressions derived from anthropometric tables (AT) [1]. However, these tables are usually not adapted to atypical populations (children, elderly, obese persons, individuals with prostheses, etc.) that are classically of interest. An alternative consists in estimating BSIPs from segments' volumes assuming a uniform density. This alternative is of growing interest as: 1) it would be suitable even for populations with atypical body mass repartition; 2) 3D body shapes acquisition has recently become easier and cheaper thanks to the developments of low-cost 3D scanners [2]. However, there are still some issues to make this measurement (3D point cloud of the external shape) usable in the context of movement analysis with minimal intervention. The main issue is the segmentation of the whole body external shape into body segments with relevant local coordinate systems (LCS) and anatomical landmarks (AL) [3].

Research Question

This study aims at proposing and evaluating a semi-automatic method (i.e. with minimal manual intervention), adapted to the human movement analysis framework, to estimate personalized BSIP from whole body 3D scanner images.

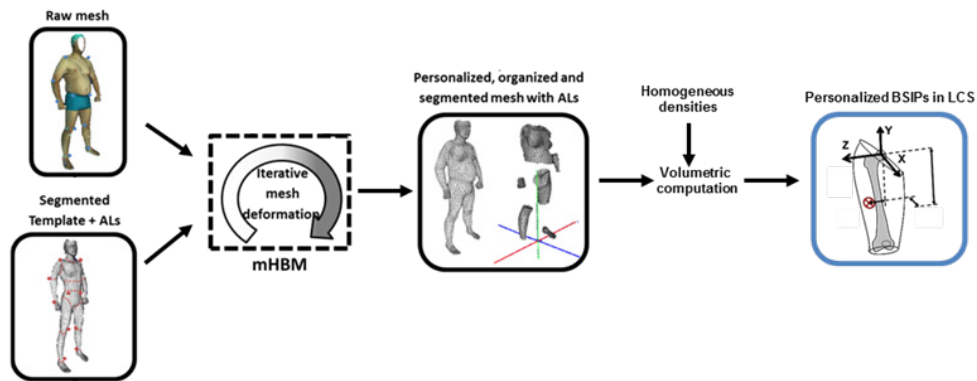
Methods

An experiment was conducted to compare BSIP from AT to those estimated from the volumetric approach. It consisted of a classical human motion capture experiment, to which a bodyscanning session was added. Nine subjects (6 M-3 F, 35±10 y.o., 171±10 cm and 84±7 kg) were equipped with 51 reflective skin markers, most of which located on specific AL. Subject external shape was acquired in a standard standing posture in a 3D body scanner (SYMCADTM II by Telmat), resulting in a raw textured mesh of about 160000 nodes. Then several functional motions were recorded using a standard movement analysis set-up (optoelectronic system and force plates). Experiments were approved by the French national ethical committee.

BSIP were estimated using both a volumetric approach and regression built on anthropometric tables. The volumetric approach primarily consisted in matching a template mesh, segmented and with identified ALs, onto the raw mesh of the subject's whole body shape. The template is a 50th percentile male mesh of about 9000 nodes prepared with MakeHuman and Blender softwares. It was previously segmented into 15 bodies and 15 AL were manually identified and used to create the body LCSs, according to anatomical definitions [1]. Then, for each individual raw mesh, 15 anatomical landmarks of the template (a subset of the reflective markers located on subject's skin, i.e. easily identifiable) were manually identified. The template was then deformed on the individual raw mesh using a non-rigid transformation tool (mHBM software [4]) that ensured a minimal distance between meshes and a match between template and target AL. It resulted in a structured, segmented and personalized mesh with identified AL. Then each segments mesh was isolated, transferred into its corresponding LCS and BSIP were estimated by volumetric computation assuming a homogeneous density [5]. BSIP were also estimated using AT [1] and 3D coordinates of markers recorded during a 10 second static posture trial.

BSIP obtained from AT and volumetric approach were compared. In addition, the whole body CM trajectory was estimated for static trials using BSIP from both volumetric and AT approaches and their projection were compared to the Centre of Pressure (CoP) measured by force plates.

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Overview of the proposed methodology to estimate personalized BSIP from a raw mesh. The template is prepared once and the remaining single manual operation to be performed for each subject is the identification of AL markers on the coloured raw mesh.

Results

Estimated BSIP by AT or volumetric methods yielded to very similar results: difference on mass distribution below 2% of body weight, differences on CM location below 1cm in the frontal and lateral axis (up to 4 cm in the longitudinal axis for the thorax and abdomen). For static trials the volumetric approach yield to slightly smaller CM-CoP distances in the AP direction (about 50% less), in particular for persons with higher BMIs, *i.e.* volumetric approach improved whole body CM estimation for the person with "less normal" body mass repartition.

Discussion

We proposed a semi-automated method estimate personalized BSIP. This method is quasi-automated (one single manual operation: identifying the AL markers on the coloured raw mesh) and adapted to the human movement analysis framework. Further investigations would be required to properly assess this method. However, it seems a promising candidate to fill the lack of proper methodology to estimate BSIP, and thus to perform dynamic movement analysis, for populations that are poorly represented in anthropometric tables.

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