Osteopathic Family Physician (2009) 1, 4-8

ELSEVIER

Osteopathic Family Physician

Evaluating consistency of anthropomorphic measurements in women with a history of gestational diabetes

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KEYWORDS:
Anthropomorphic measurements;
Waist circumference;
Hip circumference;
Metabolic syndrome

OBJECTIVE: Determination of waist circumference is now being recommended as a routine office measurement to identify women with metabolic syndrome and to monitor clinical response to therapeutic interventions. As such, the accuracy of measurement is important. In this study, we tested accuracy of a series of anthropomorphic measurements by looking for internal consistencies between them and by comparing changes in circumference to changes in weight.

METHODS: We evaluated the fluctuations in anthropomorphic measurements performed by the same group of examiners on gestational diabetics being followed during the postpartum period.

RESULTS: One-hundred sixty-six patients were identified for the study who contributed a total of 502 changes in each of the variables over time. Comparisons of different waist measurements found significant changes in 35% of cases. As many as 40.4% of women had at least one episode of significant discordance when weight changed measurably in one direction but circumference changed in the opposite direction, and 41.6% of women had at least one measurement where a circumference changed significantly, but the weight did not. The frequency of these discordances was not different between obese versus nonobese women.

CONCLUSIONS: The inconsistencies found in this real-world experience suggest that the clinical significance of the anthropomorphic measurements may be limited and must be considered in the context of the patient's weight and/or body mass index.

Body mass index (BMI) measurements have been found to provide useful estimates of obesity-related health risks at a population level, but may not be reliable for individual risk assessment.[1,2] Anthropomorphic measurements (such as waist and hip circumference) and related measures (such as waist-to-hip ratios) have been found to be predictive of increased risks for chronic diseases (such as diabetes, hypertension, stroke, and myocardial infarction).[3-5] Body fat distribution contributes to obesity-related disease risk independent of adiposity.[6] Waist measurements represent central obesity and are thought to be predictive of cardiovascular risk because they reflect the quantity of visceral fat.[7-9] In particular, waist circumference and related measurements have been reported to be more predictive for individual patients' cardiovascular risk and/or all-cause mortality than BMI (this is true in the overweight to mild obesity categories).[3,10,11] Age and gender may also be important factors to consider when interpreting these measures. Waist-to-hip ratios (but not waist circumference) have been shown to be much more accurate than BMI in predicting risk for death in men and women over age 75.[12] Waist-to-hip ratios, rather than BMI, have also been recommended for use in middle-aged persons.[3,13]

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doi:10.1016/j.osfp.2009.04.006

Table 1 Baseline characteristics h = 166

	Mean (Std)	Minimum	Maximum
Age	31.9 (5.53)	18	44
Gravity	3.23 (1.75)	1	9
Parity	2.6 (1.5)	1	8
Weight (lb)	157.3 (29.15)	101	259
BMI	29.14 (5.15)	19.80	46.57
True waist (cm)	89.1 (11.1)	66	129
Umbilical waist (cm)	99.3 (13.0)	71	136
Hip (cm)	103.2 (11.4)	75	139

Organization (WHO), and the American Association of Clinical Endocrinologists all consider an excessively large waist circumference (greater than or equal to 80−88 cm) or a waist-to-hip ratio greater than 0.85 in women as at least one defining criterion of metabolic syndrome.[14,15] Some authors have suggested that measurement of waist circumference should become a routine vital sign, especially in patients with a normal BMI.[16] Others have called for different thresholds for defining abnormalities in waist and hip measurements for subjects from various geographic/ethnic backgrounds.[16-19]

Given the pivotal role that the measurements of waist and hip circumference have in predicting risk of disease and the significance that changes in those measurements may have in monitoring risks of those substantial disease states,[20] it is important that these measurements be accurate and easy to obtain. Translation of earlier research reports into clinical practice may not render similarly reliable results. In this study, we investigate the accuracy of routine measurements of waist and hip circumferences in a real-world clinical setting. Accuracy was assessed by examining the degree of internal consistency between changes in the two different measures of waist circumference and in the degree of internal consistency between changes in weight and changes in each of the 3 measured circumferences.

