ESTIMATION OF HUMAN INTERNAL AND EXTERNAL GEOMETRY FROM SELECTED BODY MEASUREMENTS

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INTRODUCTION

The development of personalized numerical models of the human being requires a deep knowledge of the human body geometry. Several studies have been performed on the external [1] or on the internal geometry of body parts [2]. As far as the statistical relationships between external and internal geometries are concerned, most studies focused only on the relationships between stature and specific bone dimensions as the length of long bones [3]. The aim of this study is to obtain linear statistical models for estimating internal (trunk bones) and external (full body) human body geometry from a small number of body measurements.

METHODS

The geometrical data used in this work were obtained by combining internal and external measurements performed on 64 healthy adults (20-55 yrs old, 30 yrs on avg.) representative of three morphotypes (16 5th percentile female subjects, 33 50th and 15 95th percentile male subjects) collected by *Bertrand et al.* [4]. The data were analysed using the R statistical environment. The different steps of the statistical analysis are listed hereafter :

1- Agglomerative Hierarchical Clustering of the measured parameters based on the linear correlation coefficient ;
2- Identification of clusters of linearly dependent parameters ;
3- Identification of Isolated Parameters (IP) corresponding to clusters of size 1 ;
4- Selection of a subset of explanatory parameter(s) (Main Parameters, MP) in each cluster ;
5- Estimation of simple linear regression models in order to explain every non-MP parameters in a cluster (Secondary Parameters, SP) by the MP of the cluster.

This procedure was separately applied on external and on subgroups of internal data obtained by regrouping measured parameters belonging to the same anatomical group (i.e. : rib cage, cervical spine, thoracic spine, lumbar spine, pelvis). Thus, external/external and internal/internal anthropometrical models were obtained. Then, the procedure was applied on the whole external parameters associated with internal MP (MP*i*) and internal IP (IP*i*) in order to determine external/internal models, thereby enabling the prediction of MP*i* and IP*i* from external parameters (Figure 1).

RESULTS AND DISCUSSION

The present statistical analysis proposes 189 anthropometrical models (Figure 1, Table 1) enabling to estimate personalized external and internal geometry from 10 external measurements that can be easily measured on any subject : height, acromion-ground height, iliac crest-ground height, sitting height, chest axillary circumference, head (glabella-occiput) circumference, low pelvic circumference, thigh bottom circumference, greatest forearm circumference, weight. The quality of the regressions was evaluated by the Standard Error of Estimate (SEE), with 2·SEE giving the 95% of errors.

Among the 189 models estimated 117 had a 2·SEE≤10% (34 ext/ext, 72 int/int, and 11 ext/int models).

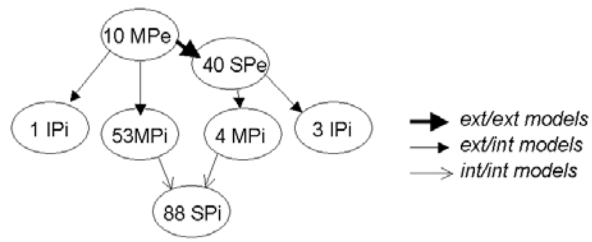

Figure 1: Organigram of MPi, SP*e*, SP*i*, IP*i* estimation from the MP*e* (*e*: external ; *i*: internal).

CONCLUSIONS

Numerous anthropometrical ext/ext (n=40), int/int (n=88), and ext/int (n=61) models were estimated and studied in this work. In particular, 11 external/internal models with 2·SEE≤10% were found, enabling the estimation of internal trunk dimensions from external body measurements. It brings a deeper knowledge on human morphology and opens the way for wide applications (human model personalisation for crash-test simulation, planning of clinical interventions…).

REFERENCES

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Table 1: Examples of ext/ext, int/int and ext/int models. The table contains for each the intercept, the regression coefficient, and its standard error in mm and in % (explained parameter (*mm*) = *coef* x explanatory parameter (*mm* or *kg*) + *intercept* ± *2·SEE*(*mm*)).

Explained parameters	*Explanatory parameters*	*R²*	*constant*	*coef.*	*2·S.E.E. (mm)*	*2·S.E.E. (%)*
eyes-ground height (standing position) (SP*e*)	height (MP*e*)	0.99	-42.4	0.96	16	1.0
Arm upper circumference (SP*e*)	weight (MP*e*)	0.91	141.2	2.28	26	8.4
height of the right half of the pelvis (MP*i*)	acromion -ground height (standing position) (MP*e*)	0.83	-3.5	0.15	14	6.4
height of the left half of the pelvis (SP*i*)	height of the right half of the pelvis (MP*i*)	0.94	-7.8	1.05	9	4.2
inferior width of the vertebral body of L2 (MP*i*)	height (MP*e*)	0.66	-15.9	0.04	6	12.3
superior width of the vertebral body of L2 (SP*i*)	inferior width of the vertebral body of L2 (MP*i*)	0.87	0.4	0.94	3	8.0