AN ONLINE REPOSITORY OF BODY SEGMENT PARAMETER MODELS

wspr.io/body-segment-param/

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Introduction

Body segment parameter estimates of mass, moment of inertia, &c., is a requirement for biomechanical analyses. Errors in parameters propagate to calculated joint moments and muscle forces [1], in some cases leading to considerable sensitivity in results to segment parameter errors [2].

However, subject-specific modelling is time-consuming and there have been few studies on the variety of extant body segment parameter models. These consist originally of cadaver studies completed before the 1970s, after which time medical scanning and photographic approaches began to be used in more comprehensive studies.

This work collates such studies into a public repository for general use and historic interest. The repository currently contains over twenty separate body segment parameter models in studies conducted from 1860 to 2011.

Relative mass models

The relative mass models provide a scaling factor for the mass of each segment relative to the total mass of the subject. The repository current includes eighteen such models, briefly described in Table 1.

- Only whole-body models with complete analysis of masses for all major segments and divisions are included.
- Trunk mass is combined from up to four subsegments for cross-model comparison.
- The model closest to the mean (RMSE = 8.0%) was the male data from Pavol et al. [3], a study on an older population.
- Large ranges (±30%) gives credence to the approach of subject-specific modelling.

The mean segment masses from the sixteen non-juvenile studies are shown in Figure 1.

Figure 1: Average mass per segment for the relative mass models for adults.

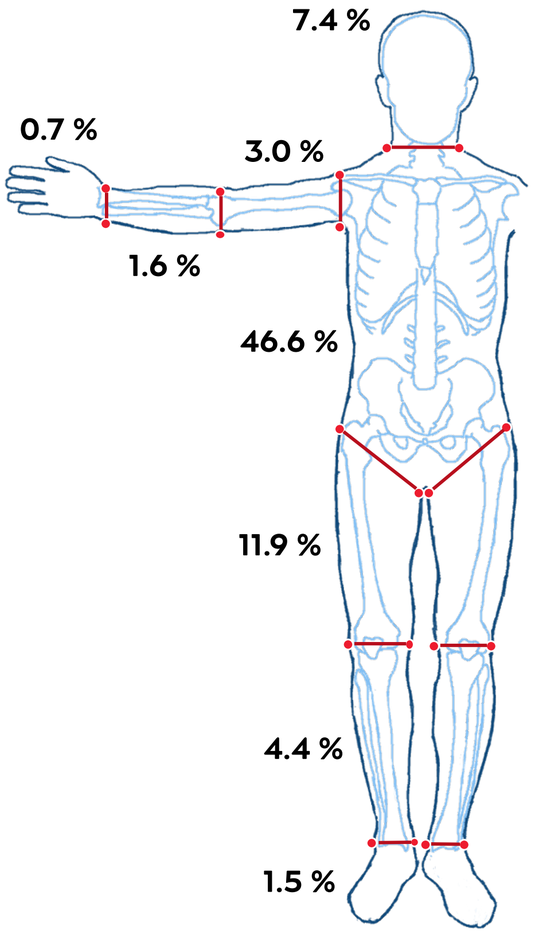
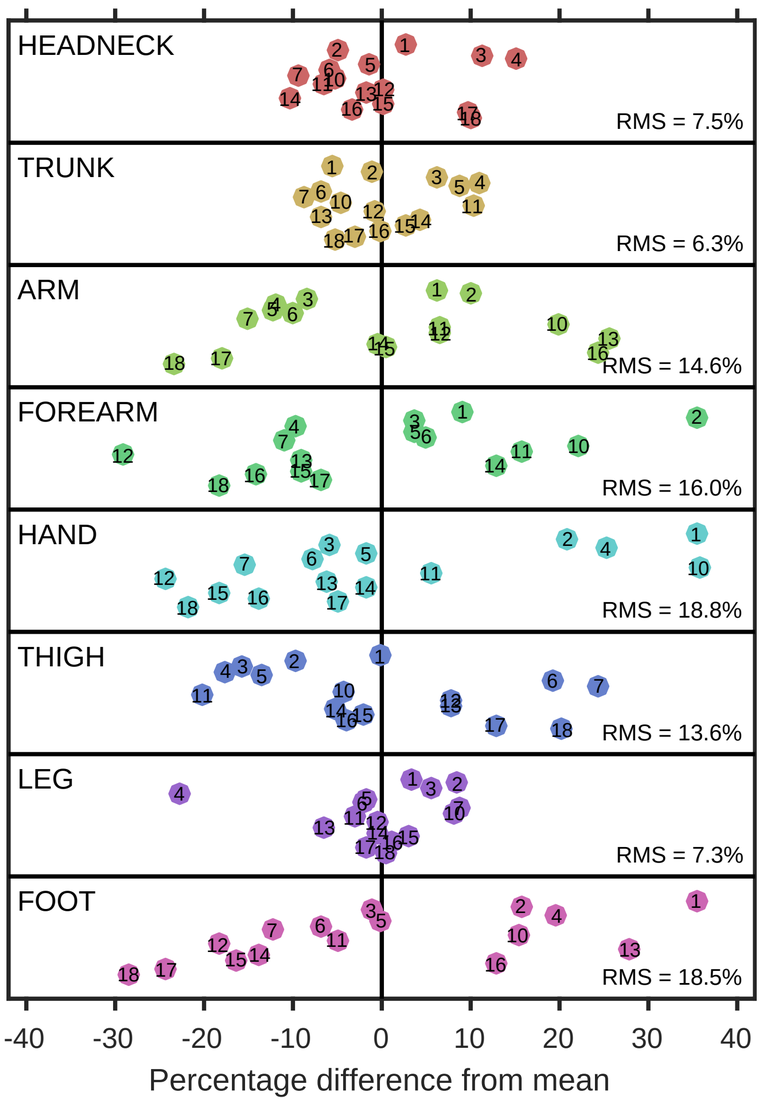


Figure 2: Relative masses for each segment of each model, excepting models eight and nine, which deviate significantly from the others.