Materials and methods

Women who have been diagnosed with gestational diabetes at the Harbor-UCLA Medical Center in Torrance, California are followed postpartum in a special clinic designed to encourage long-term healthy lifestyles and to monitor these high-risk women for development of glucose intolerance/diabetes and other markers of metabolic syndrome. This clinic serves an indigent, primarily Hispanic patient population.

At each visit, the patient's weight is recorded, as are measurements of the hip and waist circumferences. All measurements in this study were obtained by two women's health care nurse practitioners. Hip circumference was defined as the greatest lower truncal circumference, which includes the buttocks. Waist circumference was measured at 2 (potentially different) sites. One measurement was defined as circumference at the site where the patient defined as her waist (the "true waist"). The second was the circumference that included the umbilicus (the "umbilical waist"). Each waist measurement was taken at the end of an exhalation with the patient having been told to relax her abdominal muscles.

This study was approved by the Institutional Review Board of the Los Angeles Biomedical Institute at Harbor-UCLA Medical Center to study these data on an exempt basis after the data were de-identified. All women who had at least 2 visits in which all the relevant measurements were recorded are included in the study. There were no exclusion criteria beyond inadequate data. Chi square tests were used to test for differences between dichotomous variables, and a Fisher *t*-test was used to test for differences in continuous variables. Statistical significance required a $p < 0.05$.

Results

After evaluating the medical records for completeness in all measurements for at least two visits, we identified 166 patients who contributed a total of 668 visits, which provided information for 502 changes in each of the variables over time. The mean number of eligible return visits was four per patient, whereas the median was three. Baseline characteristics of the patient population are described in Table 1. The population was varied; baseline BMIs ranged from 19.5 to 45.6 kg/cm^2.

Several analyses of the changes in waist and hip circumference measurements were performed to investigate their internal consistency as a way to validate accuracy. The first analysis of the reliability of these waist measurements was to compare the magnitude and direction of changes in the 2 different measurements of the waist circumference (the true and the umbilical circumferences). Internal consistency was established if a woman's true waist circumference changed in the same direction as the umbilical waist circumference. Internal consistency was violated if the 2 measures changed significantly in opposite directions. Although others have reported precision in measurements to 0.1 cm[12], we selected

Table 2 Discordances between changes in true and umbilical circumferences*

Number of women	166
Number of visits	668
Number of changes between visits	502
Number of discordant measurements	178
% of all measurements	35.3%
% of women with ≥1 episode	57.7%
Range of discrepancies (cm) (STD)	4–26
Mean discrepancy (cm)	8.76 (5.03)
Frequency of episodes in women with BMI <30 vs. BMI ≥30	$p = 0.777$

*One waist circumference increased by at least 2 cm, whereas the other decreased by at least 2 cm.

Table 3 Discordances between changes in weight and circumference measurements*

	True waist	Umbilical waist	Hip
Number of discordant measurements	89	79	68
% of all measurement changes	17.7	15.7	13.5
% of women with ≥1 episode	40.4	34.3	30.1
Range of weight changes (lb)	2–34.5	2–34.5	2–34.5
Mean weight changes (lb) (STD)	5.76 (4.55)	5.83 (4.6)	5.33 (4.97)
Range of circumference changes (cm)	2–16	2–23	2–47.3
Mean circumference change in cm (STD)	4.8 (3.20)	5.85 (4.01)	5.65 (5.85)
Frequency of episodes BMI ≤30 vs ≥30	$p = 0.398$	$p = 0.263$	$p = 0.175$

*Circumference changed in one direction by more than 2 cm, whereas weight changed in the opposite direction by more than 2 lb.

2 cm as a cut-off for accuracy because we believed that there would be general agreement that differences greater than that would be substantially wrong. Table 2 displays information about the 177 episodes in which significant discordance was found between the 2 measurements, that is, when one waist measurement changed by at least 2 cm (increased or decreased) and the other waist measurement changed by at least 2 cm in the opposite direction and produced a net difference of at least 4 cm. Interestingly, there was no difference in the frequency of discordant measurements between obese and nonobese women.

