TECHNICAL NOTE

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Correlation of Body Mass Index with Thoracic and Abdominal Panniculus

REFERENCE: Hunter B, French D, Warner J, Remick D. Correlation of body mass index with thoracic and abdominal panniculus. J Forensic Sci 1998;43(2):427–430.

ABSTRACT: Obesity can play a significant role in chronic diseases, sudden unexpected death, and morbid obesity may be important as a cause of death for forensic pathologists. Our study attempted to determine if there is a correlation between panniculus measurements and body mass index (BMI) since BMI has been used in most studies to categorize obesity. Using data obtained from a review of 524 adult autopsies conducted at the University of Michigan from 1990 to 1992 we were able to show a correlation between both thoracic and abdominal panniculus and BMI ($r^2 = 0.335$ and 0.296 respectively) which is statistically significant ($p = 10^{-47}$ and 10^{-41} respectively). A prospective study confirmed the correlation ($r^2 = 0.552$ for thoracic and 0.436 for abdominal panniculus) when the measurements were taken at the xyphoid process and 3 cm below the umbilicus. Using these data we calculated a panniculus index (PI) which is equal to the thoracic + abdominal panniculus in centimeters divided by the square of the height (in meters). The PI strongly correlated with BMI and was able to predict obesity. Using a BMI cutoff of 39 for morbid obesity, a PI value of 4.07 for females and 3.25 for males predicted morbid obesity with the probability of a false positive less than or equal to 2.5%. Mild and severe obesity could also be determined using the PI. Based on these data we've concluded that a concise mathematical relationship does exist between BMI and panniculus measurements. Therefore panniculus measurements can be used either as a surrogate measurement of morbid obesity or to support BMI calculations.

KEYWORDS: forensic science, morbid obesity, panniculus, cause of death

It is estimated that nearly 37 million Americans suffer from some degree of obesity, 3 million of whom qualify as morbidly obese. These estimates are based on data produced by the Second National Health and Nutrition Examination Survey and the cutoffs for each category of obesity have been established by the National Center for Health Statistics (1). Currently the average height for a male is 1.75 m (5′9″) and the average weight is 77 kg (170 lbs). For non-pregnant women the average height is 1.63 m (5′4″) and the average weight is 63 kg (138 lbs). Obesity has been broken down into mild, severe, and morbid categories and expressed in terms of body mass index (BMI). BMI is calculated by the formula $BMI = kg/m^2$ (i.e., the person's weight in kilograms divided by their height in meters squared). This index allows for a comparison of weights between two people of different heights. The cutoffs for each category are 27.8, 31.1, and 39 for men respectively and 27.3, 32.3, and 39 for women respectively. These correspond to 20, 40, and 60% respectively above what the 1983 Metropolitan Life Insurance Company considers to be ideal body weight for a given height (2–5).

The prevalence and severity of obesity varies with age and ethnicity. For example African-American women have the highest incidence of obesity followed by non-African-American women, non-African-American males, and finally African-American males. For all men and among black women, the prevalence of obesity declines after age 55 whereas for non-African-American females, the prevalence of obesity from age 65–75 is higher than in the 55 to 65 age bracket. Likewise, socioeconomic factors affect the prevalence of obesity: a higher education and a higher income are associated with a decrease in the prevalence of obesity (6,7).

From a forensic standpoint, the role obesity plays in the evolution of various disease processes is significant. It has been linked to dilated cardiomyopathy, atherosclerotic cardiovascular disease and hyperlipidemia, left ventricular hypertrophy, thromboembolic disease, diabetes mellitus, hypertension, cerebrovascular accidents, sleep apnea, hepatobiliary disease, pulmonary insufficiency, increased incidence of colorectal cancer and prostate cancer for men and an increased incidence of endometrial, gallbladder, cervical, ovarian, and breast cancer for women (2,3,5,7–10). In addition, those suffering from morbid obesity have an increased rate of sudden unexpected death, 40 times that of aged matched non-obese controls (i.e., death within 6 hours of the onset of symptoms in a person previously determined to be medically stable or an unwitnessed death of a person previously recognized as being in a stable condition less than 24 hours before death (8,11)). A study done by Duflou et al. has shown that a number of these deaths can be attributed to obesity associated cardiomegaly (8). The resultant arrhythmias are similar to those which occur in people with hypertension associated cardiomegaly and those with dilated cardiomyopathies of different etiologies (8). However, there is also a subset which do not have cardiomegaly but in whom sudden, unexpected death occurs. It has been proposed that a marker for this group is a prolonged Q-T interval (12). While these obesity-complications may be seen at lesser degrees of obesity the prevalence of the morbidity and mortality associated with obesity doubles when the threshold for morbid obesity is reached (3).

