PATTERNS AND COMPOSITION OF WEIGHT CHANGE IN COLLEGE FRESHMEN

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ABSTRACT

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**Background:** The transition to the university is a vulnerable time period for weight gain. The media refers to this phenomenon as the “freshman 15,” although actual gain is much more modest (~ 3.5 lb). Regardless, weight gain during the freshman year may lead to an increased risk of cardiometabolic diseases. Little research has examined potential patterns or composition of weight change in freshmen, nor is there extensive data regarding predictors/moderators of this trend. **Objective:** The primary aims of this study were to identify critical time periods for weight change in university freshmen and to quantify change as lean versus fat mass. Secondary aims were: to investigate the accuracy of self-reported weight and height; to explore taste sensitivity as a potential predictor/moderator of this trend; and to determine the utility of using simple anthropometric indices (e.g., body mass index (BMI), waist circumference (WC)) in lieu of body composition assessment. **Methods:** Freshmen (n=236) underwent measurements for weight, height, WC, and body composition (% fat) five times during the year (arrival to campus; pre-holiday; post-holiday; pre-spring break; pre-finals). A subset of participants (n=30) rated the intensity of salty and sweet solutions. **Results:** Freshmen (n=103) gained 2.6±3.1 kg with a concomitant increase in fat (1.7±3.3%; p<0.05 for both). Weight gain (1.4±2.1 kg) was most marked during the first 10-12 weeks on campus while most fat mass was gained during the spring (1.1±2.5%; p<0.05 for both). Overall, freshmen (n=128 F) reported their weight accurately, however those who underreported weighed more (+10.2 kg) and had higher waist circumference (+8.1 cm) and % fat (+4.0%; p<0.05 for all). Taste sensitivity was not associated with weight, adiposity, or weight change. BMI and WC performed poorly in identifying truly overweight/obese individuals (67% and 50%, respectively). **Conclusions:** Early weight gain...
occurred, but was not paralleled by fat gain. Thus, the final weeks on campus may be ideal for intervention and education. Practitioners relying on self-reported weight and height should be aware than individuals most at risk may be misrepresenting their true weight and reliance anthropometric indices—whether self-reported or directly-assessed—may lead to missed opportunities for intervention and prevention efforts.
"We were together.

I forget the rest."

-W.W.

Dedicated to my wife Mia: my strength, my love, my best friend, my world. Thank you for your unconditional love and support.
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INTRODUCTION

The prevalence of overweight/obesity has increased most rapidly among young adults (Mokdad et al., 1999). Prevention of weight gain in this population is paramount as body mass index (BMI) in late adolescence is an excellent predictor of future BMI (Guo, Wu, Chumlea, & Roche, 2002) and, thus, associated health outcomes. Given the difficulty in treating obesity (Wirth, Wabitsch, & Hauner, 2014), identifying time periods where individuals are most vulnerable to weight gain may guide prevention efforts. Previous work indicates that marriage (Averett, Sikora, & Argys, 2008) and the winter holidays (Schoeller, 2014) may be such time periods. Emerging adulthood has also been implicated as a critical time period for weight gain (Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008). More specifically, weight gain during the freshman year of university has garnered significant attention in both the popular media and scientific literature. After Hovell et al. (1985) demonstrated a significantly faster rate of weight gain in university women than non-attending peers, Seventeen magazine coined the term “freshman 15” (Brown, 2008). Despite the popularity of the term, actual weight gain is far more modest. A recent meta-analysis found average gain during the freshman year to be approximately 1.6 kg (Fedewa, Das, Evans, & Dishman, 2014) and most studies report a subset of students who lose weight (Economos, Hildebrandt, & Hyatt, 2008; Gropper et al., 2009; Jung, Bray, & Ginis, 2008; Lloyd-Richardson, Bailey, Fava, & Wing, 2009). Regardless, previous work collectively agrees that the majority of freshmen gain weight (Cluskey & Grobe, 2009; Gropper et al., 2009; Hoffman, Policastro, Quick, & Lee, 2006; Leone, Morgan, & Ludy, In Press) which is especially concerning since roughly 28% of adults aged 18-24 attend a university (National Center for Education Statistics, 2013).
There is a breadth of data concerning freshman weight change, although several limitations must be noted. First, many studies employ pre-post measures which may fail to capture critical time points during the year where students are more likely to experience weight change. Given that holiday weight gain comprises the majority of adults’ annual gain (Yanovski et al., 2000), multiple measurements during the freshman year may help elucidate similar critical time points in university freshmen. For example, the transition to the university (i.e., first 10-12 weeks) and the holidays may elicit weight gain, while attempts to “tone-up” prior to spring break may result in weight loss. Identifying these time points may assist in the development and implementation of prevention, intervention, and/or education programs.

Second, the majority of studies do not differentiate between changes in lean mass and fat mass. This is of particular importance because deposition of fat mass increases the risk of chronic disease whereas lean body mass does not. Therefore, examining changes in body composition may clarify the clinical significance of freshmen weight gain. For instance, males tend to experience peak height velocity after females and later in adolescence (Bogin, 2003). Late maturing males may still be growing during the transition to the university, thus weight gain may be due to accretion of bone and/or other lean mass and may not contribute to chronic disease. While growth and development may partially be responsible for freshmen weight gain, one study found that even when weight was stable over six weeks, fat mass increased (Hull, Hester, & Fields, 2006) highlighting the importance of distinguishing between gains in lean and fat mass. Body composition assessment is often overlooked, however, because many investigations utilize self-reported weight and height (Gillen & Lefkowitz, 2011; Kapinos, Yakusheva, & Eisenberg, 2014; Yakusheva, Kapinos, & Weiss, 2011). This is problematic as individuals tend to under-report their weight and over-report their height (Connor Gorber,
Reliance on self-reported weight and height may lead to an underestimated prevalence of overweight/obesity and may prevent identification of individuals at risk for chronic disease. There is a dearth of research evaluating the accuracy of self-reported weight and height in university students (Danubio, Miranda, Vinciguerra, Vecchi, & Rufo, 2008; Larsen, Ouwens, Engels, Eisinga, & van Strien, 2008) and misreporting may be partly responsible for the large range (0.7-9.2 kg) (Fedewa et al., 2014) of weight gain reported during college.

Additionally, few studies have investigated potential predictors or moderators of weight change during the freshman year. Of those that have, most have focused on sex (Lacaille, Dauner, Krambeer, & Pedersen, 2011), race (Gillen & Lefkowitz, 2011; Webb, 2012), baseline BMI (Boyce & Kuijer, 2015), or other demographic characteristics. To date, no studies have examined the relationship of taste sensitivity and adiposity in college freshmen, nor has previous work investigated its potential moderating effect on freshmen weight change. Whether taste sensitivity is related to adiposity status (i.e., lean versus overweight/obese) is unclear as conflicting results (Pepino, Finkbeiner, Beauchamp, & Mennella, 2010; Stewart et al., 2011) preclude strong conclusions. Moreover, several studies have demonstrated improved taste acuity following weight loss (Burge, Schaumburg, Choban, DiSilvestro, & Flancbaum, 1995; Umabiki et al., 2010) although none have investigated the potential impact of taste sensitivity on weight gain or vice versa. Given the propensity for university freshmen to gain weight, they serve as an ideal population to investigate the potential for taste sensitivity to predict or moderate weight gain. Disparities in taste perception data may be partially explained by the frequent use of BMI to categorize individuals as lean or overweight/obese. BMI is an often used proxy for body fatness in determining disease risk, although it is often criticized for incorrectly classifying
muscular individuals as obese when they truly have healthy levels of body fat (Etchison et al., 2011; Ode, Pivarnik, Reeves, & Knous, 2007). More concerning, however, is the potential for BMI to misclassify individuals as healthy when they truly have unhealthy levels of body fat. These “normal weight obese” individuals demonstrate a greater prevalence of metabolic syndrome and cardiometabolic dysregulation and are most likely unaware of their health risks due to their seemingly normal BMI (Romero-Corral et al., 2010). Understanding the limitations of BMI and identifying alternative proxies may lead to increased awareness and prevention of chronic disease risk as well as provide correct classification for health-related investigations.

The primary aim of this study was to identify patterns of weight change in college freshmen and differentiate between changes in lean and fat mass. Secondary aims were: 1) to compare the predictive ability of self-reported to directly-assessed anthropometric data; 2) to determine the relationship between taste sensitivity and adiposity indicators; 3) to compare the predictive ability of health-risk of simple anthropometric indices to body composition assessment.
CHAPTER I

SEX & GEOGRAPHIC CHARACTERISTICS OF WEIGHT & ADIPOSITY CHANGE IN UNIVERSITY FRESHMEN: A META-ANALYSIS

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Abstract

Context: Modest weight gain occurs in the first year of university. However it is unknown whether weight-related trends of the locale are reflected on university campuses. The primary aim of this meta-analysis was to examine geographic patterns of weight change in college freshmen. The secondary aim was to quantify and compare weight and adiposity changes in males and females. Evidence acquisition: A total of 38 effects were identified from 33 investigations meeting inclusion criteria. Studies were categorized by region according to the Census Regions and Divisions of the United States. In order to negate the effect of study duration on weight/adiposity change, data were normalized to rates (weight: grams/week; adiposity: % fat/week) prior to analysis. Evidence synthesis: In males, mean change in the Midwest and Northeast was 36.7±19.2 g/wk and 67.7±17.6 g/wk, respectively. There were no effects in the South or West. In females, weight change was 37.5±6.6 g/wk in the Midwest, 45.1±6.8 g/wk in the Northeast, 41.2±7.8 g/wk in the South, and 78.2±9.7 g/wk in the West. Overall mean weight change was 58.6±12.9 g/wk and 44.9±4.3 g/wk in males and females, respectively. Overall mean fat change was 0.05±0.01 %/wk in males and 0.04±0.01 %/wk in females. There was no difference in weight change by region or by sex, nor was there a difference in adiposity change between sexes. Conclusions: First year weight gain tends to be ubiquitous and occur at similar rates across regions and between sexes. Universities are removed from the surrounding community and are in a unique position to attenuate undesirable weight and adiposity changes in young adults.
Context

Current methods of treating obesity have been unsuccessful in curbing the epidemic, highlighting the necessity of prevention efforts.\(^1\) However, in order to increase the likelihood of success in obesity prevention efforts, critical periods for weight gain (specifically from fat) must be identified. The winter holiday season,\(^2\) marriage,\(^3\) and emerging adulthood\(^4\) have all been implicated as such critical time points. Evidence from several national surveys (e.g., National Longitudinal Study of Adolescent Health (Add Health), Coronary Artery Risk Development in Young Adults (CARDIA), National Health and Nutrition Examination Survey (NHANES)) indicates that weight gain and obesity are substantial problems among young adults\(^4\) with 42\% of 18-24 year olds overweight/obese.\(^5\) Moreover, 66\% of 18 year olds completing high school enroll in a college or university,\(^6\) which is itself a critical period for weight gain.\(^7\) A recent meta-analysis demonstrated a modest, but significant weight gain of 1.6 kg — coupled with an increase in body fat of 1.2\% — across the 4-year undergraduate college career.\(^8\) Weight gain was most marked during the freshman year, however there is significant heterogeneity of effects. For example, the range of weight gain during the college career appears to be between 0.7\(^9\) kg and 9.2\(^10\) kg, with some studies even demonstrating weight maintenance or loss.\(^11\)

The variability among studies may at least partially be explained by the location of the university from which the sample was derived. Geographic patterns consistently demonstrate that adults in the Southern regions of the United States have higher rates of obesity, whereas a lower prevalence of obesity exists in the Northeastern region.\(^12,13\) Likewise, there is evidence of diabetes-,\(^14\) stroke-,\(^15\) and heart failure-\(^16\) “belts” (i.e., contiguous states within the Southern United States) that follow obesity “belts.” This may partially be due to social, cultural, and genetic dynamics of these regions.\(^14,15\) For instance, the prevalence of physical activity, as well
as fruit and vegetable consumption is higher in the Northeastern United States when compared to the Southern regions (i.e., Mississippi Delta and Southern Appalachian Mountains).

Whether these trends extend to local college campuses or if the university serves as a unique ‘community’ removed from the locale have yet to be elucidated.

Identifying geographic patterns for college weight gain could greatly impact the understanding of this phenomenon. Although freshman weight gain has been extensively studied, fewer studies have examined moderators of this trend. Of those that have, the evidence is inconsistent. For instance, stress has been suggested to influence weight change while others failed to identify an effect. Most students report a considerable influence of the environment on their behaviors suggesting environmental factors may influence weight and adiposity gain more so than individual, psychological factors. If university environments are indeed shaped by the region in which they are located, there is the potential for a negative impact from the surrounding community.

Heterogeneity may also result from varying distributions of male and female participants. Most samples consist of primarily, if not exclusively, female participants and data regarding the influence of large proportions of female participants is conflicting. A prior meta-analysis found that studies with a larger proportion of females demonstrated greater weight gain, while more recent work found that the percentage of female participants did not moderate weight gain. Although these analyses allude to potential disparities between males and females, no study thus far has quantified potential differences between sexes in weight or adiposity change. Females tend to experience peak height velocity early on in adolescence (~12-13 years) whereas males do so at later stages of development (~14-15 years). Furthermore, males experience a “muscle spurt” roughly 2-3 years after peak height velocity that does not occur in females. Given these
differences in developmental patterns, males may still exhibit significant accretion of lean body mass via bone and muscle growth during the first year of university resulting in small gains of “healthy” weight. While differentiating between weight gain due to normal growth and development and other factors is challenging, previous work has attempted to link psychological and behavioral factors with weight gain during college. For example, males often report a desire to gain weight\textsuperscript{18,23} and those reporting high levels of physical activity are more likely to do so.\textsuperscript{24} On the other hand, females tend to reduce physical activity during the transition to university, which may influence weight gain.\textsuperscript{9} Taken together, these results suggest that weight gain may be attributable to healthy body composition changes in males (i.e., increased muscle mass) while weight gain in females may be the result of undesirable deposition of adipose tissue.

This study sought to add to the literature by providing a deeper understanding of changes in weight and body composition during the freshman year of university. The primary aim was to examine geographic patterns of weight change. We hypothesized that the magnitude of weight gain would be exaggerated on campuses located in the Southern United States when compared to those in other regions. The secondary aim of this study was to quantify and compare weight and adiposity changes in males and females. We hypothesized both males and females would experience weight and adiposity gain during the freshman year. Because males may still be maturing, we expected males to gain more weight than females due to accretion of lean body mass.

**Methods**

**Evidence Acquisition**

This meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.\textsuperscript{25} An electronic search of
MEDLINE, SPORTDiscus, and PSYCInfo databases was conducted to identify potential studies regarding weight and/or adiposity change in university freshmen. Peer-reviewed articles published before January 21, 2015 were located using variations of the search terms *freshman*, *college*, *weight gain*, and *weight change* with search parameters of *human* and *English language*. Reference lists were searched manually to identify further articles.

**Study Selection**

Included articles were peer-reviewed, provided a measure of weight and/or adiposity changes, involved freshman participants, and were conducted within the United States. In the case of intervention studies, articles were included if they provided data for a no-treatment control arm. The literature search yielded 251 relevant articles. A total of 177 duplicates were removed, resulting in 74 articles for the analysis. An additional nine articles were identified within reference lists. Figure 1.1 depicts a flowchart of the study selection process. The location of the study was identified and studies were subsequently categorized by regions according to the Census Regions and Divisions of the United States.\(^{26}\)

**Statistical Analysis**

Previous work has acknowledged a positive correlation between study duration and weight gain.\(^{21}\) To negate this effect, data were normalized prior to analysis. Weight change and adiposity (% fat) were evaluated as ± grams/week and ± % fat/week, respectively. When weight or adiposity change effects were not reported as M±SD, it was calculated by subtracting baseline from follow-up measurements. Observed SD were graphed and a reasonable average value was used to compute approximation of SE of the effect for each study when such values were not provided. Unless otherwise indicated, data are presented as M±SE.
**Evidence Synthesis**

Data were collected from 33 investigations (Table 1.1) of weight gain in university freshmen comprising 38 effects. There were nine effects from nine studies reporting % fat. Studies were not included in analysis if they did not identify separate effects for each sex. Studies were considered to have multiple effects if multiple measures were taken throughout the study period.