Next, internal consistency was tested by comparing changes in weight to changes in the circumference measurements. Discordance was first defined as the patient's weight changed by more than two pounds in one direction (gain or loss), whereas the circumference measurement changed by more than 2 cm in the opposite direction (increase or decrease). Again, these limits were set to allow for accuracy of scale (2 lb) and relatively large (2 cm) differences in circumference measurement. Table 3 displays the frequency and degree of discordance found between weight change and each of the circumference measurements. The mean change in circumference was 5.84 cm when the women had an opposite change in weight of 5.8 lb. It can be seen that at least 30% of women had at least one episode of significant discordance between changes in weight and changes in each of the measurements of circumference. There was no statistically significant difference in the frequency of such discordance between obese and nonobese women.

In a second analysis of internal consistency, discordance was identified when there was a significant change (>2 cm) in circumference but no significant change (<2 lb) in weight. Table 4 displays the frequency and degree of these events. In the extreme, one woman had a 20.5-cm change recorded in her waist circumference that was not accompanied by any change in weight. At least one third of women had at least one episode of this discordance. Again, the frequency of this discordance did not vary between obese (BMI >30) and nonobese (BMI ≤30) subjects. There were also many episodes when the weight changed significantly but the curcumference measurements were stable (not shown).

Discussion

Obesity is epidemic in the United States; estimates are that for the first time in four centuries, life expectancy of the next generation may be less than for the current one primarily because of obesity and obesity-related diseases. Metabolic syndromes have been defined to identify individuals at high risk for cardiovascular disease. Visceral adiposity, as determined by magnetic resonance imaging/computed tomography studies, is most closely linked to dyslipidemia, insulin resistance, and other cardiovascular risk factors.[20]

Because direct measurement of visceral fat is not possible, surrogate measures have been developed to identify patients who require medical interventions and to monitor the progress of those treatments. Weight, BMI, waist circumference, hip circumference, and waist-to-hip ratios have all been studied. Anthropomorphic measurements have been found to be more sensitive than weight or BMI. Many studies have confirmed a high correlation between waist circumference and viseral obesity.[7-9,21-24] Furthermore, Jans-

Table 4 Changes in circumference not accompanied by weight changes

	True waist	Umbilical waist	Hip
Number of discordant measurements	81	103	96
% of measurement changes	16.1	20.5	19.1
% of women with ≥1 episode	35.5	41.6	39.2
Range of circumference changes	2–20.5	2–19	2–40.5
Mean circumference (STD)	5.29 (3.53)	5.59 (3.71)	4.94 (4.53)
Frequency BMI ≤30 vs ≥30	0.857	0.362	0.773

sen et al. found that within each BMI category, those patients with larger waist circumferences had higher risks for virtually every obesity-related comorbidity when compared with normal-waisted patients.[25]

Hu has demonstrated that the waist circumference measurement is also simpler to measure than the waist-to-hip ratio, that it is associated with fewer measurement errors, and that waist circumference is the most practical and simple to interpret.[20] Different cutoffs have been suggested for different ethnicities to reflect differences in muscle mass and bone density.[17]

However, our study found that the accuracy of measurements of circumference can be questionable in real-world practice. Testing available data for internal consistency, there were high rates of changes that did not make sense. In particular, we found that 57.7% of women had a significant change in abdominal girth (>2 cm) in one direction (increase or decrease) measured by "true waist", when the other measure of girth "umbilical waist" had a significant change in the opposite direction. Because the "true waist" might be considered an unreliable gauge, we also compared measurements of circumference to a more objective measurement (weight). We again found that at least 30% of women had at least one time when her circumference changed significantly (>2 cm) in one direction (increase or decrease), whereas her weight changed significantly (>2 lb) in the opposite direction. We also found changes in circumference when there was no accompanying change in weight; significant changes in weight were also seen with no changes in circumference. Virtually every woman who had multiple visits had at least one episode of inconsistent changes in some variable. Interestingly, obesity did not affect the answers; the frequency of inconsistent changes was no different between women with BMI ≥30 compared with nonobese women. If we had used lower thresholds for discordance (<1 cm or <1 lb), as has been done in other studies, the results would have been even significant.

