Body segment parameter estimation using Hatze's geometric model

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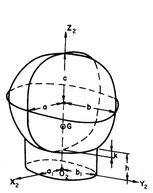

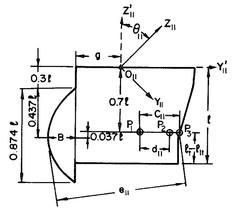

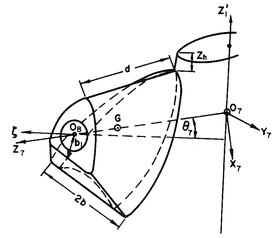

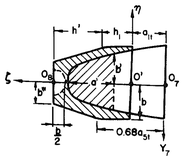

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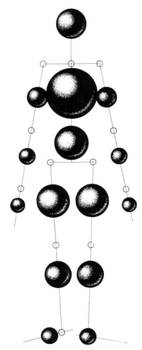
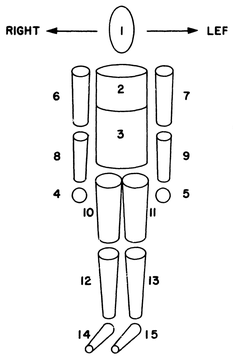
Introduction

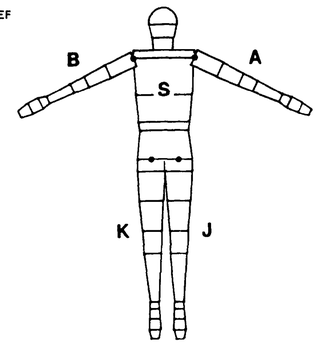
Body segment parameter models are used to estimate mass, centroid, moment of inertia, etc., for musculo-skeletal modelling. Regression models and geometric models are widely used, with simple regressions most commonly used. However, these are only suitable for specific populations, and geometric models permit greater flexibility.



Drillis (1964)



Havanan (1964)



Yeadon (1990)

Hatze's geometric model (1979) is notable for such features as: individual shoulder segments, detailed trunk segments, variable density along segments, and a subcutaneous fat scaling factor. The model requires 242 anthropometric measurements.

	M, kg			$\bar{z}$, mm			I_{xx}, g m^2		
Segment	Calc	Hatze	Err, %	Calc	Hatze	Err, %	Calc	Hatze	Err, %
Abdo-thoracic	18.487	18.487	0.00	203	203	0.00	331.265	331.264	0.00
Head-neck	5.187	5.187	0.00	137	137	0.00	32.585	32.585	0.00
Left shoulder	1.656	1.628	1.84	151	153	0.00	5.310	5.280	0.57
Left arm	2.315	2.320	0.00	−131	−131	0.00	19.624	19.671	−0.25
Left forearm	1.157	1.177	−1.69	−112	−112	0.00	7.096	7.228	−1.80
Left hand	0.539	0.542	0.00	−61	−61	0.00	0.567	0.578	−1.72
Right shoulder	2.105	2.076	0.96	157	158	0.00	7.634	7.601	0.39
Right arm	2.357	2.362	0.00	−129	−129	0.00	19.800	19.906	−0.55
Right forearm	1.310	1.343	−2.24	−114	−114	0.00	8.024	8.281	−3.14
Right hand	0.524	0.529	−1.89	−63	−63	0.00	0.570	0.562	1.79
Abdo-pelvic	9.255	9.479	−2.43	−78	−79	0.00	45.270	46.296	−2.22
Left thigh	8.962	8.938	0.22	−217	−217	0.00	150.404	150.227	0.11
Left leg	3.994	3.997	−0.25	−186	−186	0.00	61.709	61.723	−0.02
Left foot	1.098	1.098	0.00	−39	−39	0.00	4.709	4.711	0.00
Right thigh	8.937	8.915	0.34	−208	−208	0.00	141.638	141.516	0.08
Right leg	4.088	4.089	0.00	−194	−194	0.00	68.200	68.201	0.00
Right foot	1.109	1.109	0.00	−38	−38	0.00	4.698	4.700	0.00

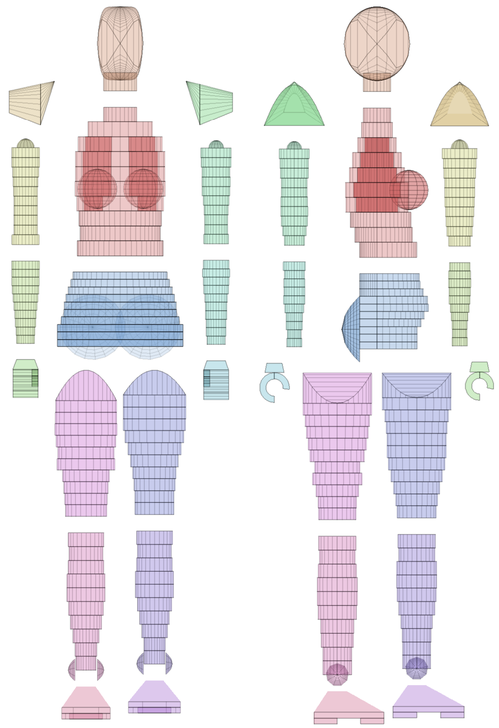
Aim

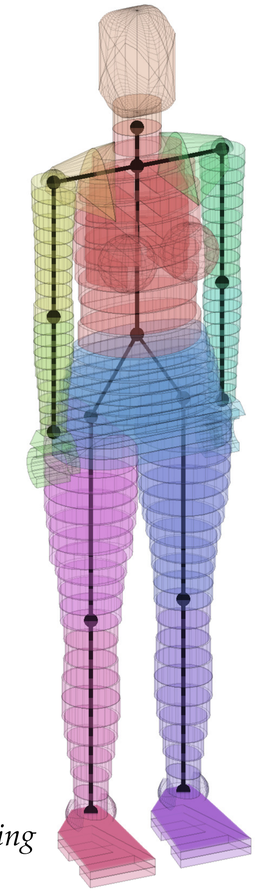
To reimplement Hatze's body model in Matlab from his extant publications.

Results and analysis

The reimplementation of Hatze's model achieves close to 100% accuracy comparing to reference data (see example tabulation). Improvements have been identified that would allow generality of the model:

- segment densities more accurately collected;
- feet, hands, and neck could be multi-segmental;
- joints could be modelled specially to avoid overlap and discontinuity.





Above/right: geometrically-accurate rendering of Hatze's body segments (Matlab).

Left: comparison of reference to calculated data.

Interpolation

The model has been extended to permit a varying number of slices per segment; this is useful both when taking fewer manual measurements or when taking many data points using 3D scans.

Results below show average percentage error when fewer measurements are taken for calculations of forearm mass, volume, centroid, and moments of inertia. Interpolation increases accuracy; fewer than ten slices per segment is justified.

Conclusion

Hatze's complete body segment parameter model has not been widely used partially due to its complexity, and this work makes it available to the biomechanics community. The model can be downloaded from: `github.com/wspr/hatze-biomech/`

Sources for Hatze's model

1. H. Hatze (1979) 'A model for the computational determination of parameter values of anthropomorphic segments', Technical Report TWISK 79, CSIR Pretoria.
2. 'Determination of anthropomorphic segment parameter values — Data collection procedures and computer program', BIOMLIB User Reference Manual TR-79-UM-003, 1979.