**Regional Analysis**

Weight change did not differ between regions for males or females. For males, there were three effects in the Midwest, eight in the Northeast, and zero in the South or West. Mean change in the Midwest was 36.7±19.2 g/wk (n=1036) and mean change in the Northeast was 67.7±17.6 g/wk (n=826). In females, there were ten effects in the Midwest (n=2091; 37.5±6.6 g/wk), ten in the Northeast (n=1133; 45.1±6.8 g/wk), four in the South (n=421; 41.2±7.8 g/wk), and two in the West (n=227; 78.2±9.7 g/wk). All effects were positive, indicating weight gain, except for one documenting no weight change. Figure 1.2 summarizes the results of this analysis.

**Sex Analysis**

**Weight**

Weight change did not differ between males and females. There were 12 effects of weight change in males comprised of 1935 participants. Mean change was found to be 58.6±12.9 g/wk. The smallest change in weight was 9.6±9.1 g/wk while the largest was 150.0±13.4 g/wk. All effects were positive, indicating weight gain. Of the 28 effects identified in females, two outliers were removed from analysis due to uncharacteristically high weight gain (>200 g/wk). In the 26 remaining effects, the mean weight change of 3940 participants was 44.9±4.3 g/wk. The range was 0.0±11.3 g/wk to 112.5±23.6 g/wk, with all but one effect greater than
zero. The results of the analysis of weight gain in males and females are summarized in Figure 1.3A.

% Fat

There was no difference in % fat change between males and females. There were three effects for % fat in males comprising 126 participants. Mean change was 0.05±0.01 %/wk. The range was 0.04±0.02 %/wk to 0.05±0.01 %/wk. In females, there were seven effects comprising 592 participants. Mean change was 0.04±0.01 %/wk. The range was 0.1±0.02 %/wk to 0.09±0.01 %/wk. All effects in both males and females were greater than zero. Figure 1.3B illustrates % fat change in males and females.

Discussion

In accordance with previous work, the present study found that significant weight gain occurs during the first year of university. However, uniformity among regions suggests that trends of the surrounding community may not be reflected on university campuses. This may be due to an inconsistency among predictors of obesity in the community and the university. The Lower Mississippi Delta has the highest concentration of poor and unemployed African Americans in the country and obesity rates are correlated with high rates of unemployment and lower education. Only 50% of individuals from low-income (i.e., bottom 20% of all family incomes) households attend a college or university. Therefore, the campus population may primarily consist of students from other locations, reducing the impact of trends and predictors from the local community. In addition to socioeconomic status, lack of regional variability of college weight gain may also be explained by discrepancies in environmental, cultural, and/or social factors between universities and the surrounding community.
University campuses are unique environments offering housing, dining, fitness, and health care facilities that are largely independent of the surrounding community. Although often criticized for offering meals in ‘all-you-can-eat’ dining halls, one study found that students who participated in a campus meal plan ate more fruits and vegetables than students who did not participate and another found that females eating five or more fruits and/or vegetables experienced a weight loss during the freshman year. Moreover, students living on-campus eat a greater variety of fruit, vegetable, and dairy products and are less likely to be overweight/obese than students living off-campus. In addition to high rates of obesity, the Southern United States also exhibits a lower prevalence of fruit and vegetable consumption. Not only is BMI negatively correlated with the presence of a healthy grocery stores in low-income neighborhoods, which are prevalent in the South, but those in closer proximity demonstrate greater odds of daily vegetable intake. Thus, increased prevalence of weight-related diseases (e.g., obesity and diabetes) in the Southern United States may result from limited access to healthy foods. However, the higher availability of fruits and vegetables on campus may elicit healthier dietary patterns in university students than residents in the surrounding community.

Geographical regions exhibit dietary patterns based upon place and heritage. The Southern United States is known for its ‘soul food,’ which may often contain high fat and fried foods. However, cultural foods and customs tend to persist at home rather than restaurants and may not be reflected on local college campuses. If cultural foods and habits are not mirrored in the local university, negative impacts of unhealthy dietary patterns in the community may not be realized in students. In a study of the food environment in students’ dormitories, it was found that parents had purchased approximately half of the food students maintain in their rooms. It is likely that at least a portion of students are from out of state and parents are most likely
purchasing food aligned with their culture and customs and not that of the region in which the campus is located. Students also tend to maintain childhood dietary habits into college\textsuperscript{63} that may prevent their adopting regional food habits and preferences. Finally, many students do not have access to an automobile, thus limiting interaction with the local community\textsuperscript{4} and preventing assimilation with the regional food culture.

Access to recreational facilities on college campuses may also partially explain a lack of variance among weight gain across regions. Physical inactivity is positively associated with obesity prevalence while the number of fitness centers per 1000 residents demonstrates a negative relationship with local obesity prevalence.\textsuperscript{54} Furthermore, females living in dormitories closer to the campus fitness facility were at a lower risk of weight gain during their freshman year.\textsuperscript{35} Although university students generally do not meet recommendations for physical activity,\textsuperscript{4} increased access to recreational facilities may offer opportunities that are not available in the surrounding community. Proximity alone does not explain discrepancies in physical activity behavior. Attitudes towards physical activity likely vary both culturally and regionally\textsuperscript{12} and the social environment may influence physical activity behaviors as much as the built environment. Adolescents tend to select friends who engage in similar physical activity behaviors and ultimately match their behaviors.\textsuperscript{64} University students also report that social support is influential in physical activity behaviors.\textsuperscript{65} A study investigating freshman weight gain and roommate assignment found that individuals whose peers exercised more frequently also exercised more frequently.\textsuperscript{40} Therefore, peer selection and influence may create a unique social environment on campus that is removed from the community and perhaps more supportive of physical activity.
The present analysis also found that males and females gained weight and % fat at a similar rate during the first year of university. This was unexpected due to differences in developmental patterns between sexes, but may be explained by psychosocial and behavioral factors. Compared with males, females are more concerned with weight gain and weight management. This may lead to unhealthy weight loss methods and, paradoxically, weight and/or % fat gain. Previous work supports this as several studies have found increases in % fat while weight was maintained or lost. Conversely, males may actually desire to gain weight and may use a combination of both healthy (e.g., “eating more healthful plus exercising”) and unhealthy methods to do so (e.g., “eating more fatty, fried, and junk foods”). In males employing unhealthy practices, weight gain will likely be due to greater deposits of adipose tissue rather than lean mass. It is also possible that males have experienced their muscle spurt before the transition to the university, thus reducing the degree of lean tissue accretion.

Sex disparities in stress responses may also influence weight and % fat change in freshmen. When stressed, males are twice as likely as females to consume excess alcohol, while females may increase energy consumption and decrease physical activity. Despite variable responses to stress, these behaviors may potentially result in weight and adiposity gain in both sexes. Acute and chronic alcohol exposure may reduce serum testosterone which is primarily responsible for male adolescents’ increases in lean body mass. Taken together, these data suggest that behavioral patterns may moderate the physical aspects of normal growth and development expected in university freshmen eliciting similar patterns in weight and % fat gain.

Environmental influences may also help clarify the similarities of male and female weight and % fat gains. A study investigating university dormitory assignments, weight gain, and related behaviors found that females exercised less and males ate more when food was easily
accessible (i.e., on-site dining hall).³⁶ Assuming freshmen males are deliberately trying to gain weight, increased availability may lead to increased consumption of unwholesome foods as a means to gain weight and, again, greater gains of adipose tissue than lean mass. On the other hand, decreased physical activity and unhealthy weight control practices (i.e., dietary restriction) in females may result in marginal weight change, but undesirable changes in body composition.

**Limitations and Future Research**

This meta-analysis is subject to several limitations. First, it is likely that studies documenting weight maintenance or weight loss were not published. This may lead to a bias towards greater weight gain than actually occurs on university campuses. Second, there was a paucity of male participants making comparisons between sexes challenging. Investigators should actively engage more male participants in order to strengthen sex-based analyses. Third, weight change was often reported as pre- and post- weights without a measure of variance (e.g., SD) of the change requiring estimation of this value in many studies. Investigators should include these values in order to strengthen subsequent analyses.

Future work should also address other potential contributors such as the proportion of out of state versus in-state students. This may have prohibited identifying a regional effect of weight change in the present study. If students are primarily from out of state, it is likely their cultures and customs will not reflect the local communities and may thus create a different social environment on campus. However, if local students attend the university, they may reflect the characteristics of the community and influence the social environment. Investigators should also explore potential differences between higher and lower academically ranked (such as US News and World Report Ranking) universities. Again, the social environment on campus may vary between Ivy League and “normal” universities, thus moderating weight and/or % fat gain. The
two outliers excluded from the present analyses due to uncharacteristically high weight gain were conducted at an Ivy League university. This lends support to the notion that weight change may vary between higher and lower academically ranked universities.

Conclusions

Freshman weight gain tends to be ubiquitous and occur at similar rates on universities across the country. Although weight gain amounts to less than 2.3 kg (~5 lb) during the freshman year, this marks a disturbing trend as it was coupled with adverse changes in body composition. First year students are living away from home—likely for the first time—and are beginning to develop lifelong habits. Universities appear to be removed from the locale and serve as their own “community,” unaffected by regional disparities in weight-related diseases. Thus, they are in a unique position to mitigate undesirable changes in weight and body composition by creating an environment supportive of healthy dietary and physical activity behaviors.
References


### Table 1.1: Peer-reviewed publications prior to 2015 regarding freshmen weight and adiposity change

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<th>N (F)</th>
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Figure 1.1: Flow chart of evidence acquisition and study selection
**Figure 1.2:** Forest plots depicting regional weight gain by sex. The size of the black box indicates the weight of the study; error bars represent 2SE. The black diamonds represent pooled effects (M±2SE) of each region. Subscripts following the author indicates multiple measurements in the same study.
Figure 1.3: Forest plots depicting A) men versus women weight change and B) men versus women fat change. The size of the black box indicates the weight of the study; error bars represent 2SE. The black diamonds represent pooled effects (M±2SE) of each region. Subscripts following the author indicates multiple measurements in the same study.
CHAPTER II

PATTERNS AND COMPOSITION OF WEIGHT CHANGE IN COLLEGE FRESHMEN

Ryan J. Leone, BS, RD; Amy L. Morgan, PhD; Mary-Jon Ludy, PhD, RD

In Press: College Student Journal
Abstract
While it is well documented that college freshmen gain weight, there is a dearth of studies examining critical time periods for this weight change. Freshmen living on campus (n=103; 21M, 82F) visited the laboratory in August/September, November, January, February/March, and April/May. Measurements at each visit included: weight, waist circumference (WC), and body composition (% fat). Overall weight gain was 2.6±3.1 kg, with most occurring during the first (1.4±2.1 kg) and final (0.5±1.5 kg; p<0.05 for all) two months of the academic year. WC did not change. Overall % fat gain was 1.7±3.3% with most (1.1±2.5%; p<0.01 for both) occurring in the final two months of the academic year. Changes in % fat were correlated with changes in WC (r=0.464) and weight (r=0.686; p<0.001 for both). Freshman weight gain can partially be attributed to accretion of fat warranting future investigations on targeted prevention programs focusing on behaviors early and late in the academic year.

Keywords: freshman fifteen; body fat; waist circumference; weight gain; nutrition; health


**Introduction**

Given that excess weight contributes to many negative physical, social, and economic outcomes, it is imperative to identify critical time periods when individuals are most susceptible to weight gain. The holiday season (Thanksgiving to New Year’s Day) (Yanovski et al., 2000), marriage (Averett, Sikora, & Argys, 2008), and college (Hovell, Mewborn, Randle, & Fowler-Johnson, 1985; Levitsky, Halbmaier, & Mrdjenovic, 2004) are acknowledged in the popular media as well as the scientific literature as particularly critical periods. Popular media feeds this fascination with a Google search yielding 7.3, 14.5, and 46.3 million hits for holiday, marriage, and college weight gain, respectively.

Young adults entering college are faced with a new environment, often living away from home for the first time. These new university students may experience heightened stress alongside their increased autonomy. One contributor to stress may be the fear of “the freshman fifteen.” After Hovell et al. (1985) observed a substantially greater weight gain among college attending females than non-attending peers (+3.6 kg versus <0.5 kg), *Seventeen Magazine* described this phenomenon as “the freshman fifteen” (Watkins, 1989) even though the magnitude of the gain was less than 15 lbs (6.8 kg).

Despite the widespread belief that a gain of 15 pounds during the freshman year is inevitable, scientific literature suggests actual gain to be much more modest (Economos, Hildebrandt, & Hyatt, 2008; Edmonds et al., 2008; Hoffman, Policastro, Quick, & Lee, 2006; Holm-Denoma, Joiner, Vohs, & Heatherton, 2008; Hovell et al., 1985; Levitsky et al., 2004; Mihalopoulos, Auinger, & Klein, 2008). A recent meta-analysis documented a weight gain of 1.8 kg during the freshman year (Vella-Zarb & Elgar, 2009), far less than the popularized value of 6.8 kg. In their review, Zagorsky and Smith (2011) found similar weight gain during the
freshman year of 1.1 kg and 1.5 kg for females and males, respectively. Further, the range of
can be between 0.7 kg (Butler, Black, Blue, & Gretebeck, 2004) and 4.0 kg,
(Hovell et al., 1985), again supporting the notion that “the freshman fifteen” is an inflated value.
Weight gain is not ubiquitous, however, as one study failed to detect any weight gain (Graham &
Jones, 2002). In fact, most report a subset of students losing weight (Economos et al., 2008;
Gropper et al., 2009; Jung, Bray, & Ginis, 2008; Lloyd-Richardson, Bailey, Fava, & Wing, 2009;
Mihalopoulos et al., 2008; Provencher et al., 2009). Conflicting results may partially be
explained by the location of the investigation. The majority of studies concerned with freshman
weight gain have been conducted in the Northeastern United States (Economos et al., 2008;
Hoffman et al., 2006; Holm-Denoma et al., 2008; Levitsky et al., 2004; Mihalopoulos et al.,
2008), a region known for healthier metabolic profiles (Centers for Disease Control and
Prevention, 2014). Regional food culture, availability, and preference, as well as physical
activity habits, may impact changes in body weight on college campuses elsewhere.

There is a breadth of data concerning weight gain during the freshman year, however
relatively fewer studies have differentiated between gains of lean mass and fat mass (Butler et
al., 2004; Edmonds et al., 2008; Graham & Jones, 2002; Gropper et al., 2009; Hajhosseini et al.,
2006; Hoffman et al., 2006; Hull et al., 2007; Jung et al., 2008; Morrow et al., 2006; Webb,
2012). Distinguishing between lean mass and fat mass is essential because fat mass substantially
contributes to the development of chronic disease, whereas lean mass does not carry this risk. Of
the studies that have examined body composition (% fat), the results are inconsistent. Two
studies, a year-long investigation conducted in female freshmen (Jung et al., 2008) and an
academic year investigation conducted in both sexes (Graham & Jones, 2002), found no change
in % fat. Another study, in both sexes, observed an increase of 2.1% fat in the 16-week fall
semester (Hajhosseini et al., 2006). The remaining studies have found increases in fat ranging from 0.7% to 1.8% (Butler et al., 2004; Edmonds et al., 2008; Gropper et al., 2009; Hoffman et al., 2006; Hull et al., 2007; Morrow et al., 2006; Webb, 2012). One investigation found an increase in % fat of 0.5% even among participants who lost weight (Gropper et al., 2009), thus highlighting the importance of exploring % fat in college freshmen. This may partly be due to unhealthy weight control behaviors (Gropper et al., 2009) and decreases in physical activity upon transition to the university (Butler et al., 2004; Jung et al., 2008; Leone, Kuhlman, Ludy, & Morgan, 2014).

