

# EFFECT OF INCREASED BODY MASS INDEX ON BODY SEGMENT PARAMETERS IN MALES

Zachary Merrill, Molly Knewton, Rakié Cham, April Chambers

University of Pittsburgh, Pittsburgh, PA, USA  
email: zfm1@pitt.edu, web: <http://www.engineering.pitt.edu/hmbl/>

## INTRODUCTION

Over the last 30 years, the obese population has grown to over 60 million people in the US. Along with obesity, the associated risk of injury related to biomechanical factors also increases [1,2]. In order to understand these mechanisms of obesity-related risk of injury, accurate body segment parameter (BSP) measurements are required to model joint contact forces and muscle forces applied during a given task.

Current anthropometry tables, which show the mass of each body part as a percent of total body weight (BW), and center of mass (COM) and radius of gyration ( $R_G$ ) locations as percent of segment length were compiled using healthy, college-age adults, however these parameters have shown to be inaccurate in predicting BSP's in subjects with an increased body mass index (BMI), as well as in different age groups [3-6]. Several methods exist for determining BSP's including cadaver-based studies, magnetic resonance imaging, computed tomography, and measurements based on bony landmarks [7-10], however these methods have some issues as far as cost, time required, and high doses of radiation. Dual energy x-ray absorptiometry (DXA) is a validated method of determining BSP's in vivo that avoids these common problems. DXA scans are commonly used to determine bone density and body composition [11], as well as mass calculations. The scan itself is an inexpensive, low radiation scan that can differentiate between bone, muscle, and fat.

The goal of this study is to determine differences in segment masses, COM's, and  $R_G$ 's in normal weight (NW), overweight (OW), and obese (OB) young males. We will focus on the differences in the torso and dominant-side thigh.

## METHODS

The subjects in this study were all between the ages of 21 and 40, and the weight groups are defined by body mass index (BMI); the normal weight group covers BMI's between 18.5 and 24.9, overweight group is between 25.0 and 29.9, and obese group is between 30.0 and 39.9  $\text{kg m}^{-2}$  (Table 1). Thirteen subjects were recruited for each weight category.

**Table 1:** Mass, height, and BMI for each group. Values are shown as mean  $\pm$  standard deviation.

Group	Mass (kg)	Height (cm)	BMI ( $\text{kg m}^{-2}$ )
Normal Weight	66.8 $\pm$ 6.2	178.4 $\pm$ 5.0	22.6 $\pm$ 1.4
Overweight	77.7 $\pm$ 7.9	175.2 $\pm$ 6.3	27.0 $\pm$ 1.1
Obese	96.4 $\pm$ 11.2	178.5 $\pm$ 6.4	32.3 $\pm$ 2.6

During the single study visit, the height and weight of each participant were recorded in order to calculate BMI to confirm eligibility and then each participant was then scanned using a Hologic Discovery DXA System (Hologic, Bedford, MA, USA) to collect a frontal plane, full body image.

Predetermined anatomical landmarks were used to define the boundaries between BSP's in each DXA scan. The head segment covered the most superior point of the head to the base of the mandible. The torso extended from the acromion to the superior border of the greater trochanter, with lateral boundaries defined by a line connecting the acromion through the axilla, and another line connecting the greater trochanter and ischial tuberosity. The thigh segment extended from the superior greater trochanter to the knee joint center, lateral to the inferior portion of the torso section. Lastly, the shank segment started at the knee joint center, and ended at the lateral malleolus.

In order to calculate segment COM's and radii of gyration, each segment was separated into small slices. Each slice covered the width of the segment, and had a height of 2-3 pixels, corresponding to 2.6-3.9 cm tall. The analysis determined the mass of each sub-region, and used the masses and known slice height to calculate the segment parameters. For each segment, COM and  $R_G$  were expressed as percent of the segment length, and mass was expressed as a percent of the total body mass. A two-tailed t-test was used to compare each BSP of interest between each of the three groups, with significance set at  $\alpha = 0.05$ .

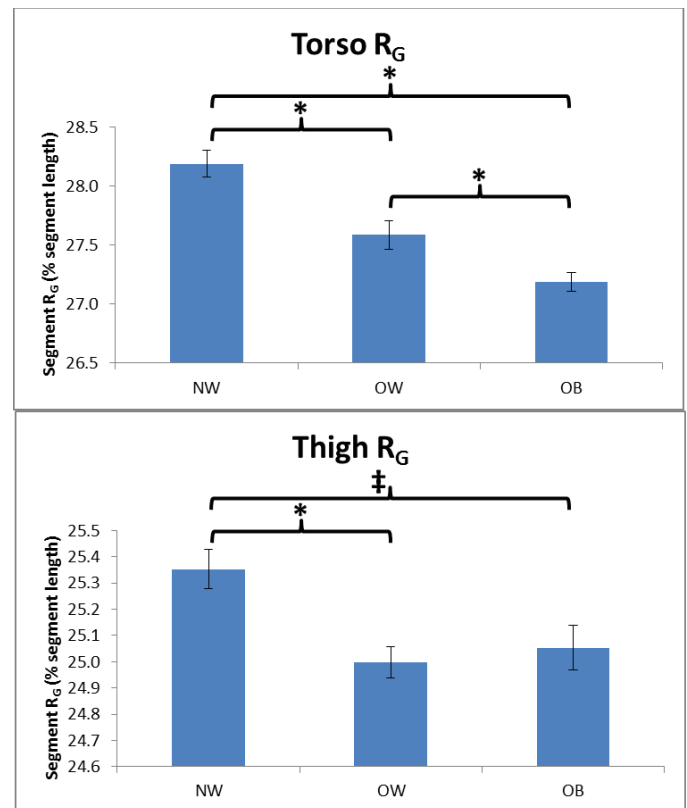
### RESULTS AND DISCUSSION

Significant differences were found for the thigh and torso radii of gyration (Figure 1), with the normal weight group having more distally located  $R_G$ 's. While the differences appear relatively small, they are all highly statistically significant.

The normal weight group also has statistical trend toward lower torso and thigh masses as a percent of body weight compared to the overweight and obese groups, however these differences are not statistically significant (Table 2). As would be expected, no significant differences were determined for any of the segment lengths.

### CONCLUSIONS

Current anthropometry tables were designed using young, normal weight adults as the measurement standard, however these parameters are not accurate in people with varying age and BMI. Significant differences were found between young normal weight, overweight, and obese males in the torso and thigh radii of gyration. These differences demonstrate that the current anthropometry sets cannot be applied across all body types, especially when analyzing gait. This study highlights the need to develop age and size specific anthropometry sets.



**Figure 1:** Torso and thigh  $R_G$  values, expressed as distance from proximal joint. \* indicates  $p < 0.01$ , and ‡ indicates  $p < 0.02$ . Error bars show standard error.

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**Table 2:** Torso and thigh mass and center of mass values. Mass is shown as percent BW, and COM is shown as percent segment length. \* indicates  $p < 0.10$  between NW and OB groups. Values shown as mean  $\pm$  standard deviation.

Group	Torso Mass (%)	Torso COM (%)	Thigh Mass (%) *	Thigh COM (%) *
NW	41.78 $\pm$ 0.52	51.96 $\pm$ 0.26	11.50 $\pm$ 0.18	46.82 $\pm$ 0.35
OW	41.91 $\pm$ 0.72	52.41 $\pm$ 0.21	11.69 $\pm$ 0.25	46.34 $\pm$ 0.30
OB	42.15 $\pm$ 0.75	52.41 $\pm$ 0.34	11.94 $\pm$ 0.17	46.00 $\pm$ 0.24