BODY SEGMENT PARAMETERS IN NORMAL WEIGHT VERSUS OBESE YOUNG FEMALES

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INTRODUCTION

In recent years, the percentage of workers in the United States classified as overweight or obese has risen to over 60% [1]. This rise in obesity yields health concerns as the obese population is more highly susceptible to medically attended injuries [2], the mechanisms of which are not fully understood [3]. In order to understand the cause of this difference in injury rates between susceptibility of obese and non-obese populations, additional research is required. Certain biomechanical research requires physical information about a subject not easily or affordably collected. Therefore, researchers rely on anthropometric tables to give accurate approximations of subjects’ measurements. Specifically, anthropometric tables include predictions of body segment parameters (BSPs). Common examples of studied parameters include lengths, masses, center of mass locations, and radii of gyration of the body’s segments (head, torso, upper arm, lower arm, thigh, and shank).

Current anthropometric models were developed with subjects in a normal weight range [4] [5], so they do not accurately predict BSPs of obese individuals. For example, Chambers et al. found a significant difference between trunk segmental mass, center of mass, and radius of gyration in obese versus non-obese elderly [6]. Matrangola et al. quantified the changes in segmental parameters over a period of weight loss, finding significant differences in many of the center of mass locations and radii of gyration of various segments [7]. Therefore, there is a need for an accurate way to predict segmental specifications for the working population while accounting for obesity.

OBJECTIVE

This study aims to quantify the effect of obesity on body segment parameters of in a young female population using DXA scanning and analysis techniques.

HYPOTHESIS

We expect significant differences in segment masses, segment center of mass locations, and segment radii of gyration between the normal weight and obese subgroup. We expect no significant difference in segment lengths between the groups.

METHOD

Obesity corresponds to a BMI between 30 and 40 kg/m^2, while normal weight corresponds to a BMI of 18.5 to 25 kg/m^2. Thirteen obese females and thirteen normal weight females aged 21 to 39, who work full time, were recruited for participation in this study. Written informed consent approved by the University of Pittsburgh Institutional Review Board was obtained prior to participation. Each participant underwent a full body DXA scan (Hologic Discovery DXA System) lying supine with legs internally rotated and maximum plantar flexion.

In analysis of the DXA scan, bony landmarks and joint centers were used to define the boundaries between head, torso, thigh, shank, upper arm, and lower arm segments (Figure 2) [4]. The head segment extended from the vertex to the base of the mandible. The torso was defined from the acromion to the greater trochanter. The torso was separated from the arms with a boundary through the medial acromion to the axilla, and it was separated from the thigh with a boundary just lateral to the anterior superior iliac spine and the ischial tuberosity of the pelvis. The thigh was defined from the greater trochanter to the center of the knee joint. The shank extended from the knee joint center to the lateral malleolus. The hands and feet were excluded from analysis. Each of these body segments was further divided into horizontal sub-regions with vertical height.

Many methods have been used to create predictive models and regression equations such as cadaver-based studies [8], imaging [4], computerized tomography [5], and biplanar radiography [9]. However, each of these methods has disadvantages such as time-intensiveness, monetary cost, and/or delivery of high doses of radiation to the participant. Dual energy X-ray absorptiometry (DXA) is a quick, inexpensive, low-radiation full body scan that can distinguish the difference between bone, muscle, and fat tissue, allowing it to calculate accurate densities and masses of the body’s segments. It is a verified method of finding segmental mass, center of mass, and radius of gyration in the frontal plane [10].
of 2 or 3 pixels, corresponding to 2.6 or 3.9 cm, respectively (Figure 2). Masses were calculated for each sub-region and used to determine BSPs for the segment.

Scans were analyzed for segment length as a percent of body height (SL), segment mass as a percent of body mass (SM), longitudinal distance from the proximal end to the center of mass of the segment as a percent of segment length (COM), and frontal plane radius of gyration as a percent of segment length (RG) [11]. A two-tailed t-test was run to compare the parameters for the obese subjects to those of the normal weight subjects. Statistical significance was set at 0.05.

RESULTS

As expected, no significant differences were found in SL between the two subgroups, as greater BMI does not affect relative lengths of bones. There were no significant differences in any parameters of the thigh segment. However, obesity was found to significantly affect RG, COM, and SM in various other segments (Table 1).

Torso and lower arm RG of the obese population were found to be smaller than that of the non-obese population, indicating that subjects with a larger BMI had a higher distribution of mass in their torso and lower arm segments. Head RG was found to be larger for subjects with a greater BMI. Head and shank SMs were smaller for obese than normal weight subjects. Shank COM of obese subjects was found to be more proximal than that of normal weight subjects. Additionally, obese participants had a significantly greater SM in the upper arm segment when compared against normal weight subjects.

DISCUSSION

The objective of this study was to quantify the impact of obesity on BSPs. No significant differences were found in the thigh segment. However, there were significant differences between populations in at least one BSP for all other segments.

The decrease in RG of the torso in the obese population is an intuitive result as people with a greater BMI have more mass concentrated at the midsection of their torso, as discussed in Chambers et al. and Matrangola et al. [6,7]. Previous studies on a geriatric population have found a significantly higher SM in the torso segment of obese versus normal weight populations [6], but this result was not present in our findings. One potential reason for the difference in these findings may be the distinct age ranges of analyzed subjects, but further testing on the effects of aging on BSPs would be needed. The variance in RG with no significant change in SM between the groups indicates the groups had a similar proportion of mass in their torso but a dissimilar distribution of that mass within the segment.

In accordance with current literature [6], head and shank SMs were found to be smaller for obese than normal weight subjects. These segments do not store a large portion of the body’s soft tissue, so they do not show much variation in overall mass between normal weight and obese subjects. However, since the obese subjects have a larger full body mass, the head and shank segments contain a significantly smaller percent of total body mass than they do for normal weight participants. Additional weight is not distributed evenly throughout the body, nor evenly throughout the segments themselves as the shank COM was found to be more proximal for the obese than the normal weight subgroup, again in agreement with previous studies [6]. Muscle bellies are nearer to the superior end of the shank segment, when in anatomical position, moving the center of mass more proximally for subjects with a higher BMI. The use of current regression equations to predict segment parameters in the obese population would simply scale the parameters with respect to the increase in mass but would not account for the redistribution of this mass.

Over the past few years, there has been an increase in the percent of United States workers classified by BMI as either overweight or obese. In order for researchers to study obese populations and develop preventative measures, they call upon anthropometric data. Current anthropometric sets are based on a normal weight population. However, many BSPs were found to be significantly different between the normal weight and obese subgroups, indicating that obesity impacts physical characteristics of mass distributions throughout the body. Additional mass is not distributed evenly throughout the body, nor evenly throughout the segments themselves, suggesting a need for new anthropometric prediction methods or models that account for BMI variations in the population to more accurately study this growing population.

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REFERENCES


Table 1: Mean and standard deviation of statistically significant (p<0.05) body segment parameters of obese and normal weight females. * denotes p<0.01.