Few studies have measured waist circumference (WC) (Edmonds et al., 2008; Gropper et al., 2009; Morrow et al., 2006; Webb, 2012) during the freshman year. This is particularly concerning because WC is an independent risk factor for chronic disease (National Heart, Lung, and Blood Institute, 2000). It provides further insight about the composition of weight gained, however data is sparse. Of the studies that examined WC, all but one (Webb, 2012) found significant increases during the freshman year. Two studies were conducted across the entire academic year finding increases of 0.9 cm (Morrow et al., 2006) in females and 1.0 cm in males and females combined (Gropper et al., 2009). The other investigation was conducted over 6-7 months demonstrating an increase of 2.5 cm in female participants (Edmonds et al., 2008).

The current literature primarily uses pre- and post- measures, sometimes including a midpoint assessment, to quantify weight gain. This model fails to isolate potential critical time periods such as the first several weeks on campus, the holiday season, and preparation for final exams which may contribute to excess weight gain. Alternatively, students may exhibit healthier behaviors in an effort to tone up prior to spring break, perhaps resulting in weight loss. The positive association between study duration and increases in weight (Vella-Zarb & Elgar, 2009)
suggests a linear model of weight gain during the freshman year, however some researchers have demonstrated that weight gain occurs primarily during the first semester (Gropper et al., 2009; Holm-Denoma et al., 2008; Lloyd-Richardson et al., 2009). Significant changes in % fat, with no concomitant increase in weight, have been observed in college students in as little as six weeks (Hull, Hester, & Fields, 2006). Moreover, research in adults has demonstrated that approximately half of annual weight gain occurs over the holiday season (Yanovski et al., 2000) suggesting even relatively brief time periods may substantially contribute to weight gain.

Although freshman weight gain is far more modest than the media portrays, small increases in weight, accompanied by increases in fat mass, may still carry considerable health consequences, especially if the associated behaviors continue beyond the freshman year. Moreover, identifying critical time periods where individuals are more vulnerable to weight gain is necessary in order to develop and implement effective prevention strategies, although this is a frequently neglected research topic. The purpose of this study was twofold. The primary objective was to identify patterns of weight change among freshmen at a Midwestern university in order to determine critical time periods. The secondary objective was to identify the composition of weight change by examining WC and % fat.

**Methods**

**Participants and Testing Schedule**

First-year, first-semester freshmen attending a large, Midwestern university were recruited via fliers, email, social media, and welcome week activities. Although participants were aware they would receive anthropometric measurements, this study was advertised to evaluate health patterns during the freshman year. The purpose of this advertising was to avoid self-selection bias of only students concerned with weight. Eligibility criteria were as follows: age
≥18 years; on-campus residence; non-claustrophobic; not pregnant or planning pregnancy; and ≤250 kg (scale capacity) and no implanted medical device(s) (contraindications to body composition testing). A total of 190 students agreed to participate in this longitudinal study. The sample was mostly Caucasian (n=159, 83.7%), with a minority of African Americans (n=20, 10.5%) and other (n=2 Asian, n=8 Hispanic; n=1 unspecified; 5.8%), which was characteristic of the university.

Assessments occurred at five time points throughout the freshman year: the first three weeks of fall semester (August/September; start of academic year); two weeks prior to Thanksgiving break (November; pre-holiday); the first two weeks of spring semester (January; post-holiday); two weeks prior to spring break (February/March; pre-spring break); and the final two weeks of spring semester (April/May; pre-finals). At the first test visit, participants completed a self-administered, demographic questionnaire soliciting sex, age, race/ethnicity, and scholastic major. All test visits included assessments for height, weight, WC, and % fat. All participants changed into compression clothing provided by researchers prior to each testing visit to minimize air trapping. Participants were asked to refrain from exercise and eating or drinking anything other than water for at least two hours prior to each testing visit because an elevated body temperature and/or breathing rate post-exercise, as well as the presence of food and/or beverages in the gastrointestinal tract, may influence results (Heiss et al., 2009).

Procedure

A calibrated, wall-mounted stadiometer was used to measure height. Participants stood with their feet in the outline of the base plate while researchers verified the participant’s back was touching, but not leaning against the device and that their head was in the Frankfort plane. The head plate was lowered to the top of the participant’s head and height was recorded to the
nearest 0.1 cm. WC was measured according to the National Institutes of Health protocol (National Heart, Lung, and Blood Institute, 2000). A retractable tape was placed parallel immediately superior to the iliac crest, roughly at the umbilicus. Measurement was recorded to the nearest 0.1 cm.

Body fat was estimated to the nearest 0.1% using air-displacement plethysmography via BODPOD (Cosmed, USA, Concord, CA), following standard protocols (McCrorry, Molé, Gomez, Dewey, & Bernauer, 1998). Weight was measured to the nearest 0.1 kg on the digital, calibrated scale coupled with the BODPOD prior to entering the testing chamber. Using weight and volume measurements, body density was converted to body fat percentage using the Siri equation (Siri, 1961) for Caucasian, Hispanic, Asian, and unspecified participants and the Brozek equation (Brozek, Grande, Anderson, & Keys, 1963) for African Americans. The university’s Institutional Review Board approved this study and all participants provided written informed consent prior to data collection. At each visit, participants earned $5 in campus spending money and received another small item (e.g., Frisbee, t-shirt, or reusable grocery bag) for their participation.

**Statistical Analysis**

Repeated measures analysis of variance (ANOVA) was performed to compare anthropometric variables across all five visits with Bonferroni adjustments used for multiple comparisons. Time was a within-subjects factor and sex was a between-subjects factor. Pearson correlation coefficients were conducted to identify associations between changes in anthropometric variables, as well as to identify relationships among changes in weight, BMI, WC, and % fat. Attrition bias was examined using chi-square tests for sex and
overweight/obesity. Independent samples t-tests were used to compare baseline height, weight, BMI, WC, and % fat.

The following cut-points were used to indicate disease risk: BMI ≥ 25 kg/m² for both sexes and WC > 102 cm for males and > 88 cm for females (National Heart, Lung, and Blood Institute, 2000). Participants were considered weight stable if they maintained their weight within ±0.5 kg of their baseline weight (Hull et al., 2006; Mihalopoulos et al., 2008). Statistical analyses were conducted using IBM SPSS Statistics Version 22.0 (IBM Corporation, Armonk, NY). A two-tailed alpha level of p≤0.05 indicated significance, while alpha levels between 0.05 and 0.10 were considered trends worthy of further investigation.

Results

Attrition

Of the 190 original participants, 103 completed all testing visits. There was no sex difference between drop-outs and participants, although more health majors than non-health majors (p=0.016) completed all visits. There was no difference in WC or % fat between drop-outs and participants who completed all visits, but weight tended to be higher among drop-outs (+3.4 kg, p=0.055) resulting in a higher BMI (+1.6 kg/m², p=0.028). Baseline anthropometrics of participants who completed all five visits are presented in Table 2.1.

Weight and Height

There was a time effect for weight (p<0.001), resulting in an overall gain of 2.6±3.1 kg during the freshman year. Patterns of weight change are portrayed in Figure 2.1A. The majority (75.7%; n=78) of participants gained >0.5 kg, whereas 17.4% (n=18) lost >0.5 kg and 6.8% (n=7) maintained their weight within ±0.5 kg. There was a modest time effect for height (+0.5
cm; \( p<0.001 \), with height increasing from 170.7±8.2 cm to 171.1±8.3 cm at the start of the academic year to pre-holiday \( (p<0.001) \) and remaining stable for the duration of the year.

**Body Mass Index**

Changes in height and weight elicited an increase in BMI \( (0.7±1.1 \text{ kg/m}^2; \ p<0.001) \) over the course of the year. Participants demonstrated an increase of \( 0.3±0.8 \text{ kg/m}^2 \) \( (p=0.008) \) between the start of the academic year and pre-holiday. An additional \( 0.4±1.0 \text{ kg/m}^2 \) \( (p=0.018) \) was gained between pre-holiday and pre-finals visits. Patterns of BMI change are portrayed in Figure 2.1B.

Using the BMI cut-point of 25 kg/m\(^2\) for overweight/obesity, 81.6% of participants were classified as normal \( (n=74) \) or underweight \( (n=10) \) while 18.4% \( (n=19) \) were overweight/obese at the start of the academic year. By the completion of the study, seven students previously classified as underweight were considered normal weight while seven previously normal weight students were classified as overweight/obese. This resulted in 74.8% of participants classified as normal \( (n=74) \) or underweight \( (n=3) \) and 25.2% \( (n=26) \) classified as overweight/obese at the pre-finals visit.

**Waist Circumference**

Using the WC cut-points of 102 cm and 88 cm to indicate increased chronic disease risk for males and females, respectively, 13.6% \( (n=14) \) were classified as abdominally obese at the start of the freshman year. At the end of the freshman year, 10.7% \( (n=11) \) were abdominally obese. WC was 79.9±13.8 cm at the start of the academic year and 81.3±15.5 cm at pre-finals visit. Changes in WC did not achieve statistical significance.
**Body Composition**

In contrast to WC, % fat increased (1.7±3.3%; p=0.001) throughout the year. The majority of gain (1.1±2.5%; p=0.010) occurred between post-holiday and pre-finals. Patterns of % fat change are portrayed in Figure 2.1C. There was no significant sex interaction among any of the variables.

**Correlations**

Baseline BMI demonstrated a weak, positive association (r=0.194; p=0.049) with weight change meaning that overweight/obese students were susceptible to greater weight gain over the academic year. WC changes throughout the academic year were strongly and positively correlated with changes in weight (r=0.560), % fat (r=0.464), and BMI (r=0.507; p<0.001 for all). Changes in % fat were strongly and positively correlated with changes in weight (r=0.686). Changes in % fat and changes in BMI (r=0.695; p<0.001 for both) also demonstrated strong, positive correlations. There was no significant association between baseline weight, WC, or % fat with overall weight change throughout the year.

**Discussion**

This study sought to quantify weight change in first year college freshmen at a Midwestern university, identify critical time periods for weight change during the freshman year, and determine the composition of weight change. Our findings corroborate with previous literature suggesting that although freshmen do gain weight, “the freshman fifteen” is largely a myth with only 10% (n=10) students gaining ≥15 lbs (6.8 kg). Nevertheless, the majority of freshmen (78%; n=80) gained >0.5 kg. This finding is consistent with previous research demonstrating weight gain in 66% (Gropper et al., 2009; Jung et al., 2008) to 77% (Lloyd-Richardson et al., 2009) of college freshmen, confirming that the transition to university is a
potentially critical time period for weight gain. Weight gain, on average, was 2.6 kg, which falls within the range of previously reported gains of 0.7 kg to 4.0 kg (Vella-Zarb & Elgar, 2009) and resulted in an overall increase in BMI, however BMI remained within the healthy range.

Weight gain was similar among males and females which is consistent with most previous data (Economos et al., 2008; Holm-Denoma et al., 2008; Mihalopoulos et al., 2008; Vella-Zarb & Elgar, 2010). However, other studies have identified differences between sexes (Gropper et al., 2009; Lloyd-Richardson et al., 2009), suggesting that predictors of weight change may differ between males and females (Economos et al., 2008). This could be related to varying perceptions across the sexes. For example, males who have lost weight during freshman year report being less satisfied with the transition to university (Provencher et al., 2009). Males may associate weight gain with increases in muscle mass and thus deem weight gain as desirable. Conversely, females who experience weight gain report a greater drive for thinness and body dissatisfaction than those who lose weight (Provencher et al., 2009).

Regardless of perceptions and magnitude, the clinical significance should not be discounted. Participants also demonstrated a significant increase in % fat (1.7%) during the academic year. College students transitioning to university experience increased autonomy and begin to develop lifelong behaviors. Weight gain, with concomitant increases in % fat, suggests an adoption of unhealthy behaviors. Furthermore, the prevalence of overweight/obesity rose from 18.4% to 25.2%. This marks a disturbing trend as BMI at 18 years old is an excellent predictor of adult obesity (Guo, Roche, Chumlea, Gardner, & Siervogel, 1994).

While the physiology of weight gain is complex and multifactorial, several behaviors – namely dietary and physical activity habits – are frequently suggested to play key roles in weight management. Several specific dietary predictors, such as increased evening snacking, higher
consumption of high fat foods, and eating in all-you-can-eat style dining halls, have been implicated in partially predicting weight gain in freshmen (Levitsky et al., 2004). Decreases in physical activity after transitioning to the university have also been observed (Butler et al., 2004; Jung et al., 2008; Leone et al., 2014), however the data is contradictory (Edmonds et al., 2008). One study found that physical activity may influence weight in freshman males, but not females, (Holm-Denoma et al., 2008) while others failed to identify an effect in either sex (Economos et al., 2008; Kasparek, Corwin, Valois, Sargent, & Morris, 2008). Alternatively, there may be other mediating factors on freshman body weight such as proximity to campus dining halls and exercise facilities (Kapinos, Yakusheva, & Eisenberg, 2014) and roommate assignment (Yakusheva, Kapinos, & Weiss, 2011).

This study was the first to attempt to isolate specific periods throughout the freshman year where students may be more vulnerable to weight gain. The majority of weight gain occurred during the first 12 weeks on campus. These data agree with previous work suggesting that most students who gain weight do so in the first semester (Hajhosseini et al., 2006; Levitsky et al., 2004; Lloyd-Richardson et al., 2009). Interestingly, % fat remained stable during this period and height increased. This suggests that early weight gain may result from an increase in lean body mass, perhaps due to late maturation, and may not be indicative of increased risk for chronic disease. This is a novel finding considering most (Butler et al., 2004; Gropper et al., 2009; Hajhosseini et al., 2006), but not all (Jung et al., 2008), previous work investigating % fat has found significant increases during the fall semester. However, two of these studies (Butler et al., 2004; Jung et al., 2008) only investigated women, which may partially explain the lack of agreement with current data, although no significant difference was noted between males and females in the present study. Moreover, previous investigations have used skinfold thickness
(Butler et al., 2004) or bioelectrical impedance analysis (Gropper et al., 2009; Hoffman et al., 2006; Jung et al., 2008) to assess % fat, whereas the current study used air-displacement plethysmography.

Research in adults demonstrates a propensity for weight gain during the holiday season (Yanovski et al., 2000), but it appears this does not hold true for college freshmen. This may be related to decreased autonomy living at home during the holiday season. The present data, in agreement with previous work involving both freshmen and upperclassmen (Hull et al., 2006), did not observe weight gain during this time period. However, participants gained 0.5 kg during the final eight weeks of the freshman academic year. This supports some previous work measuring weight gain into the spring semester (Edmonds et al., 2008); nevertheless there are discrepancies (Gropper et al., 2009; Holm-Denoma et al., 2008; Lloyd-Richardson et al., 2009). Though more weight was gained during the initial transition to the university, the 8 weeks between spring break and final exams is also a critical time period for weight gain. Moreover, the majority of % fat gain (1.1%) occurred during spring semester further supporting this concept. Given that overweight college students are three times as likely as normal weight students to exhibit at least one marker of metabolic syndrome (Huang et al., 2004), freshmen exhibiting weight gain with corresponding increases in % fat are at a greater risk for chronic disease persisting into adulthood. Stress and poor coping with stress have been linked with increases in BMI in female college students (Adams & Rini, 2007). Preparation for final exams and expectation of the transition home for the summer months may elicit stressful feelings, altering eating and activity patterns which may at least partially explain weight gain during this time.

Baseline BMI was a weak \( r=0.194, \ p=0.049 \) predictor of weight gain suggesting that heavier participants experienced greater gain. This was supportive of previous work finding that
initial BMI was associated with weight gain; overweight (BMI ≥25 kg/m²) participants gained twice as much weight as those with a BMI <25 kg/m² (Kasparek et al., 2008). However, other data (Cluskey & Grobe, 2009) has shown that weight gain was more common among under- or normal weight students compared to overweight students. In the present study, individuals who did not complete all assessments tended to weigh more and had higher BMI at baseline than those who completed the study. It is possible that continuing participants may have had greater concern for their health and weight or were more likely to participate in health-promoting behaviors. Students with greater weight gain may have felt uncomfortable returning for future assessments, although results were not shared until after the final study visit. This self-selection bias may have contributed to an underestimation of the predictive value of baseline BMI.

