H76 Can Femoral Shape be Used to Estimate Weight?

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The goals of this presentation are to investigate the relationship between body mass index and femoral shape, and to determine the utility of using cross-sectional measurements in body mass index estimations.

This presentation will impact the forensic science community by providing evidence that being overweight or obese significantly impacts external femoral shape in a specific pattern. Despite poor classification results, these significant shape differences necessitate further investigation into the use of long bone shape to estimate weight, a visible trait that could be integrated into the biological profile and used to aid in forensic identification efforts.

It has been known for several decades that long bone shape is affected by body mass; however, there has been limited investigation into the impact that obesity has on load-bearing bones despite its high prevalence in modern populations. Given that obesity is a condition that clearly affects how an individual appeared to others in life, this research can benefit the forensic community by investigating whether bone geometry is sufficient to estimate weight, potentially adding another trait for use in biological profile determinations.

Previous research in this concentration demonstrated a significant positive relationship between body weight and mediolateral (ML) dimensions of the proximal femur. Using a larger sample with increased representation of obese individuals, this project sought: (1) to further investigate the relationship between body mass index (BMI) and femoral shape; and, (2) to determine the utility of using cross-sectional measurements to estimate BMI classification. This project was designed under the null hypothesis that individuals from all BMI classes would have the same mean anteroposterior (AP) and ML dimensions. Using standards largely devised by Ruff (1983), external AP and ML measurements were taken at 20%, 35%, 50%, 65% and 80% bone shaft length, with 20% and 80% indicating the distal-most and proximal-most measurement, respectively.

Four categories were formed based on BMI: underweight (BMI < 17.5), normal weight (BMI = 19 - 24.5), overweight (BMI = 26 - 30) and obese (BMI > 31.5). Age was controlled for in all statistical tests. Control for ancestry, sex and secular trends was effectuated through sampling, as only males of European ancestry with a date of death within the last century were included for this research. The final sample consisted of 268 total individuals, 37 obese, 88 overweight, 86 normal weight and 57 underweight.

After controlling for age, multivariate statistics show a significant (*p-value* < 0.01) relationship between midshaft and proximal ML dimensions and BMI. MANOVA results also report a significant Wilk's λ (*p-value* < 0.05) for BMI. T-tests with an LSD correction for uneven sample sizes confirm ML dimensions are significantly larger in the overweight and obese BMI classes (*p-value* < 0.05). Additionally, size and shape variables were computed according to Mosimann and colleagues (Mosimann 1979; Darroch and Mosimann 1985). ANOVA results show that BMI has a significant effect on overall ML size (*p- value* < 0.01). MANOVA results report a significant effect of BMI on shape-standardized variables at all five ML locations (*p-value* < 0.05) with a significant Wilk's λ (*p-value* < 0.05).

There was a significant effect of BMI on AP dimensions at all five diaphyseal locations (*p-value* < 0.05) using the raw data. However, a significant interaction between age and BMI was observed at all five AP locations (*p-value* < 0.01) when using the transformed size-standardized data, invalidating any further analysis of BMI effect alone. These results suggest that the femora of overweight individuals undergo abnormally high rates of ML stress irrespective of age, but that both age and BMI operate in conjunction to impact AP dimensions. It is also possible that pelvic movements in overweight/obese individuals create abnormally high ML torques of the femur, rendering any age effect irrelevant.

Finally, a discriminant function analysis with cross-validation was conducted to assess the classificatory power of using ML measurements to discern BMI status. Poor classification results were obtained, with 58% correct classification for underweight, 57% for normal weight, 50% for overweight and 36% for obese. Collapsing underweight and normal weight individuals into one category and overweight and obese individuals into another resulted in little difference, with 58% correct classification into the underweight/normal weight BMI category, and 45% into the overweight/obese BMI category.

Three important conclusions are drawn from this research: (1) there is a significant relationship between femoral shape and BMI, but this relationship differs for AP and ML dimensions; (2) this relationship has poor use in classifying individuals into their respective BMI categories; and, (3) these femoral shape changes correlate well with documented biomechanical modifications made by overweight/obese individuals during locomotion. Given that previous research has demonstrated the importance of internal cross-sectional geometry in bone strength properties, it is possible that use of external measurements alone is not sufficient to estimate BMI classification.

Obesity, Bone Morphology, Weight Classification

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