A visualisation of the non-juvenile models is shown in Figure 2, in which segment mass for each is compared to the mean. A deviation of at least ±10% is seen for each segment, indicating a large degree of variation in different populations and with different techniques.

Mass–height regression models

The repository also includes two comprehensive works that define segment parameters using mass and height as regression variables [16, 17]. These works describe six models, respectively: Chinese F & M, German F & M, and Russian F & M. Each contains data for mass, centroid, and moments of inertia.

Figure 3 shows variation in segment mass between models, for three heights per subject. High variability (e.g., head–neck segment for model 2, Chinese M) indicates caution should be used when applying these models outside of their original subject population ranges.

Figure 3: Visualisation of six mass–height regression models for a mass of 70 kg and heights of 1.6 m, 1.7 m, 1.8 m (square, circle, diamond, resp.).

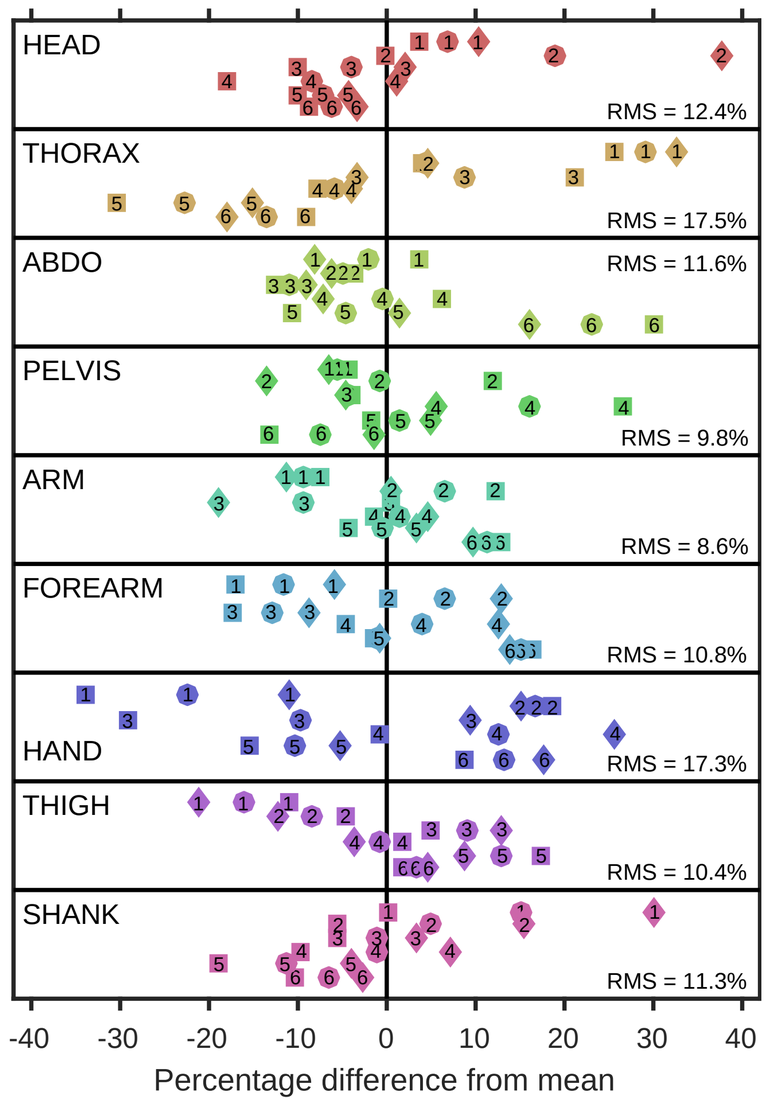


Table 1: Relative mass models in the repository.

Ref.	Name	Pop.	Method	Sex	N	SDev	CoM
1.	Harless (1860)		Cadaver	M	2		
2.	Braune et al. (1889)		Cadaver		3		
3.	Dempster (1955)		Cadaver	M	8	○	
4.	Fujikawa (1963)	Japan	Cadaver		6		
5.	Clauser (1969)		Cadaver	M	13	○	○
6.	Zatsiorsky et al. (1979)	Russia	CT	F	15		○
7.	Zatsiorsky et al. (1979)	Young adult	CT	M	100		○
8.	Jensen (1986)	12 yr	Photo	M	12		
9.	Jensen (1989)	6 yr	Photo	M	8		
10.	Jensen (1989)	18 yr	Photo	M	8		
11.	Jensen et al. (1994)		Photo	F	12	○	
12.	Jensen et al. (1994)	Elderly	Photo	M	7	○	
13.	Cheng et al. (2000)	China	MRI	M	8	○	○
14.	Pavol et al. (2002)		Geometric	F	50	○	○
15.	Pavol et al. (2002)	Older	Geometric	M	29	○	○
16.	Chen (2011)	Adult	Kinetic		12	○	○
17.	Ma et al. (2011)		3D scan	F	40	○	○
18.	Ma et al. (2011)	Korea	3D scan	M	40	○	○

Further work

Data for the nonlinear Zatsiorsky et al. [16] models are included but not yet 'interfaced'. Further work includes adding:

- a catalogue of segment densities;
- a variety of non-full-body models;
- visualisations of standard deviations and centres of mass;
- further models based on nonlinear regression and geometric approaches.

Conclusion

A survey of body segment parameter models shows an expected and substantial variance in results between studies. The models have been collated in standard form with example code in an online repository for further use by the biomechanics community.

Bibliography

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