BMI is frequently used to evaluate health, however it may not adequately capture disease risk. WC is a powerful and independent predictor for chronic disease (National Heart, Lung, and Blood Institute, 2000). Although easily obtained, few studies have examined this disease marker in college freshmen. One study observed an increase of 1.0 cm (Gropper et al., 2009) and another found a gain of 2.5 cm (Edmonds et al., 2008) in females during freshman year. Contrary to prior data, there was no significant change in WC in the present study. However, there were significant positive associations between changes in WC and changes in % fat, weight, and BMI. Positive associations were also observed between changes in % fat and changes in BMI and weight. Taken together, the relationship among increases in WC, % fat, weight, and BMI indicate that weight gain was, indeed, due to increases in fat mass. This finding is particularly concerning given the risk associated with excess fat and that fat deposited in the abdominal region exerts more negative health effects than peripheral, subcutaneous fat (National Heart, Lung, and Blood Institute, 2000).
Limitations

There are several limitations to this study. First, this study used a convenience sample. This may have introduced self-selection bias among students with an interest in weight and health, thus reducing generalizability. Self-selection bias may also have permeated into retention efforts. Of the original sample, 46% did not complete all assessments and there were significant differences in major, weight, and BMI between participants and drop-outs (i.e., more non-health majors and individuals with higher weights and BMIs dropped out). Second, a small proportion of male compared to female participants may have prohibited detecting differences between sexes. Finally, our study only investigated on-campus freshmen residents. It has been suggested that students living on campus experience greater weight gain and exhibit poorer dietary habits (Freedman, 2010). Further, freshmen in the present study did not gain weight over the holidays, which they were presumably spending with their parents/families. Therefore, our findings cannot be generalized beyond freshmen residing on campus.

Conclusions

The first 10-12 weeks on campus elicited significant gains in both height and weight with no concomitant increase in % fat, indicating accretion of lean body mass. However, spring semester appears to be a critical period where students are susceptible to undesirable weight and % fat changes. These findings should serve as an impetus for future research efforts in developing and implementing targeted prevention programs aimed at college freshmen.

Acknowledgments

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References


high school to university in females. *Journal of the American Dietetic Association, 108*(6), 1033-1037.


Table 2.1: Baseline anthropometric indices of all participants

<table>
<thead>
<tr>
<th></th>
<th>Male (n=21)</th>
<th>Female (n=82)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>73.8±14.8</td>
<td>62.0±15.7</td>
<td><strong>0.002</strong></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.2±4.9</td>
<td>164.1±6.7</td>
<td><strong>&lt;0.001</strong></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.5±5.0</td>
<td>23.0±5.3</td>
<td>0.641</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>80.1±12.5</td>
<td>79.7±10.8</td>
<td>0.899</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>16.0±9.7</td>
<td>27.5±7.5</td>
<td><strong>&lt;0.001</strong></td>
</tr>
</tbody>
</table>

BMI = body mass index, WC = waist circumference
Comparisons based on independent samples *t*-tests
Data presented as mean±SD
Significant differences between males and females are bolded
A

B

Males  Females
Figure 2.1: A) Patterns of weight over time. Mean±SD weight increased between the start of the academic year to pre-holiday, as well as pre-holiday to pre-finals. B) Patterns of BMI over time. Mean±SD BMI increased between the start of academic year to pre-finals, the start of the academic year to pre-holiday, and pre-holiday to pre-finals. C) Patterns of body composition (% fat) over time. Mean±SD % fat increased between the start of the academic year to pre-finals, post-holiday to pre-finals, and pre-spring break to pre-finals. Comparisons are based on repeated measures ANOVA with Bonferroni adjustment. N=103 (21M, 82F). Start of academic year: August/September; pre-holiday: November; post-holiday: January; pre-spring break: February/March; pre-finals: April/May.
CHAPTER III
VALIDATION OF SELF-REPORTED ANTHROPOMETRICS IN FEMALE COLLEGE FRESHMEN

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Plan for submission: International Journal of Exercise Science
Abstract

Introduction: Most investigations concerning the validity of self-reported anthropometrics focus on weight, height, and body mass index. This study extends those investigations by exploring the impact of self-reporting bias on the disease risk indicators of waist circumference and body fat percentage. Methods: Female college freshmen (n=128) self-reported weight and height, then underwent measurements for weight, height, waist circumference, and body fat percentage. Self-reporting bias was defined as self-reported minus directly-assessed anthropometric value.

Results: Despite no differences in self-reported versus directly-assessed weight or height for the total group, students with high waist circumference and excess fat under-reported their weight by 2.3±4.4 lb (p<0.05). Self-reporting bias was negatively correlated with waist circumference (r=-0.362; p<0.001) and body fat percentage (r=-0.317; p<0.001). Conclusion: Although many female college freshmen accurately represent their weight, those with excess fat and waist circumference under-reported their weight. This may lead to missed opportunities for risk identification, prevention, and intervention.

Keywords: body mass index; obesity; waist circumference; women’s health; young adult
Introduction

Self-reported anthropometric data is convenient and inexpensive, but relying on this data requires an accurate estimation of weight and height. Data consistently demonstrate under-reporting of weight and over-reporting of height (Connor Gorber, Tremblay, Moher, & Gorber, 2007; Engstrom, Paterson, Doherty, Trabulsi, & Speer, 2003). Under-reporting of weight occurs particularly among women (Bonn, Trolle Lagerros, & Bälter, 2013; Connor Gorber et al., 2007; Danubio, Miranda, Vinciguerra, Vecchi, & Rufo, 2008; Gil & Mora, 2011; Merrill & Richardson, 2009) and overweight/obese individuals (Bonn et al., 2013; Connor Gorber et al., 2007; Engstrom et al., 2003; Gil & Mora, 2011; Merrill & Richardson, 2009; Nawaz, Chan, Abdulrahman, Larson, & Katz, 2001; Powell-Young, 2012). Conversely, height tends to be over-reported, regardless of sex (Connor Gorber et al., 2007).

Since young women transitioning to the university setting are particularly vulnerable for weight gain (Wane, van Uffelen, & Brown, 2010), they are a population of interest for health-related studies. Self-reported anthropometric data is often used in order to reach a larger sample or due to poor equipment mobility. However, this may lead to an underestimation of overweight/obesity prevalence and associated disease risk. Although body mass index (BMI; \( \text{kg/m}^2 \)) is a commonly used proxy for body fatness, individuals may be classified as healthy when they actually have unhealthy levels of body fat (Ludy, Leone, & Morgan, 2015; Ode, Pivarnik, Reeves, & Knous, 2007) – a misclassification which occurs especially in the normal and overweight BMI categories (Frankenfield, Rowe, Cooney, Smith, & Becker, 2001).

It is thus important to use more accurate indicators of disease risk whenever possible. Previous studies have primarily focused on BMI and demographics, such as race and age, as predictors of self-reporting error. To date no studies have extended this research to explore
associations with more accurate risk markers, such as WC and body fat percentage (% fat). In women, BMI and WC increase by 0.4% annually, with the greatest increases among those aged 18 to 39 years (Ladabaum, Mannalithara, Myer, & Singh, 2014). This is particularly concerning, given that costs of overweight/obesity are also higher in women (Dor, Ferguson, Langwith, & Tan, 2010). Identification of individuals, specifically women, at risk for overweight/obesity may help to offset these costs. This study contributes to the growing body of research by 1) determining the degree of accuracy between self-reported and directly-assessed anthropometrics in female college freshmen, as well as 2) examining the relationship between these biases and more accurate indicators of disease risk.

Materials & Methods

Participants & Procedure

As part of a larger study examining patterns and composition of weight change in college freshmen conducted in 2012-2014, participants were asked to complete a self-administered demographic questionnaire soliciting age, race/ethnicity, scholastic major, weight in pounds, and height in inches during the testing visit. In total, 147 first-year, female students at a large, Midwestern university were recruited via public advertisements, classroom announcements, and welcome week activities. Students were eligible to participate if they met the following criteria: on-campus residence, age ≥ 18 years, non-claustrophobic, non-pregnant, ≤ 250 kg (scale capacity), and no implanted medical device(s). Participants were aware they were to undergo anthropometric measurements during the testing visit. Since an elevated body temperature or breathing rate post-exercise, or presence of food and/or beverages in the gastrointestinal tract may influence the accuracy of results (e.g., overhydration would falsely reduce body fat
percentage) (Heiss et al., 2009), participants were instructed to refrain from exercise and eating/drinking anything other than water within two hours of their scheduled testing visit.

Following completion of the demographic questionnaire, participants changed into compression clothing and a Lycra swim cap provided by researchers; shoes, socks, jewelry, and/or hair accessories were removed prior to testing to minimize air trapping. Measurements included weight, height, WC, and % fat.

Height was measured with a wall-mounted, calibrated stadiometer. Participants stood with their backs touching, but not leaning against the device. Feet were placed in the outline on the base plate and researchers verified the participant’s head was positioned in the Frankfort plane. The head plate was lowered to touch the top of the participant’s head, without undue pressure, and measurement was recorded to the nearest 0.1 cm.

WC was measured using a retractable tape placed immediately superior to the iliac crest, approximately at the navel line (National Heart, Lung, and Blood Institute, 2000). Measurements were taken with the tape parallel, recording the measurement to the nearest 0.1 cm.

Body composition was assessed using air-displacement plethysmography (ADP) via BODPOD (Cosmed USA, Concord, CA), according to standard procedures (McCory, Molé, Gomez, Dewey, & Bernauer, 1998). Body fat was estimated to the nearest 0.1% using the Siri equation (Siri, 1961) for Caucasian and Hispanic participants and the Brozek equation (Brozek, Grande, Anderson, & Keys, 1963) for African Americans. Prior to entering the testing chamber, weight was obtained using the calibrated scale coupled with the BODPOD and recorded to the nearest 0.1 kg.

Data were collected during the first three weeks on campus and written informed consent was obtained from all participants at the beginning of their test visit. Participants received $5 in
campus spending money and another small item (i.e., reusable grocery bag or Frisbee). The university’s institutional review board approved this study.

**Statistical Analysis**

Directly-assessed weight, height, and WC were converted from metric to imperial units (1 kg = 2.2 lb; 1 cm = 0.39 in) and rounded to the nearest whole number. BMI was calculated as weight (lb) / height² (in) * 703. The differences between self-reported and directly-assessed weight, height, and BMI were compared via paired sample t-tests. Self-reporting biases of weight, height, and BMI were calculated as self-reported minus directly-assessed values for each variable. Pearson correlation coefficients were conducted to identify associations between self-reported and directly-assessed anthropometric values, as well as to identify relationships among self-reported weight bias with WC and % fat.

Participants were dichotomized into groups who under-reported their weight (i.e., self-reported – directly-assessed < 0) (under-reporter group) and those who reported accurately or over-reported (i.e., self-reported – directly-assessed ≥ 0) (accurate-/over-reporter group). Accurate- and over-reporters were grouped together due to the reduced propensity for health risk among the members in this group of relatively healthy females. Independent samples t-tests were used to compare weight, BMI, WC, and % fat among these groups.

Sensitivity was calculated as the ability of the self-reported anthropometric data to correctly classify participants as overweight/obese based on directly-assessed BMI. Specificity was calculated as the ability of the self-reported anthropometric data to correctly classify normal weight participants as normal weight based on directly-assessed BMI. Positive predictive value was calculated as the proportion of the amount of “true positives” (i.e., self-reported overweight/obese and directly-assessed overweight/obese) to all positives (i.e., true positives +
false positives). Negative predictive value was calculated as the number of “true negatives” (i.e., self-reported normal weight and directly-assessed normal weight) to all negatives (i.e., true negatives + false negatives). Cohen’s κ was calculated to identify level of agreement between self-reported and directly-assessed BMI.

The following cut-points were used: BMI $\geq 25$ kg/m$^2$ (National Institutes of Health (NIH)) standard cut-point for overweight (National Heart, Lung, and Blood Institute, 2000), WC $> 35$ in (NIH standard cut-point for disease risk based on WC (National Heart, Lung, and Blood Institute, 2000)), and body fat $\geq 33\%$ (based on a multiple regression model equating BMI $\geq 25$ kg/m$^2$ to body fat $\geq 33\%$ in 283 young adult women (Gallagher et al., 2000)). Analyses were performed using IBM SPSS Statistics Version 22.0 (IBM Corporation, Armonk, NY). A two-tailed alpha level of $p \leq 0.05$ was used to indicate significance. Alpha levels between 0.05 and 0.10 were considered trends worthy of further investigation.

**Results**

Nineteen participants did not provide complete data (i.e., left self-reported height and/or weight blank on demographic questionnaire) and were thus excluded from analyses, resulting in a total of 128 participants aged 18.1±0.4 years. There was no difference in directly-assessed weight, height, BMI, WC, or % fat ($p > 0.05$ for all) between excluded individuals and participants. The majority of participants were Caucasian (n=108; 84.4%), with the remainder Black/African American (n=15; 11.7%) and Hispanic (n=5; 3.9%). The sample mirrors the racial/ethnic background of the campus (85.6% Caucasian/other, 10.7% Black/African American, and 3.7% Hispanic) (Bowling Green State University, 2012). In terms of major, 45.3% of participants were health majors (n=58) while 54.7% (n=70) were non-health majors. According to directly-assessed BMI, 4.7% (n=6) were underweight, 68.8% (n=88) were normal
weight, 18.0% (n=23) were overweight, 5.5% (n=7) were obese class I, 1.6% (n=2) were obese class II, and 1.6% (n=2) were obese class III. Using the BMI cut point of 25 kg/m² to indicate disease risk, 26.6% (n=34) were classified as overweight/obese. Elevated WC was identified in 18.8% (n=24) of participants while 25.0% (n=32) had excess % fat (determined by ADP).

There was no overall difference between self-reported and directly-assessed anthropometric data for any variable (Table 3.1) when all participants were considered. Using a cut-off of 5 lb to classify accurate reporting (Brunner Huber, 2007), weight was accurately reported in 84.4% (n=108) of participants. Weight was under-reported in 10.2% (n=13) of participants and over-reported by in 5.5% (n=7) of participants. When classified by BMI, weight was under-reported (-2.0±4.4 lb; p=0.014) in participants with BMI ≥25 kg/m² leading to subsequent underestimation of self-reported BMI (-0.6±1.4 kg/m²; p=0.022). When classified by WC, participants who had high WC also under-reported their weight (-2.3±4.4 lb; p=0.018), however differences in BMI did not achieve statistical significance. When classified by % fat, those with excess fat (>33%) under-reported their weight (-2.3±4.4 lb; p=0.007), resulting in a trend towards an underestimation of self-reported BMI (-0.5±1.5 kg/m²; p=0.056). There was no difference between self-reported and directly-assessed anthropometrics in participants with healthy BMI, WC, or % fat. Differences in self-reported and directly-assessed height did not achieve significance in any group, nor was there a difference between any self-reported and directly-assessed anthropometric value in health and non-health majors.

There were strong, positive correlations between self-reported and directly-assessed weight, height, and BMI for all participants, as well as when under-reporters and accurate-/over-reporters were analyzed separately (r≥0.859, p<0.001 for all). Moderate negative correlations were observed between self-reported weight bias and WC (r=-0.362; p<0.001) and % fat (r=-
0.317; p<0.001) as depicted in Figure 3.1. Self-reported and directly-assessed weight, height, BMI, and self-reporting bias of all participants are presented in Table 3.1.

Compared to those who accurately- or over-reported their weight, individuals who under-reported their weight weighed more (+22.5 lb) and had a greater BMI (+3.5 kg/m²), WC (+3.2 in), and % fat (+4.0 %) (Table 3.1; p<0.05 for all). Height did not vary significantly between groups. Sensitivity, representing the proportion of self-reported overweight/obese (via BMI) students who were indeed overweight/obese, was 94.1%. Specificity, representing the proportion of self-reported normal/underweight (via BMI) students who were correctly identified as normal/underweight using directly-assessed values, was 97.9%. Positive predictive value, the probability that self-reported overweight/obesity (via BMI) truly indicates overweight/obesity, was 94.1%. Negative predictive value, the probability that self-reported normal/underweight truly indicates normal/underweight (via BMI) was 97.9%. There was almost perfect agreement between self-reported and directly-assessed weight indicated by κ=0.92.