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Received 12 May 1997; and in revised form 14 July 1997; and accepted 16 July 1997.

The ability to make the diagnosis of morbid obesity with confidence and accuracy is important to the forensic pathologist. Traditionally it has been done through the measurement of weight and height with the calculation of BMI. Usually measurement of body wall fat content (i.e., panniculus) and gestalt are used only as supportive data. However, to our knowledge no previous publication has shown a correlation between panniculus and BMI. The goal of this study is to determine if there is a correlation between body mass index and panniculus measurements and to develop a formula that will allow for diagnosis of morbid obesity in the event that a weight measurement can not be obtained. The value of such a correlation is two fold. The first is that in situations where weight can not be measured (e.g., a scale is not available) panniculus measurements can be used as a surrogate measurement for the diagnosis of morbid obesity. The second is that it can provide additional data to support the diagnosis of morbid obesity as a cause of death.

Materials and Methods

Two independent studies were conducted. The first was a retrospective review of autopsy protocols. Based on the encouraging results of this study, a prospective study was performed where the panniculus was measured at predetermined locations. For the retrospective study, autopsies performed at the University of Michigan between 1990 and 1992 were reviewed and selected based on the availability of the following data: age (only those over 18 were used), sex, race, weight, height, and thoracic and abdominal panniculus measurements. All cases which met criteria were included. A total of 526 cases from this review met the inclusion criteria: 218 females (41%) and 308 males (59%). For the prospective phase of this study measurements were taken in 82 patients. The thoracic and abdominal panniculus was measured at 2 designated locations: at the xiphoid process for the thoracic panniculus and 3 cm below the umbilicus for the abdominal panniculus. Again age, gender, race, height and weight were recorded. For this study, the lower age limit was 16.

For the retrospective study, the BMI was calculated and correlated with either the thoracic or abdominal panniculus using the Pearson Product Moment Correlation. For the correlation of the panniculus with BMI in both the retrospective and prospective studies, males and females were included in a single analysis. Two males with unusually large BMI were excluded from the study because they were obvious outliers. The statistical analysis showed a larger error for the retrospective study compared to the prospective study. Therefore, all subsequent analysis was done with the prospective analysis.

For the prospective study, the data for males and females was separated, since the equations for the regression lines were different between the sexes. Investigation of the relationship between the panniculus and the BMI showed that a panniculus index (PI) could be calculated from the equation PI = (Thoracic + Abdominal Panniculus)/h^2, where the panniculus is measured in cm and the height is expressed in meters. The calculated PI was then correlated with the BMI and probability values determined from the regression coefficients using the SAS statistical software.

Results

In the retrospective study there were a total of 524 patients including 306 males and 218 females. The average age was 54 with a range from 18 to 94 years (Table 1). The abdominal panniculus averaged 3.2 cm with a range from .2 to 20 cm, while the thoracic panniculus averaged 2.1 cm with a range from .2 to 9 cm. The average BMI was 28.0 with a range from 14.0 to 68.9. In the retrospective portion of this study, no correlation was found between age and BMI, or between age and thoracic or abdominal panniculus ($p = 0.87, 0.48, 0.74$ respectively). However, BMI was correlated with thoracic wall panniculus ($r^2 = 0.335$) and abdominal wall panniculus ($r^2 = 0.296$) and both correlations showed a high degree of significance ($p = 10^{-47}$ and 10^{-41} respectively). Figure 1 shows the correlation between the panniculus and BMI. For this figure, both males and females were combined.