It is interesting to note that, as important as these measurements appear to be, there are no standardized protocols for determining any of the anthropomorphic measurements. WHO has provided guidance, but those recommendations are not universally followed. National Health and Nutrition Examination Survey criteria specified that the waist circumference is to be measured with a steel measuring tape to the nearest 0.1 cm at the high point of the iliac crest at minimal respiration.[21] However, these criteria are often, but not always, used.[22] For example, for hip circumference, Sönmez et al. measured the circumference in the standing position from the plane of both major trochanters.[2] On the other hand, Zhang et al. measured hip circumference at the level of maximum width of the buttocks with the subject in a standing position.[16] Noble determined hip circumference at the widest point over the greater trochanter.[23] Similarly, Sönmez et al. measured the waist circumference in the standing position at a point midway between the lowest rib and the iliac crest.[2] Zhang measured waist circumference 2.5 cm above the umbilicus.[16] The Department of Defense advises the clinician to "feel to locate the upper hip/bone and top of the right iliac crest and locate the midpoint. The tape is placed in a horizontal plane around the abdomen at the level of that landmark. Measurements are made to the nearest half inch.[24] Others record the waist circumference at the level of the umbilicus.[5,23]

Although we recognize the theoretical importance of waist circumference, our study highlights the need to consider several real-world sources for potential error. For example, distinct problems arise by measuring waist circumference at only one site. As women gain weight, the abdominal panniculus often falls. This can create a situation in which the upper abdomen may become more slender. At the same time as the umbilicus droops toward the mons, the lower abdomen may increase greatly in girth. To reflect the variability of anatomical locations of both visceral and subcutaneous fat, this study defined 2 different measures of waist circumference. Some of the discordance seen between changes in true waist and umbilical waist measurements may be explained by this "settling" or "drooping" effect.

In addition, there is a possibility of error in measurement. There is a suggestion of this potential in the way data have been reported in earlier studies. Price et al. performed duplicate measurements of waist and hip circumference and reported discarding instances when there was greater than 3% difference between the duplicate measurements. They averaged remaining data points and reported waist circumference to the nearest millimeter.[12]

Beyond the definitional and mechanical factors such as respiratory excursion and positional changes that may introduce measurement errors, patients themselves may also contribute some to the uneven findings. In their embarrassment, there is a tendency for the patients to "suck it in" or contract their abdominal muscles whenever they are being measured. In reproductive-aged women, the menstrual cycle may also affect abdominal circumference measurements. During the premenstrual phase, the patient's bloating and constipation may add to the total circumference, as may food or air in the gastrointestinal tract or an enlarged uterus. Although Janssen et al. and Zhang reported recording their measurements to the nearest millimeter,[16,25] our data suggest that at least changes less than 2 cm are too unreliable to be considered clinically significant.

Even though all the measurements were made by trained professionals, it is clear that very unusual patterns of weight change and anthropomorphic measurement changes were observed. Therefore, just as BMI may be an indirect and imperfect measurement of adiposity and has several limitations,[20] our study finds that measurements of waist and hip circumference also are indirect and (occasionally) imperfect measures of visceral obesity. Clearly precision may not be needed to establish the initial diagnosis of visceral obesity, but accuracy and reliability of these measurements may be very important in monitoring a patient's response to treatment. Bosy-Westphal et al. have concluded that waist circumference and hip-to-waist ratios are not able to capture all the information that is needed to assess obesity-related metabolic risk, especially in the context of lean body mass.[1]

Although changes in these anthropomorphic measures are important in assessing risk status and determining the effect of therapeutic interventions,[6] our study suggests that a more uniform and evidence-based method of anthropometric measurements would be helpful but may not be sufficient. Instead, the totality of weight and BMI changes, as well as changes in waist and hip measurements, should be considered in the context of the patient's body habitus before judging the success or failure of a given intervention.

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