**Discussion**

This study sought to determine the degree of accuracy between self-reported and directly-assessed anthropometrics in female college freshmen as well as examine the relationship between self-reporting biases and other indicators of disease risk (i.e., WC and % fat). The results of the present study demonstrate very strong positive correlations between self-reported and directly-assessed weight, height, and BMI. Overall, there was a high level of agreement between self-reported and directly-assessed weight (-0.1 lb), height (+0.2 in), and BMI (-0.1 kg/m²). This was unexpected as women typically under-report their weight (Bonn et al., 2013; Danubio et al., 2008; Gil & Mora, 2011; Jacobson & DeBock, 2001; Merrill & Richardson, 2009) anywhere from -0.4 lb to -7.7 lb (Engstrom et al., 2003). In female college students
specifically, other studies found height to be over-reported by +0.5 in (Larsen, Ouwens, Engels, Eisinga, & van Strien, 2008) and +1.1 in (Danubio et al., 2008) and weight to be under-reported by -4.2 lb (Danubio et al., 2008) and -7.5 lb (Larsen et al., 2008). However, both of these studies measured participants’ weight wearing light clothing and without indication of instruction on how to report their weight (i.e., light clothing, with or without shoes, etc.), perhaps contributing to reporting error. Nevertheless, the high overall level of agreement between self-reported and directly-assessed anthropometrics in the present study is a novel finding.

The high sensitivity (94.1%) suggests the use of self-reported anthropometrics indeed captures actual cases of overweight/obesity. This finding corroborates with previous studies in both adults (Bes-Rastrollo, Sabaté, Jaceldo-Siegl, & Fraser, 2011; Brunner Huber, 2007) and older adolescents (Brener, McManus, Galuska, Lowry, & Wechsler, 2003). However, some prior studies demonstrated sensitivities of 48% (Larsen et al., 2008) to 52% (Elgar, Roberts, Tudor-Smith, & Moore, 2005). In both of these studies, participants were unaware they were to be weighed, while in the present study, participants were aware their weight would be measured. This may have contributed to reporting accuracy as it has been suggested that the expectation of being weighed results in more precise self-reported weight (Cash, Counts, Hangen, & Huffine, 1989); however, Nawaz et al. (2001) found that although overweight/obese, middle-aged adult female participants were told they would be weighed, weight was still under-reported. It is unlikely that the age of our sample impacted reporting behavior as previous work has established that women under-report their weight across the lifespan (Merrill & Richardson, 2009).

This study was unique in that it examined other indicators of overweight/obesity and disease risk in addition to BMI. Previous studies have determined that increases in weight and/or BMI coincide with increases in the degree of under-reporting (Bes-Rastrollo et al., 2011; Bonn et
al., 2013; Connor Gorber et al., 2007; Engstrom et al., 2003; Larsen et al., 2008; Merrill & Richardson, 2009; Nawaz et al., 2001). Similar tendencies were observed in the present study; weight was under-reported to a greater extent when WC and % fat were higher. Moreover, individuals who under-reported their weight had significantly higher weight, BMI, WC, and % fat than those who accurately- or over-reported their weight. When dichotomized by WC and % fat, individuals with abdominal obesity significantly under-reported their weight, as did individuals with excess fat. It is unclear whether under-reporting one’s weight is intentional, resulting from social desirability or unintentional due to lack of knowledge regarding one’s current weight status. Moreover, weight gain is not uncommon during transition to the university (Wane et al., 2010). Previous data indicate that female freshmen gain 2.9 lb during their first 10 to 12 weeks on campus (Leone, Morgan, & Ludy, In Press). Therefore, it is possible to have gained weight during the first three weeks (i.e., during the measurement period) resulting in an unintentionally under-reported weight.

Several limitations must be noted. This study used a convenience sample as it was part of a larger project. It was advertised as a health-related study and thus more health-conscious individuals may have participated, partially explaining the accuracy of self-reported weights. However, there were no significant differences between health and non-health majors. Incomplete data from 19 participants and failure to acknowledge when and where (e.g., home, physician, gym) participants last weighed themselves were other limitations. Participants were also not instructed on how to report their weight (e.g., light clothing, without shoes). Finally, the generalizability of the findings may be limited to female university students and future research in other, less educated populations is warranted.
Implications for Practice and/or Policy

These findings suggest that individuals at greater disease risk are more likely to under-report their weight – a finding that complements previous studies using BMI only. Older adolescents do not perceive themselves to be at risk (Morrell, Lofgren, Burke, & Reilly, 2012) and it is common for overweight/obese individuals to underestimate their weight as a health risk (Vandelanotte, Duncan, Hanley, & Mummery, 2011). Thus, susceptible female freshmen may not engage in health-promoting behaviors. Misclassification of overweight/obese individuals as maintaining a healthy weight may further decrease the likelihood of participating in weight control practices (Larsen et al., 2008). As young adults entering college begin to establish lifelong behaviors, practitioners in this setting are in a unique position to intervene and mitigate disease risk. Early identification may lead to lifestyle modifications and reduced risk of chronic disease (Morrell et al., 2012). However, reliance on inaccurate reports of anthropometric data may prevent identification of at-risk individuals. The current findings, as well as previous work (Engstrom et al., 2003; Larsen et al., 2008), support the recommendation that, aside from surveillance data, direct assessment should be used whenever possible.

Conclusions

Given the high sensitivity, correlation, Cohen’s κ, and overall reporting accuracy, our results suggest that self-reported anthropometrics are an acceptable substitution for objective data in female college freshmen when measurement is not feasible and group data or population averages are desired. However, due to reporting bias in overweight/obese individuals, reliance on BMI calculations based on erroneous weight and height values may result in misclassification of disease risk among individuals with greatest need.
Acknowledgments

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References


Dor, A., Ferguson, C., Langwith, C., & Tan, E. (2010). *A heavy burden: The individual costs of being overweight and obese in the United States*. George Washington University, School of Public Health and Health Services, Department of Health Policy.


Table 3.1: Anthropometric data for all participants, under-reporters, and accurate- or over-reporters

<table>
<thead>
<tr>
<th></th>
<th>SR Mean (SD)</th>
<th>DA Mean (SD)</th>
<th>SR Bias&lt;sup&gt;a,b&lt;/sup&gt; Mean (SD)</th>
<th>p&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Participants (n=128)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>140.6 (33.0)</td>
<td>140.7 (34.6)</td>
<td>-0.1 (4.4)</td>
<td>0.824</td>
</tr>
<tr>
<td>Height (in)</td>
<td>64.7 (2.8)</td>
<td>64.6 (2.5)</td>
<td>0.2 (1.3)</td>
<td>0.137</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>23.6 (5.0)</td>
<td>23.7 (5.4)</td>
<td>-0.1 (1.2)</td>
<td>0.217</td>
</tr>
<tr>
<td>WC (in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Under-Reporters (self-reported weight bias &lt; 0; n=35)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>151.8 (51.3)</td>
<td>157.0 (52.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-5.3 (4.2)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Height (in)</td>
<td>64.8 (3.1)</td>
<td>64.7 (2.9)</td>
<td>0.1 (1.0)</td>
<td>0.609</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>25.3 (7.6)</td>
<td>26.3 (8.3)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-1.0 (1.5)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>WC (in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Accurate- or Over-Reporters (self-reported weight bias ≥ 0; n=93)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>136.4 (21.7)</td>
<td>134.5 (22.0)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.9 (2.4)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Height (in)</td>
<td>64.7 (2.7)</td>
<td>64.5 (2.4)</td>
<td>0.2 (1.4)</td>
<td>0.164</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>22.9 (3.4)</td>
<td>22.7 (3.4)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.2 (0.9)</td>
<td><strong>0.038</strong></td>
</tr>
<tr>
<td>WC (in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
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</table>

SR = self-reported, DA = directly-assessed, BMI = body mass index, WC = waist circumference.

<sup>a</sup> SR Bias = SR-DA.
<sup>b</sup> Negative values indicate under-reporting.
<sup>c</sup> Significant differences (p<0.05) between SR and DA are bolded. Comparisons between SR and DA are based on paired samples t-tests.
<sup>d</sup> Significant differences (p<0.05) between under-reporters and accurate- or over-reporters. Comparisons between under-reporters and accurate- or over-reporters are based on independent samples t-tests.
Figure 3.1
Scatterplots depicting the relationship between self-reported weight bias (self-reported – directly-assessed weight) and (A) waist circumference and (B) body fat percentage. Analyses were performed using Pearson correlation coefficients (p<0.001; n=128 for both).
CHAPTER IV
LACK OF ASSOCIATIONS BETWEEN TASTE INTENSITY AND ADIPOSITY MEASURES IN AN ADOLESCENT POPULATION

Robin M. Tucker; Mary-Jon Ludy; Ryan J. Leone

Under Review: Chemosensory Perception
Abstract

Introduction: Whether there are true differences in the taste perception of lean and overweight/obese individuals is unresolved. Body mass index (BMI) is frequently used to classify participants’ adiposity, but BMI is not a measure of body fatness. We hypothesized that salty and sweet taste intensity ratings would be more strongly correlated with other measures of adiposity than BMI. Methods: First-year students were recruited from a large, Midwestern university. Measurements of waist circumference (WC), waist-to-height ratio (WTHR), and percent body fat measured by bioelectrical impedance analysis (BIA) and air-displacement plethysmography (ADP) were measured twice over a 5 month period. Participants rated the intensity of suprathreshold concentrations of sweet and salty solutions via visual analog scale at both baseline and follow-up. Results: Seventy percent of participants (N = 21) gained weight. No measures of adiposity were associated with taste intensity ratings at baseline. At follow-up, BMI, weight, WC, and WTHR, were all positively associated with intensity ratings of the low concentration salty solution (r = 0.47-0.5; P < 0.008). No associations were seen between intensity and either BIA or ADP. WTHR performed better than BMI at correctly identifying overweight/obese participants when compared to ADP. Taste ratings at baseline did not predict risk of weight gain over time. Conclusions: Taste deficits do not appear to precede weight gain in this young, predominantly lean sample. Implications: WTHR should be used to categorize adiposity status in the absence of specialized equipment.

Keywords: Taste sensitivity, Taste perception, BMI, Obesity, Body fat
Introduction

“Taste,” or more correctly “flavor,” is typically cited as the primary reason a food is selected for consumption (Dressler and Smith, 2013), and preferences are developed with repeated tasting (Sullivan and Birch, 1990). Energy consumed is a direct outcome of food selection, and when caloric intake through eating is greater than caloric expenditure through activity, weight gain occurs. Therefore, taste and weight are intertwined. As the prevalence of overweight and obesity has grown to more than 1 in 3 adults worldwide (Ng et al., 2014), determining whether taste perception differs between lean and overweight/obese individuals is of increasing interest.

Whether there are true differences in taste perception between lean and overweight/obese individuals is unresolved, as results from classical psychophysical experiments exploring these disparities vary. Some studies detect significant differences in taste sensitivity between lean and overweight/obese individuals (Simchen et al., 2006; Pasquet et al., 2007; Pepino et al., 2010; Stewart et al., 2011; Sartor et al., 2011; Overberg et al., 2012) while others report no differences (Grinker et al., 1972; Rodin, 1975; Malcolm et al., 1980; Frijters and Rasmussen-Conrad, 1982; Scruggs et al., 1994; Pepino et al., 2010). Although intriguing, taste sensitivity often fails to correlate with liking and preference, as taste qualities in foods and beverages exist at suprathreshold concentrations (Bartoshuk, 1979). Similar to taste sensitivity, differences in liking, preferences, and intensities of suprathreshold taste stimuli between lean and overweight/obese individuals are demonstrated in some studies (Rodin et al., 1976; Johnson et al., 1979; Pepino et al., 2010), but not in others (Malcolm et al., 1980; Rodin, 1980; Frijters and Rasmussen-Conrad, 1982; Cox et al., 1999; Mela, 2006; Pepino et al., 2010; Bueter et al., 2011).

Misclassification of adiposity status (lean vs. overweight/obese) may contribute to the
variable findings if participants are mistakenly considered overweight/obese when actually lean or vice versa. Body mass index (BMI) is frequently used to classify participants as overweight/obese in taste testing studies (Stewart et al., 2011); however, BMI is not a measure of adiposity or body fatness. Rather, BMI is an indicator of cardiometabolic risk, and its use as a proxy for adiposity can be problematic. This is especially true in extremely muscular individuals who have a high BMI but are actually lean or in individuals who have a normal BMI but are overweight/obese based on body fat percentage – the so-called “skinny fat” or normal weight obese (Romero-Corral et al., 2010). While BMI is frequently used because it is easy to calculate and requires no specialized equipment, more accurate methods exist to determine adiposity, including: waist circumference (WC), waist-to-height ratio (WTHR), and percent body fat.

Taste testing of lean and overweight/obese participants is commonplace, but prospective psychophysical studies examining changes in taste and weight are few (Burge et al., 1995; Umabiki et al., 2010; Fischer et al., 2014), and all but one (Fischer et al., 2014) have focused on taste changes following weight loss. Evidence of improved taste acuity exists in both overweight individuals after losing just 3.5 kg in 12 weeks (Umabiki et al., 2010) and in obese individuals experiencing substantial weight loss following gastric bypass surgery (Burge et al., 1995). These findings give rise to the question: does weight gain impair taste sensitivity or perception? While others have recently observed that higher baseline taste intensity ratings for salty but not sweet were predictive of weight gain after 5 years, taste intensity was not measured at follow-up, leaving questions about whether taste perceptions changed over time (Fischer et al., 2014).

The primary purpose of this pilot study was to examine the association between taste intensity ratings and adiposity indicators. We hypothesized that salty and sweet taste intensity ratings would be more strongly correlated with other measures of adiposity than BMI. Other
adiposity measures included: WC, WTHR, and percent body fat as measured by bioelectrical impedance analysis (BIA) and air-displacement plethysmography (ADP). We hypothesized that ADP would be most closely associated with taste intensity ratings as percent body fat measurements obtained with ADP closely match those obtained with hydrostatic weighing, the gold standard (Lukaski et al., 1985). A secondary analysis evaluated whether taste intensity perception of sweet and salty changed as weight changed over time. We hypothesized that participants who gained weight or increased in body fatness over time would rate the solutions as less intense at baseline and at follow-up compared to those who maintained or lost weight.

**Methods**

**Participants**

First-year university students are at increased risk of gaining weight (Holm-Denoma et al., 2008; Vella-Zarb and Elgar, 2010) making them an ideal population to assess associations between taste and weight changes over time. As part of a larger investigation (Leone et al., in press), newly enrolled first-year students living on the campus of a large university in Ohio were invited to participate via flyers, social media, e-mail, and new-student orientation activities. Participants were informed that anthropometric measurements would be taken, but study advertising emphasized an interest in characterizing health patterns to avoid self-selection bias of students only concerned about weight. For inclusion in the study, participants had to: be ≥18 years old; live on-campus; be non-claustrophobic (contraindicated for ADP testing); not be pregnant or planning pregnancy; weigh ≤250 kg (scale capacity); and have no implanted medical device(s) (contraindicated for BIA testing). Upon providing written informed consent, participants came to the laboratory twice for testing and were instructed not to exercise or eat or drink anything except water for at least two hours prior to each visit to minimize errors in body
composition testing (Heiss et al., 2009). Baseline testing occurred in August/September (beginning of the academic year) and mid-January (after winter break). Each visit consisted of body composition testing and taste intensity ratings. The university’s institutional review board approved the study, and all participants received a small item (e.g., Frisbee, t-shirt) for their participation after each visit.

**Body Composition**

Anthropometric indices were assessed by measuring height to the nearest 0.1-cm using a stadiometer and weight using a calibrated electronic scale, which was coupled with ADP, measuring to the nearest 0.1-kg. BMI was calculated from these measurements (weight in kilograms divided by the square of height in meters). WC was recorded to the nearest 0.1-cm using a measuring tape placed just above the iliac crest. WTHR was calculated by dividing WC by height. Percent body fat was assessed in two ways: 1) by BIA (InBody 230; Biospace, Seoul, Korea) and 2) by ADP (BOD POD; COSMED, Concord, CA). Participants wore compression shorts/tops and swim caps to provide consistency in terms of apparel worn while weighing between visits and to ensure accurate ADP measurements by minimizing any air trapped in hair or loose fitting clothing. The following values were used to determine overweight/obesity status: BMI ≥25 kg/m² (National Heart, Lung, and Blood Institute, 2000); WC >102 cm in men and >88 cm in women (Janssen et al., 2002); WTHR > 0.5 (Ashwell and Hsieh, 2005); BIA and ADP percent body fat > 25% in men and > 30% (Shah and Braverman, 2012).