TABLE 1—*Demographic data: retrospective study. This study included a total of 524 patients, 306 males and 218 females.*

	Average	Minimum	Maximum
Age	54	18	94
Weight, kg	78.5	22	164
Height, m	1.68	.99	2.06
Thoracic, cm	2.1	.2	9
Abdominal, cm	3.2	.2	20
BMI	27.9	14.0	68.9

In the prospective arm of our study there were a total of 82 patients. The average age was 50 with a range from 16 to 86 (Table 2). The abdominal panniculus had an average thickness of 3.3 cm with a range from 0.5 to 7.5 cm while the thoracic panniculus averaged 2.1 cm with a range from 0.1 to 6. The prospective study showed an average BMI of 31.9 with a range from 17.0 to 50.2. We also found a significant correlation between BMI and thoracic wall panniculus ($r^2 = 0.552$) and between BMI abdominal panniculus ($r^2 = 0.436$, see Fig. 2). These data confirm the validity of the retrospective data in demonstrating a correlation between the panniculus and BMI. Using the data from the prospective arm of our study, we were able to calculate a panniculus index as defined in the methods section. To improve the correlation between the PI and BMI, males and females were considered separately. Figure 3 demonstrates the relationship between the PI and BMI for males, while Fig. 4 is the relationship for females. The Pan index, or PI was strongly correlated with the BMI for both males and females. Using a definition of morbid obesity as a BMI greater than 39, we determined levels of the PI that could be used as surrogate indicators for the diagnosis of morbid obesity. A PI of 4.07 or greater indicates morbid obesity in females, and a PI of 3.25 or greater indicates morbid obesity in males with the probability of a false positive prediction less than or equal to 2.5%.

We then determined if the calculated PI could be used to define other levels of obesity using the definitions of mild obesity having a BMI greater than 27.5 and severe obesity having a BMI greater than 31.5. With these definitions we were able to accurately predict mild obesity, severe obesity, and morbid obesity using the values listed in Table 3. Our criteria for correlation between the PI and BMI was set very high in order to increase the specificity of the test. Using the values from Table 3 we determined the false positive rate each of the diagnoses of obesity. In the male group there were no false positives for the mild or severe obesity classifications, and a 3% false positive rate for the diagnosis of morbid obesity in males. There were no false positives in the female group for any of the obesity groups.

Discussion

Based on the above data a concise and meaningful correlation exists between body wall panniculus and body mass index. Because this relationship can be expressed in a simple formula (abdominal

