Scaling strength in human simulation models

Annegarn J [1], Rasmussen J [2], Savelberg HHCM [1], Verdijk LB [1], Meijer K [1]
[1]*Dept. of Health Sciences, Maastricht University, The Netherlands*
[2]*Dept. of Mechanical Engineering, Aalborg University, Denmark*

Introduction: Simulating human movement, with multi-body models, enables virtual experiments that are too difficult, costly or dangerous to perform in reality. When simulation models are used for subject specific goals, like planning a rehabilitation intervention, it is important that they are based on subject-specific data. Therefore, accurate strength scaling, accounting for subject specific differences, is required. Unfortunately, current strength scaling methods are poorly validated. The aim of this study was to develop scaling laws of increasing complexity and validate them with experimental data on upper leg and arm strength.

Method: Using the AnyBody software [1], a leg model and an arm model were developed. Three different scaling laws with increasing levels of complexity were implemented. The simplest law involved geometric scaling for segment mass (Strength~mass$^{2/3}$), whereas the most complex approach also accounted for body composition, age and gender differences. For this purpose, two different approximation methods were used (multiple linear regression and a cumulative approximation [2]). All scaling laws were validated against isometric strength measurements on arm (N=26) and leg (N=63) muscles of a heterogeneous population (age; 19-84 yrs, men & women, BMI; 18-35).

Result: The correlations between measured and predicted strength ranged from 0.39 to 0.88 for the leg and from 0.64 to 0.99 for the arm. The lowest correlations were obtained for geometric scaling and the highest correlations were obtained for the cumulative approximation. The best predictions were obtained for the arm strength (figure 1).

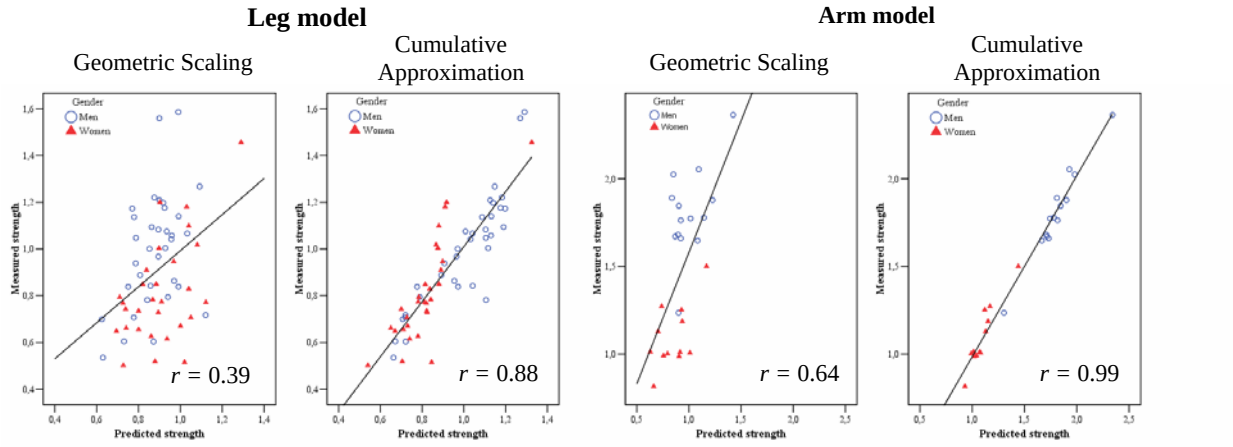

Figure 1: Correlations between the predicted and measured strength

Conclusions: This study is the first step towards a validated scaling approach in human simulation systems. Our results show that simple geometric scaling is not sufficient for an adequate model prediction. Instead age and gender are important factors that need to be taken into account. Future steps will include the validation of the newly developed scaling laws on different populations and apply them to study complex movements.

References:

[1] www.anybodytech.com
[2] Rasmussen, J. Nonlinear programming by cumulative approximation refinement. Structural Optimization. 1998;15:1-7.