**Taste Testing**

Six taste solutions were presented to the participants in random order. Sweet solutions consisted of sucrose dissolved in deionized water. The concentrations presented included: 0.1 M (low), 0.5 M (medium), and 1.0 M (high) and were selected to represent suprathreshold
concentrations. Salty solutions consisted of sodium chloride dissolved in deionized water. The concentrations presented were identical to the sweet solutions. Participants wore nose clips, swished 5 mL of solution in their mouths, expectorated, and proceeded to rate the intensity of the solution using a 100 mm visual analog scale (VAS) with anchors of “extremely weak” and “extremely strong.” Participants rinsed with deionized water and expectorated between presentations.

Statistics

The data are presented using means and standard deviations (SD). The level of significance was set at P < 0.05. Data were analyzed using IBM SPSS Statistics 22 (Chicago, IL). Paired t-tests examined differences between baseline and follow-up values for the entire group. Independent samples t-tests were used to identify differences between participants who increased in adiposity measures (gainers) versus those who did not (maintainers/losers). Repeated measures analysis of variance evaluated differences between low, medium, and high concentrations. A Bonferroni adjustment was used for multiple comparisons. Pearson’s correlation coefficients evaluated correlations between body composition measures. Logistic regression was used to determine risk of weight gain based on initial taste sensitivity. Since some participants changed BMI categories between baseline and follow-up or gained in terms of WC but perhaps not in terms of percent body fat, the sample sizes used for each analysis are shown in Table 4.1.

Results

Adiposity Measures

Thirty participants (7 male; 23 female; 90% Caucasian; age 18.1±0.1 years) completed both baseline and follow-up testing. Five subjects were considered overweight/obese according
to BMI (≥25 kg/m²) at baseline; this number increased to 7 at the follow-up visit (Table 4.2). All measures of body composition were significantly and positively correlated at baseline (r = 0.38 – 0.91; P < 0.03) and follow-up (r = 0.37 – 0.94; P < 0.04), with the exception of weight and percent body fat as determined by BIA at both baseline (r = 0.31, P = 0.08) and follow-up (r = 0.23; P = 0.21). Weight gained between baseline and follow-up was significantly correlated with all adiposity measures (r = 0.49 – 0.59; P ≤ 0.006) except BIA and ADP (r = 0.16 – 0.18; P > 0.32 for both). All measures of adiposity were significantly elevated upon follow-up testing (P < 0.018) (see Table 4.3), with 70% of participants (21 out of 30) gaining weight (gainers). Mean weight gain among gainers was 2.5 ± 2.0 kg (range: 0.4 – 7.5 kg). Five participants gained 3.4 kg or more (excessive gainers). Mean weight gain among all participants was 1.6 ± 2.2 kg (range: -1.7 to +7.5 kg). In only two cases did a participant improve in terms of adiposity risk factors between baseline and follow-up. One participant reduced risk based on WC, and another reduced risk based on BMI.

**Taste Measures**

For both the sweet and salty solutions, taste intensity ratings for the low concentrations were significantly lower than either the medium or high concentrations (P < 0.001 for both). Intensity ratings did not differ between medium and high concentrations (P > 0.05 for both). Taste intensity ratings did not significantly differ between baseline and follow-up for any taste quality (Table 4.4).

**Taste as a Function of Adiposity**

For the entire group, no measures of adiposity were associated with baseline taste intensity ratings (P > 0.05). At follow-up, a significant positive association was observed
between low salty solution ratings and follow-up values for BMI, weight, WC, and WTHR (r = 0.47-0.5; P < 0.008).

No differences in taste intensity ratings at baseline or follow-up were identified when comparing: 1) BMI categories of lean vs. overweight/obese; 2) weight gainers vs. weight maintainers/losers; 3) those who increased vs. those who were stable/decreased WC; 4) those who increased vs. those who maintained/lost WTHR; and 5) those who gained vs. those who maintained/lost body fat according to ADP (P > 0.05 for all). Excessive weight gainers (≥ 3.4 kg) did not rate the intensity of any solution differently than those who gained moderately or who maintained/lost (P > 0.05). Among those whose percent body fat increased according to BIA, ratings of the medium sweet solution were lower (53.5 ± 22.8) compared to those who were stable/decreased (74.2 ± 12.1; P = 0.009) at follow-up.

Regression analysis failed to demonstrate that any of the baseline taste intensity scores could be used to predict the odds of weight gain.

**Discussion**

Our primary purpose was to explore the relationships between taste sensitivity and indicators of adiposity that are more accurate than BMI. For the entire group, significant positive correlations between taste intensity ratings for the low salty solution and measures of BMI, weight, WC, and WTHR were observed, but not between taste sensitivity and weight gained, or percent body fat as measured by BIA or ADP. Positive correlations agree with the findings of some, but not others. Massively obese adolescents rated the intensity of both sweet and salty solutions significantly higher than non-obese adolescents at concentrations comparable to the low salty stimulus we used, but that hedonic responses for the salty solution were lower (Pasquet et al., 2007). The authors posit that the increased intensity perception but decreased hedonic
responses to the low salty solution may serve as a means of discouraging additional sodium consumption. The similarity in ages between our participants and the morbidly obese participants may help to explain the positive nature of the correlations we observed. Others have found no difference in taste intensity ratings of lean and overweight individuals, but these did not include measurements of salty taste qualities (Rodin et al., 1976; Pepino et al., 2010), making direct comparisons impossible. In contrast with these findings, overweight/obese participants reported sweet and salty qualities as less intense than their lean counterparts (Sartor et al., 2011) in another study. Age differences may contribute to these discrepancies (see discussion below), but it does not appear to fully explain them. The average age of participants in our study was 18 while the average age of participants in the study reporting results opposite to ours was 23 (Sartor et al., 2011).

In contrast to our salty findings, sweet ratings were not associated with adiposity measures. However, sweet ratings of the medium sweet solution were lower in gainers compared to those who maintained/lost, but only at follow-up. Plausible mechanisms by which weight change might impact taste involves differences in glucagon-like peptide-1 (GLP-1) and leptin concentrations between lean and obese individuals. GLP-1 is a satiety hormone that is also released by taste receptor cells and is positively correlated with sweet taste sensitivity (Shin et al., 2008) and food reward (Dossat et al., 2011). Postprandial GLP-1 release, measured by area under the curve, is lower in the obese (Verdich et al., 2001). Postprandial GLP-1 concentrations typically increase after bariatric surgery before major weight is lost – in as little as 2 weeks (Jacobsen et al., 2012). Due to GLP-1’s role in taste sensitivity and food reward, this change in GLP-1 has been posited to contribute to the weight loss typically seen after surgery (Miras and le Roux, 2010). Leptin, a hormone associated with appetite suppression, is elevated in obese
individuals and thought to serve as a signal to reduce consumption (Considine et al., 1996). Leptin administration in rats resulted in decreased taste nerve response (Kawai et al., 2000) and behavioral responses to sucrose and saccharin (Shigemura et al., 2004). Elevated leptin in the obese population could contribute to diminished perception and reward. Even with these possible mechanisms, it seems likely that the change in intensity perception between baseline and follow-up may be unreliable as no other adiposity measures demonstrated differences between testing visits, BIA and ADP values were very closely correlated at both baseline ($r = 0.89; P < 0.001$) and follow-up ($r = 0.93; P < 0.001$), and the relationship did not hold among excessive gainers.

BMI is frequently used to categorize taste testing participants as normal, overweight, or obese. As discussed previously, BMI is quick and easy to determine, but its use can be problematic as values can be skewed in certain populations, and more accurate methods exist to estimate body fatness. A recent meta-analysis supports the superiority of WTHR to other methods that do not require specialized equipment (Ashwell et al., 2012), while ADP is commonly considered to be as good as, if not superior, to BIA (Macias et al., 2007; Benton and Swan, 2007; Hillier et al., 2014). Compared to ADP, BMI failed to identify 50% of those considered to be overweight/obese at baseline and 36% at follow-up. In contrast, WTHR failed to identify 50% of those considered to be overweight/obese at baseline and 9% at follow-up. Due to the ease of measurement and calculation, there is a strong argument to be made for the use of WTHR to categorize the adiposity status of participants in taste studies.

In addition to adiposity misclassification, other factors may explain the variability in findings between lean and overweight/obese individuals in previous studies. These inconsistencies may be related to differences testing methods, genetics, age, and body composition. First, variations in testing protocols include: the taste qualities studied (Pepino et
al., 2010), detection vs. recognition thresholds compared to suprathreshold tasting (Scruggs et al., 1994; Simchen et al., 2006; Pepino et al., 2010), solutions vs. taste strips (Overberg et al., 2012), and one-time vs. repeated testing sessions (Tucker et al., 2014). Second, genetic variability likely contributes to differences in sensitivity and perception. For example, sensitivity to fat taste is associated with CD36 genotype (Pepino et al., 2012; Keller et al., 2012), a receptor that responds to long-chain fatty acids (Martin et al., 2012). Third, the age of participants may also contribute to variations in findings as participants with a BMI ≥ 28 kg/m² were less sensitive to sweet, sour, bitter, and salty than participants with a BMI < 28 kg/m², but this held only in those younger than 65 and was reversed in those older than 65 (Simchen et al., 2006). Finally, health risks increase the longer a person is overweight/obese (Janssen et al., 2004); however, the duration of overweight/obesity is frequently unreported. Thus, newly obese individuals might have dissimilar responses to those who have been obese for a longer time if the gustatory system is damaged by obesity.

Our secondary purpose was to determine whether taste intensity perception of sweet and salty changed as weight changed over time. The amount of weight gained and increase in percent body fat in our sample is in line with the work of others measuring weight gain among first-year students (Vella-Zarb and Elgar, 2009; Fedewa et al., 2014). All adiposity measures were significantly and positively correlated. This was expected because – while not measures of body fatness – BMI, WC, and WTHR are indicators for weight-related health risks. Interestingly, weight gain in this sample was associated with BMI, WC, and WTHR but not with BIA or ADP, the only actual measures of body fatness undertaken in this study. These findings suggest that the weight gained is predominantly lean mass, which agrees with previous work (Hoffman et al.,
Thus, the lack of concomitant increases in fat mass may have tempered negative effects of weight gain on taste sensitivity changes.

The longitudinal aspect of this study begins to shed light on two questions: 1) does suprathreshold taste perception differ in those who are predisposed to weight gain prior to the gain, and 2) does weight gain change taste sensitivity? In regards to the first question, the answer, in our young, predominantly lean population, appears to be that taste deficits do not precede weight gain. Baseline taste perception did not differ between gainers and maintainers/losers. When considering whether weight gain alters taste sensitivity, the fact that virtually no taste changes were observed regardless of adiposity measure, even in the excessive gainers, suggests that acute, low-level weight gain that is primarily lean mass does not impact taste sensitivity over a 5 month period. Whether these findings will hold with higher weight gains over a longer period of time has yet to be elucidated.

This study has a number of strengths and limitations. The narrow age range and variety of adiposity measures reduces possible confounders, while the pre-post test design allows for repeated measurement to detect changes in taste perception. Future work should explore the following questions. First, are the findings replicable with larger sample sizes? Second, do these relationships hold in other age groups and races/ethnicities? Third, what is the effect of larger weight gains over longer periods of time using more complicated stimuli, e.g., Fischer et al. 2014, or Salbe et al. 2004? Fourth, do these findings translate into non-model systems, that is, real foods and beverages e.g., Drewnowski et al. 1985?

In summary, it appears that adiposity – regardless of the method used to determine status – was not strongly related to taste intensity perception before or after gaining weight in lean college students. Moreover, taste intensity ratings did not predict one’s risk of gaining weight
over time. In the absence of BIA or ADP, WTHR should be calculated to classify taste test participants as lean, overweight, or obese.
References


Table 4.1: Changes in the number of subjects who maintained/lost or gained between baseline and follow-up by adiposity measure

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Maintained/Lost (N)</th>
<th>Gained (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Waist to Height Ratio</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>% fat by BIA</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>% fat by ADP</td>
<td>4</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 4.2: Number of participants classified as overweight/obese or at high-risk for poor health by adiposity classification between baseline and follow-up

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline (N)</th>
<th>Follow-Up (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Waist to Height Ratio</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>% fat by BIA</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>% fat by ADP</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

At risk cut-points: BMI (≥ 25 kg/m²); WC > 102 cm in men and > 88 cm in women; WTHR > 0.5; BIA and ADP percent body fat > 25% in men and > 30% in women.

Table 4.3: Mean values for each measurement of body composition ± SD.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline</th>
<th>Follow-Up</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m²)</td>
<td>23.5 ± 4.4</td>
<td>24.0 ± 4.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.5 ± 14.7</td>
<td>66.0 ± 15.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>78.6 ± 10.4</td>
<td>80.7 ± 12.6</td>
<td>0.018</td>
</tr>
<tr>
<td>Waist to Height Ratio</td>
<td>0.48 ± 0.1</td>
<td>0.49 ± 0.1</td>
<td>0.020</td>
</tr>
<tr>
<td>% fat by BIA</td>
<td>24.5 ± 11.3</td>
<td>27.6 ± 10.2</td>
<td>0.011</td>
</tr>
<tr>
<td>% fat by ADP</td>
<td>25.3 ± 11.0</td>
<td>27.0 ± 10.7</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 4.4: Mean values for each taste solution ± SD

<table>
<thead>
<tr>
<th>Taste Quality</th>
<th>Baseline</th>
<th>Follow-Up</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Sweet</td>
<td>17.9 ± 15.1</td>
<td>14.1 ± 10.5</td>
<td>0.280</td>
</tr>
<tr>
<td>Medium Sweet</td>
<td>47.1 ± 23.8</td>
<td>58.5 ± 22.5</td>
<td>0.069</td>
</tr>
<tr>
<td>High Sweet</td>
<td>58.3 ± 24.1</td>
<td>62.3 ± 27.8</td>
<td>0.346</td>
</tr>
<tr>
<td>Low Salty</td>
<td>28.9 ± 19.9</td>
<td>20.6 ± 16.5</td>
<td>0.080</td>
</tr>
<tr>
<td>Medium Salty</td>
<td>65.7 ± 24.0</td>
<td>73.1 ± 15.8</td>
<td>0.153</td>
</tr>
<tr>
<td>High Salty</td>
<td>74.3 ± 21.4</td>
<td>81.0 ± 16.2</td>
<td>0.060</td>
</tr>
</tbody>
</table>

Concentrations: 0.1 M (low); 0.5 M (medium); 1.0M (high). VAS anchors: extremely weak (0) and extremely strong (100).
CHAPTER V
PREDICTING HEALTH RISK OF FEMALE COLLEGE FRESHMEN: ANTHROPOMETRIC INDICES VERSUS BODY COMPOSITION MEASUREMENT

Mary-Jon Ludy, PhD; Amy L. Morgan, PhD; **Ryan J. Leone, BS**

Plan for submission: *International Journal of Exercise Science*
Abstract

Objective: The predictive ability of simple anthropometric indices for assessing health risk was compared to body composition measurement. Participants: Seventy-nine female college freshmen were recruited in August 2012. Methods: Anthropometric assessments included body mass index (BMI; calculated from height and weight) and waist circumference (WC). Body composition was assessed using bioelectrical impedance analysis (BIA). Results: BMI categorized 19% of participants as overweight or obese, while WC indicated health risk in 17%. BIA categorized 22% as overfat. Although health risk defined by anthropometric indices showed high specificity (93% for both BMI and WC), sensitivity was poor (67% for BMI and 50% for WC). Conclusions: Female college students with high-risk adiposity may be misclassified as “healthy” when screening tests are based on anthropometric indices rather than direct body composition measurement. Individuals who would benefit from additional health education may be overlooked.
Introduction

Body mass index (BMI) and waist circumference (WC) are simple anthropometric markers used to provide an indicator of body fatness and assess health risk. According to the Centers for Disease Control, “BMI provides a reliable indicator of body fatness for most people and is used to screen for weight categories that may lead to health problems”\(^1\) while excessive abdominal fat (assessed by WC) indicates greater risk for developing obesity-related diseases (e.g., cardiovascular (CV) disease and diabetes).\(^2\)

Although BMI, a value calculated from height and weight, is a widely accepted marker of obesity, it is problematic because it does not provide a direct measurement of body composition (i.e., body fat percentage). Despite correlations between BMI and body fat percentage ranging from 0.6 to 0.8,\(^3\) patterns of inconsistency have emerged.\(^4,5\) For instance, younger adults have higher lean mass and lower fat mass than weight-matched older adults,\(^6\) while height and BMI are negatively correlated in young adult females.\(^7\) Additionally, non-Europeans (e.g., South Asians, Chinese, and blacks) have higher fat mass and develop metabolic diseases at lower BMIs than those of European descent,\(^8-10\) while athletes commonly have higher BMIs with low to normal body fat percentages.\(^11,12\)

Misclassification of individuals by BMI – whether based on age, height, sex, race, or muscularity – may lead to missed or inappropriate interventions, as well as public mistrust of healthcare providers.\(^13\) College females are particularly vulnerable since obesity rates are higher in reproductive-aged women than similarly-aged men,\(^14\) perceptions of weight status are negatively associated with physical and emotional self-concept,\(^15,16\) and students are making their first autonomous health decisions. The most pressing issue is misclassification of at-risk individuals – those who are normal weight or BMI, but with adverse metabolic status. This
group is believed to “represent the most severe subtype along the phenotypic spectrum of individuals genetically predisposed to CV disease, such that they have unfavorable metabolic features, even without excess weight.”