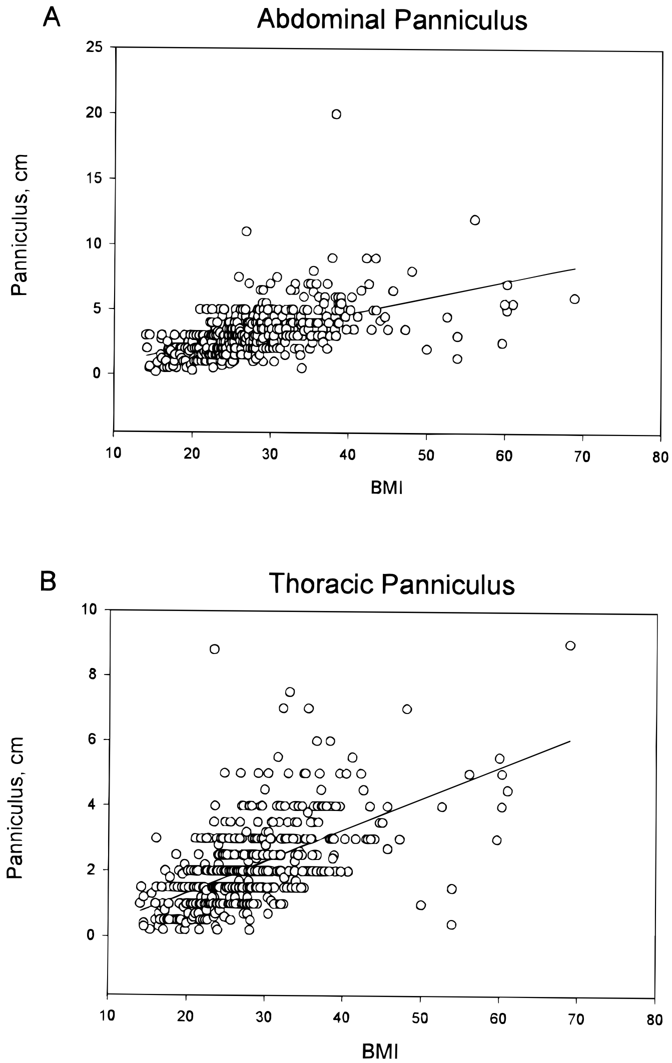

FIG. 1—*Correlation of BMI and panniculus, retrospective study. Males and females were combined for this figure. The line is a simple linear regression fitted to the data. These data were generated from a review of autopsy records. Both the abdominal panniculus (part A) and the thoracic panniculus (part B) were strongly correlated with BMI.*

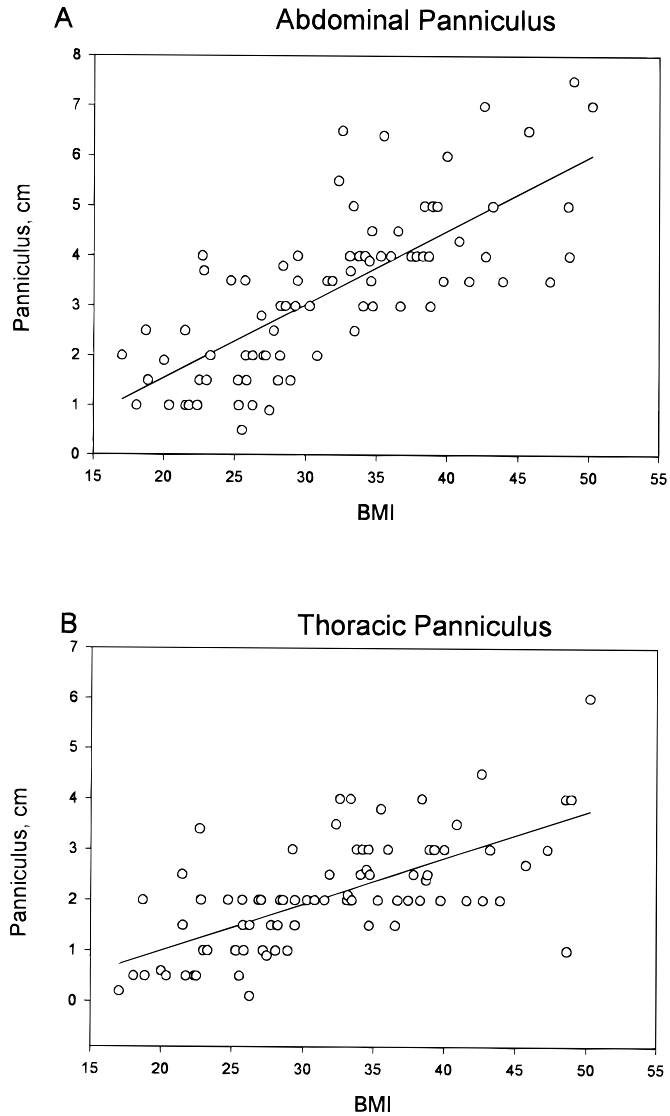

FIG. 2—*Correlation of BMI and panniculus, prospective study. Males and females were combined for this figure. The line is a simple linear regression fitted to the data. These were generated by measuring the thoracic panniculus at the xyphoid process, and the abdominal panniculus 3 cm below the umbilicus. Both the abdominal panniculus (part A) and the thoracic panniculus (part B) were strongly correlated with BMI.*

TABLE 2—*Demographic data: prospective study. This study included a total of 82 patients, 46 males and 36 females.*

	Average	Minimum	Maximum
Age	50	16	86
Weight, kg	93	43	183
Height, m	1.71	1.47	1.97
Thoracic, cm	2.1	0.1	6
Abdominal, cm	3.3	0.5	7.5
BMI	31.9	17.0	50.2

panniculus + thoracic panniculus/height^2 (meters)) routine and standardized measurements of body wall panniculus can provide additional quantitative data which can either confirm the body mass index calculation in situations where a person has an excessively elevated body-fat percentage (morbid obesity) or make the diagnosis when a body weight measurement cannot be obtained. These data also bring up new questions regarding the value of panniculus measurements and possibly new avenues of research. For example, can panniculus measurements predict increased risk of morbidity and mortality independently? They may be more accurate in defining obesity in situations of increased overall size such as occurs with in Division I-A college football linemen who have low percent body fat measurements (average percent body fat of 18) but high BMI (13)