Anthropometric indices are frequently chosen as markers of obesity and used to assess health status because they are non-invasive, portable, inexpensive, and require minimal time and training. However, the long-term consequences associated with health-risk misclassification warrant consideration. The annual per-person cost of being obese – such as direct medical costs, absenteeism, and daily needs – is $4879 for women and $2646 for men, while the annual cost of being overweight is $524 for women and $432 for men. Given that obesity-related costs are higher for women and that college is a critical transitional period for developing autonomy and lifelong health habits, the purpose of this study was to determine if the anthropometric indices of BMI and WC accurately predict obesity and assess health risk when compared to body composition.

Methods

Participants

Seventy-nine female freshmen at a large Midwestern university participated. Eligibility criteria included campus resident, minimum age 18 years, maximum weight 250 kg (scale capacity), not pregnant, and no implanted medical device(s). Participants were 18.1±0.3 yrs old. They were predominantly Caucasian (82.3%), with a minority identifying themselves as black (13.9%) or Hispanic (3.8%). The study was approved by the university’s institutional review board. Participants were recruited via campus fliers, social media messaging, newspapers, classroom announcements, and welcome week activities. Written informed consent was
obtained from each participant at the beginning of the test visit. Participants received reusable grocery bags and modest monetary compensation.

**Testing Schedule**

Upon arrival at the laboratory, participants dressed in compression clothing provided by researchers. Shoes, socks, jewelry, and hair accessories were removed prior to conducting measurements. Participants were instructed to abstain from exercise and consuming anything other than water for at least 2 hrs prior to the test visit. Measurements included weight, height, WC, and body fat percentage. Measurements were conducted once. Each participant completed all measurements.

**Anthropometric Measures**

Weight was measured to the nearest 0.1 kg using a calibrated electronic scale. Height was measured to the nearest 0.1 cm using a calibrated stadiometer. BMI was calculated as body mass in kilograms divided by height in meters squared. WC was measured to the nearest 0.1 cm using a retractable measuring tape just above the iliac crest (roughly the navel line).²

**Body Composition Analysis**

Body composition (i.e., body fat percentage) was determined using bioelectrical impedance analysis (BIA) with a direct segmental multi-frequency method with hand and foot electrodes (InBody 230; Biospace, Seoul, Korea). Empirically-derived formulas supplied by the manufacturer were used to calculate body fat percentage.

**Statistical Analysis**

Analyses were performed using IBM SPSS Statistics Version 20 (IBM Corporation, Armonk, NY). Results are reported as mean ± standard deviation. Associations between
anthropometric indices and body composition measurements were assessed by Pearson correlation coefficients.

To dichotomize variables for sensitivity and specificity analyses, health-risk cut-points were defined as BMI $\geq 25$ kg/m$^2$ (National Institutes of Health (NIH) standard cut-point for overweight$^2$), WC $>88$ cm (NIH standard cut-point for high waist$^2$), and body fat $\geq 33\%$ (based on a multiple regression model by Gallagher et al.$^{19}$ equating BMI $\geq 25$ kg/m$^2$ to body fat $\geq 33\%$ in 283 young adult women).

Sensitivity and specificity analyses were conducted in a manner similar to Ode et al.$^{11}$ Participants were classified into the following categories: 1) true positive (TP; overweight/high waist and overfat), 2) false positive (FP; overweight/high waist and normal fat), 3) false negative (FN; normal weight/normal waist and overfat), and 4) true negative (TN; normal weight/normal waist and normal fat). Sensitivity was calculated as the ability of the anthropometric index (i.e., BMI or WC) to correctly classify overfat participants as overfat based on body composition measurement with BIA (i.e., TP/(TP+FN)). Specificity was calculated as the ability of the anthropometric index to correctly classify normal fat participants as normal fat based on BIA (i.e., TN/(TN+FP)). Positive predictive value (PPV) was calculated as the ability of the anthropometric index to correctly classify participants as overfat who were actually overfat based on BIA (i.e., TP/(TP+FP)). Negative predictive value (NPV) was calculated as the ability of the anthropometric index to correctly classify participants as normal fat who were actually normal fat based on BIA (i.e., TN/(TN+FN)). Accuracy was calculated as the proportion of participants who were correctly identified as normal fat by anthropometric indices when they were actually normal fat based on BIA, or overfat when they were actually overfat (i.e., (TP+TN)/all)). Misclassification was calculated as the proportion of participants who were misclassified as
normal fat by anthropometric indices when they were actually overfat based on BIA, or vice versa (i.e., (FN+FP)/all)).

**Results**

**Descriptive Data**

Participants had a weight of 62.8±18.0 kg, height of 163.3±6.5 cm, BMI of 23.5±6.2 kg/m², WC of 80.2±12.5 cm, and body fat of 28.4±8.5%. Based on a 25 kg/m² BMI cut-point, 18.9% (n=15) were classified as overweight or obese. Based on an 88 cm WC cut-point, 16.5% (n=13) were classified at increased obesity-related disease risk. Based on a 33% body fat cut-point, 22.3% (n=18) were classified as overfat.

**Correlations**

Correlations were strongest between anthropometric indices (i.e., BMI vs. WC; $r=0.926$), with comparatively smaller correlations between body composition measurements and simple anthropometric indices (i.e., WC vs. BIA, $r=0.808$; BMI vs. BIA, $r=0.822$; $p<0.01$ for all). Despite these very strong positive correlations, some unexplained variance exists, indicating that some individuals are being misclassified.

**Sensitivity and Specificity Analysis**

Compared to body composition measurement with BIA, BMI had 67% sensitivity, 93% specificity, 75% PPV, 90% NPV, and 87% accuracy. Figure 5.1A demonstrates that, based on BMI, 13% of participants were misclassified relative to BIA (FP=4, FN=6). WC had 50% sensitivity, 93% specificity, 69% PPV, 86% NPV, and 84% accuracy. Figure 5.1B demonstrates that, based on WC, 16% of participants were misclassified relative to BIA (FP=4, FN=9).
Comment

Our results confirm the limitations of simple anthropometric indices in distinguishing health status. Although BMI and WC are two of the primary “measures” of obesity, neither distinguishes lean (i.e., muscle, bone, and fluid) versus fat mass, which are the true components affecting health risk. We found, to a limited extent, that anthropometric indices misclassified muscular individuals as overfat (i.e., misclassifying 4 participants (5.1%)) – presenting the risk for unnecessary interventions and adoption of negative health practices (e.g., disordered eating or exercise behaviors) to achieve a “normal weight.” However, the bigger problem in our sample was under-classification of health risk in those at seemingly normal BMI and WC (i.e., misclassifying 6-9 participants (7.6-11.3%)) – a group called “metabolically overweight/obese but normal weight” (MONW) by the scientific community.

Women who are MONW require particular attention. They suffer from “silent obesity” and experience similar rates of CV disease and all-cause mortality as their peers who are classified as overweight and obese by BMI. These MONW individuals experience hyperinsulinemia, insulin resistance, hypertriglyceridemia, and are predisposed to diabetes. Identifying MONW women of childbearing age is of specific importance, because adverse pregnancy outcomes (e.g., neural tube defects, miscarriage, stillbirth, gestational diabetes, and preeclampsia) are positively associated with pre-conception obesity. Equally concerning is that body fat percentage increases approximately 2.4% per decade in women ages 20-70. A key message for MONW individuals is that metabolic factors are potentially reversible and responsive to diet and exercise modifications. Important for healthcare professionals is that obese individuals whose provider spoke with them about losing weight had 2.8 times the odds of attempting weight loss, compared to those individuals for whom strategies to manage and treat
obesity were not discussed. Given the shift in focus from physical attractiveness/appearance to “healthier values” that occurs between college enrollment and graduation, freshman year presents an ideal time for intervention.

To facilitate opportunities for intervention, healthcare professionals need simple techniques to assess body composition in routine clinical settings. BIA was selected for this study because it is fast, non-invasive, and requires minimal technical skill. Although more accurate techniques exist (e.g., air-displacement plethysmography, dual energy X-ray absorptiometry (DXA), and hydrostatic weighing) – they are also more expensive, time consuming, require testing by experienced practitioners, and available only at specialized facilities. A high-quality, whole body BIA machine costs $1000-$5000 and can be used for 10 years with little maintenance. Based on the maximum machine price and its projected life expectancy, the cost is approximately $0.25 per test if used to screen every female freshman at a similarly-sized institution. In other words, screening 20,000 female freshmen over 10 years equals the cost of obesity for one obese woman during one year of her life.

Limitations

First, there is no consensus cut-point for excess body fat, with proposed values ranging from 30-37% in women. Second, BIA tends to underestimate body fat, especially among individuals with higher fat mass (-4.8% in young adult women with ≥32% body fat, compared to DXA). Despite this, the overall reproducibility/precision of BIA is 2.7-4.0%, and underestimation of fat mass would highlight an even greater disparity between anthropometric indices and health risk. Third, the study was advertised as a “Freshman Health Study.” This may have influenced the students who responded to recruitment advertisements (e.g., leading to self-selection of students interested in health). Finally, although participants were advised to
refrain from exercise and fast for at least 2 hrs prior to their test visit, it is possible that some participants were non-complaint. Exercise-induced fluid shifts or the presence of food/beverages in the gastrointestinal tract may have influenced the accuracy of results (e.g., dehydration would falsely elevate body fat percentage).\textsuperscript{31,32}

**Conclusions**

Health-risk misclassification has the potential to yield many consequences for individuals and their healthcare providers. This preliminary work highlights the need to reconsider the measures currently employed to classify the health risk of individuals, specifically, female college students. Body composition measurement by BIA identified an increased number of students, those with seemingly normal weights and WC measurements, at risk for poor health and correctly identified those with higher muscle mass as healthy. Thus, BIA presents a practical, cost-effective technique that can be used in college health settings to provide an “early warning sign” to MONW students. By providing an alternate assessment of obesity, college health professionals can raise public awareness about the potential to be metabolically obese while normal weight – presenting an opportunity for students to learn that body fat percentage has more implications than visual appearance. Accurate health-risk classification of obese college students has associated long-term effects related to cost, intervention, and educational programming. In the current healthcare climate, we would be remiss not to acknowledge the importance of this issue.

**Acknowledgments**

This study was supported by a research development grant from Bowling Green State University’s College of Education and Human Development. The authors would like to thank Lara Fickes, Jamal Niles, and Andrew Richardson for their assistance with data collection and entry.
References


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Figure 5.1. Scatterplots of anthropometric indices (BMI in A and WC in B) and body fat percentage (by BIA) for each participant. Quadrants are labeled to illustrate correct classifications (TP and TN) and misclassifications (FP and FN). The X-axis reference line depicts the cut-point for increased health risk based on anthropometric indices (overweight based on BMI in A and high WC in B). The Y-axis reference line depicts the cut-point for overfat based on body fat percentage. The fit lines reflect relationships between anthropometric indices and body fat percentage. WC = waist circumference, BIA = bioelectrical impedance analysis, TP = true positive, TN = true negative, FP = false positive, FN = false negative.
CONCLUSIONS

The primary aim of this study was to identify patterns of weight change in college freshmen and quantify in terms of lean and fat mass. In addition, this study sought to: 1) compare the predictive ability of self-reported to directly-assessed anthropometric data; 2) to determine the relationship between taste sensitivity and adiposity indicators; 3) to compare the predictive ability of health-risk of simple anthropometric indices to body composition assessment. The findings hold implications for universities, researchers, and health care practitioners working with college aged young adults.

In agreement with previous work, the present study demonstrated a modest weight gain during the freshman year of university, which was paralleled by increases in adiposity. Interestingly, most weight was gained early in the year (first 10-12 weeks) while the largest increases in adiposity came during spring semester. Although only several participants gained the infamous “freshman 15,” the majority of participants gained weight. Freshmen entering campus experience increased autonomy and begin to establish lifelong behaviors. Given that BMI in late adolescence is an excellent indicator of BMI in adulthood, it is critical that universities develop and implement appropriate prevention programs to mitigate this weight gain. These efforts would be best exploited during the spring semester when undesirable weight and adiposity changes occur.

It was hypothesized that taste sensitivity would predict weight gain and would diminish with corresponding gain, however this did not hold true. This may be due to the fact that taste measures were included only during the fall semester when weight gain was primarily lean mass. While the hypothesis was not realized, the results suggest that 1) negative effects of taste sensitivity may only predict adipose tissue gain and 2) taste sensitivity may only be attenuated
with deposition of fat, and not lean, mass. This was the first study to examine taste perception in college students and these data serve as an impetus for future research.

The current findings also highlight several limitations to commonly used methods of assessing body weight, adiposity, and health risk. First, self-reported weight and height was accurate when all participants were considered, however those who did understate their weight tended to be at greater risk (e.g., higher BMI, WC, % fat, etc.). Health care professionals must be aware of this trend as it appears individuals who would benefit most from intervention and education may go undetected and classified as ‘healthy’ when they are not. If misreporting is unintentional, this compounds the issue as young adults tend not to engage in health-promoting behaviors and may be less likely to do so if they are unaware they are at risk. Whenever possible, direct assessment of weight and height should be used in order to prevent missed opportunities for early risk identification. Likewise, simple anthropometric indices may also lead to misclassification of health risk, at least in female students. When compared to BIA, both BMI and WC performed poorly at identifying individuals at risk for chronic disease. For instance, a portion of individuals at seemingly healthy BMI and WC actually had unhealthy levels of body fat. These “normal weight obese” individuals are perhaps at greater risk than overweight counterparts because BMI is frequently used to determine disease risk in health care settings. These individuals’ normal BMI precludes health care professionals from identifying their risk of chronic disease. BIA is relatively inexpensive and its use may potentially increase the health of college aged females through adulthood.