The latter situation brings up an interesting question which has not been completely addressed within the nutritional or medical literature: is it overall size that correlates with increased morbidity and mortality or increased body fat? Do the linemen in college football who have a low percentage of body fat have the same risk of developing diseases like diabetes mellitus or have the same risk of sudden unexpected death as an obese individual does? At the core of these questions is the problem of identifying those individuals who are at increased risk for the complications of

FIG. 3—*Correlation of BMI and panniculus index (males). This figure shows the correlation between the BMI and the panniculus index (Pan index) for males in the prospective study. The line is a simple linear regression fitted to the data. A Pan index ⩾3.25 indicates a diagnosis of morbid obesity.*

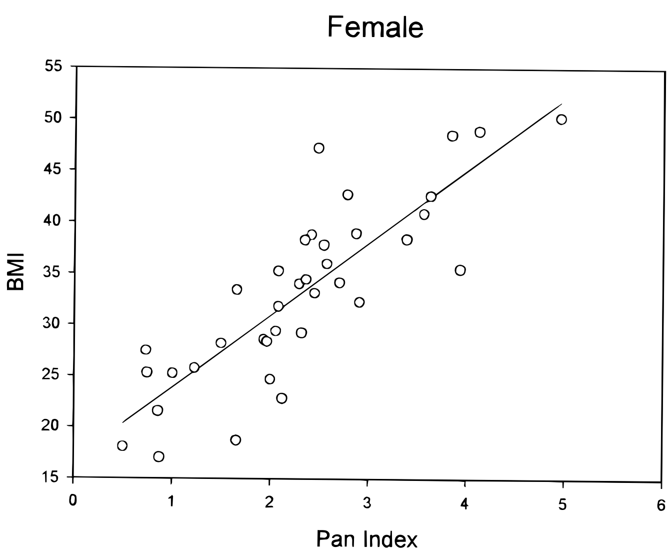

FIG. 4—*Correlation of BMI and panniculus index (females). This figure shows the correlation between the BMI and the panniculus index (Pan index) for females in the prospective study. The line is a simple linear regression fitted to the data. A Pan index ⩾4.07 indicates a diagnosis of morbid obesity.*

TABLE 3—*PI values for classifying different levels of obesity. Males and females were analyzed separately using the definitions of obesity and BMI indicated in the table. An obesity diagnosis could be determined if the calculated PI was greater than the value listed in the table. For example, if a male patient had a PI of 3.00 he would qualify as severely obese, but not morbidly obese.*

Obesity Group	BMI	PI-Female	PI-Male
Mild	27.5	2.92	2.37
Severe	31.5	3.31	2.65
Morbid	39.0	4.07	3.25

obesity. In compiling the morbidity and mortality statistics used to classify individuals as morbidly obese (i.e., 100 lbs over their ideal weight) insurance companies did not differentiate between those with increased lean body mass and those with increased body fat in their risk stratification. Therefore, ratios which only take into account size relationships like waist to hip circumference rations, abdominal circumference index and body mass index (the usual standard within the medical and nutritional literature) could be considered as accurate in assigning individuals to relative risk categories (2,7,14). Studies validating these conclusions, however, have not been done. There are studies which have shown that the above definition of obesity and the use of body mass index to classify individuals as morbidly obese may lack the desired specificity and sensitivity (respectively) when compared with the 45% body fat marker (13). Also the work of Sjostrom suggests that it is more useful to classify obesity by body compartments (11). Using CT-guided anthropometry, he has developed several equations which allow for the calculation of lean body mass, total weight of body adipose tissue, subcutaneous adipose tissue, and visceral adipose tissue. His statistical analysis indicates that visceral adipose levels most closely correlate with the morbidity and mortality traditionally associated with obesity (11). These data currently suffers from not having the normal control data that is currently available for body mass index calculations. It does, however, provide some new insights into how we classify people who are overweight.

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