These findings highlight several recommendations for future research. First, researchers should actively engage more male students for participation; there is extensive work on female university students, however males comprise a small part of the overall participant pool. Second,
taste sensitivity should be evaluated over a longer period of time and in which gains in adiposity are more likely (e.g., spring semester). Third, the present study only investigated the accuracy of self-reported anthropometrics in females due to a lack of male participants. Future work should evaluate males as they often exhibit a desire to gain weight and thus may overstate their weight or misperceive their body composition. Finally, anthropometric data should be compared to body composition in a larger sample size and more equal distribution of lean and overweight/obese individuals. This would facilitate firm conclusions on which settings the use of anthropometric data is sufficient and when body composition assessment should be employed.
REFERENCES


Body mass index (BMI) is often used to classify taste sensitivity study participants as lean, overweight, or obese. Compared to lean individuals, obese individuals have reduced taste sensitivity in some studies, while others show no difference. Doubt exists whether BMI is the best screening tool to evaluate adiposity and health risk. Other adiposity measurements include waist circumference (WC), bioelectrical impedance analysis (BIA), and air-displacement plethysmography (ADP). All have been shown to be better predictors of cardiometabolic health than BMI, yet BMI is a quick assessment commonly used by researchers. One explanation for the discrepancy among the obese is that BMI may misclassify participants’ true adiposity. This pilot study examined whether other measures of adiposity are better correlated with salty and sweet taste sensitivity. College freshmen (n=9M, 33F) were recruited through campus advertisements and underwent assessments for BMI, WC, BIA, and ADP. Taste sensitivity to salty and sweet solutions was also evaluated. BMI classified 76.1% as lean, 16.7% as overweight, and 7.2% as obese. BMI (23.7±4.5 kg/m²), WC (M79.9±7.1 cm, F80.5±11.8 cm), BIA (M11.3±4.1%, F29.1±9.2%), and ADP (M11.4±6.9%, F29.7±8.0%) were positively correlated (r>0.478, p≤0.001 for all). There were no correlations between taste sensitivity and any adiposity measure. For this young population, taste sensitivity does not appear to be
associated with adiposity. However, the limited sample size and low adiposity rates may not allow for detection of differences.
Introduction: Body mass index (BMI) is frequently utilized to classify obesity and predict cardiometabolic disease risk. Although BMI is independent of age, its predictive ability across age groups has been questioned. Objective: This pilot study sought to identify age-dependent variations in simple anthropometric indices and body composition (% fat) in sex-, height-, and BMI-matched adults of varying ages. Methods: ‘Older’ participants were middle-aged and older adults and ‘younger’ participants were college freshmen. Older (n=28, 7M, 21F; age: 57.3 ± 5.4 years, range: 50-74 years) and younger participants (n=28, 7M, 21F; age: 18.0 ± 0.2 years, range: 18-19 years) were matched for sex, height (± 1 cm), and BMI (± 1 kg/m²). Waist circumference (WC) and height were measured to the nearest 0.1 cm and waist-to-height ratio (WHtR) was subsequently calculated as WC/height. Body composition was assessed by air-displacement plethysmography (ADP via BODPOD). Results: Older (height: 167.4 ± 7.8 cm, BMI: 23.9 ± 3.4 kg/m²) and younger adults (height: 167.2 ± 7.8, BMI: 23.9 ± 3.2 kg/m²) had similar WC (86.7 ± 11.0 cm vs. 82.2 ± 9.7 cm, p=0.113) and WHtR (0.52 ± 0.06 vs 0.49 ± 0.05, p=0.108). However, body fat was higher in older adults (29.9 ± 7.9%) compared to younger adults (24.9 ± 9.5%, p=0.037). Discussion: Older individuals demonstrate higher body fat percentage than younger individuals despite similar height, BMI, WC, and WHtR. Thus, body composition assessment may be a better indicator of obesity and cardiometabolic disease risk in these individuals.
Background: College is a transitional period where lifelong health habits are being developed. Changes in health-related variables may predict long-term disease risk. This observational study sought to investigate the effect of time on health-related risk factors in college freshmen.

Methods: Freshmen (n=126; 81% female; 87% Caucasian; age 18.2±0.4 years) residing on campus were recruited via public advertisements posted on campus and online. Study visits occurred upon arrival to campus (late August), pre-holidays (early November), and post-holidays (early January). Health-related measures included physical activity (validated questionnaire), body fat (air-displacement plethysmography; ADP via BODPOD), body mass index (BMI; calculated from measured weight and height), and blood pressure (automated cuff). Repeated measures analysis of variance was performed to assess the effect of time on health-related variables. Sex was a between-subjects factor.

Results: Moderate physical activity decreased in all participants (p=0.009) with a greater decrease in males than females (-1.4 vs. -0.1 days/week, respectively; p=0.034). Body fat increased in all participants (p<0.001) with a greater increase in males than females (+1.1 vs. +0.6%, respectively; p=0.032). Weight increased in all participants (p<0.001) and tended to increase more in males than females (+2.6 vs. +1.5 kg, respectively; p=0.086). BMI (+0.5 kg/m^2; p<0.001) and systolic blood pressure (+4.2 mmHg; p<0.05) increased in all participants, but did not vary by sex. Weight, BMI, moderate physical activity,
and body fat changed significantly in the first 2.5 months on campus (p≤0.01 all), but plateaued over the holiday season. No changes were noted in vigorous physical activity or diastolic blood pressure. **Conclusion:** Although all participants exhibited worsening health-related parameters, effects were heightened among males and predominant in the first 2.5 months on campus. Further research is needed to identify possible causation for worsening health-related outcomes in males than females and develop interventions targeted toward students arriving on campus.
Validation of Self-Reported Anthropometrics in Female College Freshmen

Ryan J. Leone, Mary-Jon Ludy, Amy L. Morgan FACSM

American College of Sports Medicine (ACSM) Annual Meeting, Orlando, FL, May 2014

Self-reported anthropometric measures (e.g., weight and height) are used to classify disease risk (e.g., type 2 diabetes and cardiovascular disease). Previous research suggests that individuals overestimate height and underestimate weight, rendering self-reported anthropometric data unreliable. These inaccuracies can lead to misclassification of disease risk. **Purpose:** The purpose of this study was to determine the validity of self-reported anthropometrics in quantifying disease risk in female college freshmen. **Methods:** Within three weeks of arriving on campus, students (n=128; age=18.1±0.4; 84% Caucasian) were recruited via public advertisements in the newspaper, online, and fliers on campus. Participants self-reported weight and height, then underwent measurements for height, weight, waist circumference (WC), and body composition (% fat). Body composition was determined using bioelectrical impedance analysis (BIA) and air-displacement plethysmography (ADP via BODPOD). Disease risk was classified according to the NIH-accepted standard of WC ≥ 35 in, while a 33% fat cut-point was used to indicate excess fat (Gallagher et al. 2000). **Results:** Excess fat was identified in 25.0% (n=32) and 24.2% (n=31) of students by ADP and BIA, respectively. High WC was identified in 20.3% (n=26) of students. There were no significant differences in self-reported versus actual weight or height. Weight discrepancy (i.e., self-reported minus actual) was negatively correlated with % fat (r= -.330 BIA; r= -.312 ADP) and WC (r= -.358; p<0.001 for all). **Conclusions:** Individuals who underreported their weight had higher % fat and WC. These data suggest that
although not all individuals misrepresent their body weight, those who do are at increased disease risk.
The purpose of this study was to explore the prevalence of health risk indicators in college students upon commencement of freshman year. Within three weeks of arriving on campus, freshmen (n=20 M, 68 F; 18±0.4y) underwent measurement of height, weight, body mass index (BMI), waist circumference (WC), blood pressure (BP), and body composition (BF%) using air-displacement plethysmography. Subjects also completed the International Physical Activity Questionnaire. Subjects predominantly displayed a healthy BMI (24.5±4.5 kg/m2): 57% normal weight, 37% overweight/obese, and 5% underweight. WC was 88.1±14.7 cm (M) and 82.3±11.1 cm (F); 23% had increased health risk based on high WC. Systolic (117.9±11.4 mmHg) and diastolic (69.7±9.4 mmHg) BP demonstrated that 5% were hypertensive, 35% were prehypertensive, and 60% were normotensive. BF% was 20.5±9.6% (M) and 29.7±7.9% (F), indicating that 32% were overfat. ACSM guidelines for physical activity were met by 81% of participants. Despite self-reporting sufficient physical activity, a large percentage of freshmen (58%) had ≥ 1 health risk indicator based on BMI, WC, BP, or BF%; 35% had ≥ 2 indicators. In conclusion, these data indicate that a majority of entering college freshmen are at increased health risk and support the need to develop targeted interventions on campus.
According to the National Health and Nutrition Examination Survey, there has been a consistent increase in overweight and obesity in adolescents over the past several decades. Overweight teenagers are at a substantially higher risk for obesity later in life, which is associated with a myriad of chronic diseases. **Purpose:** To explore the disease risk indicators in first year college students upon commencement of freshman year. **Methods:** Within the first three weeks of arriving on campus, first year college students (n=22/79 male/female; age 18 ± 0.3 yr) were recruited via public advertisements in the newspaper, online, and fliers on campus. Participants were screened for height, weight, BMI (calculated as kg/m²), waist circumference, blood pressure (using an automated cuff), and body composition. Body composition was determined using bioelectrical impedance analysis (BIA) and air-displacement plethysmography (ADP via BODPOD). Participants also completed the International Physical Activity Questionnaire to estimate activity level. **Results:** Participants predominantly displayed a healthy BMI (23.3 ± 5.7 kg/m²); 74% were categorized as normal weight, 19% as overweight/obese, and 7% as underweight. Mean waist circumference for males and females was 75.9 ± 7.1 cm and 81.0 ± 12.6 cm, respectively; 12% of students were categorized as having a risk factor associated with high waist circumference. Systolic (119.3 ± 11.9 mmHg) and diastolic (71.5 ± 8.6 mmHg) blood pressure demonstrated that 7% of students were hypertensive, 46% were prehypertensive, and 48% were normotensive. Body composition, determined by BIA (M: 13.3 ± 4.8%, F: 28.4 ±
8.5%) and ADP (M: 13.1 ± 5.4%, F: 28.1 ± 8.0%), indicated that 23-24% of freshmen have excess or risky high body fat. ACSM guidelines for weekly physical activity were met by 72% of participants. **Conclusion:** These data suggest that nearly three quarters of students arriving on campus have a healthy BMI, waist circumference, body composition, and activity levels. Despite this, more than half of participants demonstrated an elevated blood pressure. In order for universities to develop appropriate interventions, further research is necessary to identify possible causal factors of elevated blood pressure among first year students.
HEALTH-RELATED VARIABLES AND ACADEMIC SUCCESS IN FEMALE COLLEGE STUDENTS
A.M. Kuhlman, M. Ludy, PhD, RDN, A.L. Morgan, PhD, R.J. Leone, BS
Food & Nutrition Conference & Expo (FNCE), Atlanta, GA, October 2014

Background: College students’ academic performance and long-term career success are strongly related. Research regarding health-related variables and academic performance is inconsistent, with most studies focusing on younger age groups. This study’s purpose was to assess the relationship between several health-related variables and academic performance in female college students. Methods: Sixty-six female college students (age 18.4±0.6 years; 96.2% Caucasian; 77.3% freshmen, 22.7% sophomores) residing on campus were recruited via public advertisements. In the two weeks preceding Thanksgiving, body mass index (BMI), waist circumference, body fat (via bioelectrical impedance analysis), alcohol consumption, diet, physical activity, and behavioral difficulties were assessed using anthropometric measurements and validated questionnaires. Grade point averages (GPAs) were obtained from the registrar after fall semester. Associations between variables were determined using Pearson correlation coefficients. Results: Participants predominantly displayed a healthy BMI (23.7±4.2 kg/m²); 30% were overweight/obese. Waist circumference was 31.4±3.9 in; 17% had high waist circumference. Body fat was 28.9±7.6%; 30% had excess/risky high body fat. Eighty percent met physical activity guidelines. Eighteen percent misused alcohol. Fourteen percent had behavioral difficulties. GPA was 3.4±0.6. Higher GPAs were associated with lower BMI, body fat, alcohol consumption, and behavioral difficulties (r=-0.283 to -0.371, all p<0.05), and tended to be associated with lower waist circumference.
Self-reported diet and physical activity were not associated with academic performance. **Conclusion:** Approximately one-third of students demonstrated health-related risks including overweight/obesity, high waist circumference, high body fat, physical inactivity, alcohol misuse, and/or behavioral difficulties. Modifying health-related behaviors may help students to improve academic performance.
Body mass index (BMI) and waist circumference (WC) are simple anthropometric measures used to indicate body fatness and assess health risk. ‘While BMI provides a reliable indicator of body fatness for most people’ (CDC), it does not provide a measure of body composition. This may lead to poor identification of those at risk (e.g., underestimates fatness in older individuals). Therefore, within specific populations it is important to identify the best health risk indicator. **Purpose:** This study in male college freshmen was designed to determine the ability of various anthropometric measures to accurately predict health risk when compared to body composition. **Methods:** Within three weeks of arriving on campus, students (n=41; age 18.2±0.4 yr; 80.5% Caucasian) were screened for BMI (calculated from weight, 75.4±14.5 kg, and height, 176.8±6.3 cm) and WC. Body composition (% fat) was determined via air-displacement plethysmography (ADP; BODPOD) following manufacturer recommendations. For anthropometric measures, health risk was classified according to accepted standards (WC ≥ 102 cm; NIH; BMI ≥ 25 kg·m⁻²; NIH, WHO), while a 20% fat cut-point was utilized to indicate excess fat (Gallagher et al., 2000). Sensitivity, i.e., ability of anthropometric measure to correctly classify overfat participants, and specificity, i.e., ability of anthropometric measure to correctly classify normal fat participants, were determined. **Results:** All measures were highly correlated (≥0.823; p<0.01). When comparing our participants to accepted
screening values, 34% (n=14) were categorized as overweight or obese by BMI (24.2±4.8 kg·m⁻²), 9.8% (n=4) were identified with a WC (82.3±12.3 cm) as a positive risk factor, and 26.8% (n=11) were identified as overfat as measured by ADP (16.0±7.7%). However, 17.1% (n=7) and 2.4% (n=1) were misclassified as not at risk utilizing WC and BMI, respectively, when ADP indicated an elevated % fat. **Conclusion:** In young men entering college, if measures of % fat are not available, BMI, but not WC, is an acceptable alternative for identifying those at risk for poor health. However, BMI should only be utilized as a screening test when measures of % fat are not available due to overidentification of health risk.
Background: The transition to college is a vulnerable period for weight change. Unwanted weight gain (e.g., the “freshman 15”) is widely touted by the popular press, while smaller gains are supported by the scientific literature. It is unclear whether weight gain occurs steadily and is limited to fat mass. The purpose of this observational study was to assess the patterns and composition of weight change in first-semester freshmen.

Methods: Freshmen (n=14 male, 59 female; age 18.1±0.4 years; 83.6% Caucasian) residing on campus were recruited via public advertisements posted on campus and online. Anthropometric (weight, height, body fat, and waist circumference) measurements occurred at three time points (late August, early November, and early January). Repeated measures analysis of variance was performed to assess the effect of time on anthropometric variables. Sex was a between-subjects factor. Pearson correlation coefficients were used to determine associations between anthropometric variables.

Results: During their first 10-12 weeks on campus, males and females gained 3.9±5.2 and 4.1±3.9 lbs, respectively (p<0.001). Whereas rapid weight gain tended to continue in males (2.9±5.0 lbs) during the holiday season, weight plateaued in females (0.1±3.5 lbs, p=0.077 for interaction). Weight, height, body mass index, body fat, and waist circumference increased significantly in first-semester freshmen (all p<0.05). Weight change was positively correlated with changes in body fat and waist circumference (r=0.510 and 0.520, respectively, both p<0.001).

Conclusion: These findings provide valuable insight on weight change in first-semester freshmen. To develop
appropriate interventions, future research is necessary to confirm differences between males and females.
ACCURACY OF DISCRETE MEASURES AS INDICATORS OF BODY COMPOSITION IN COLLEGE FRESHMEN

Amy L. Morgan, Ph.D., FACSM, Mary-Jon Ludy, Ph.D., R.D., Ryan Leone

ACSM Annual Meeting, Indianapolis, IN, May 2013

Body mass index (BMI) and waist girth are often used as measures of obesity. The CDC states that ‘BMI provides a reliable indicator of body fatness for most people.’ However, there is evidence that BMI can overestimate obesity in muscular athletes and underestimate obesity in older individuals. Clinically, it is important to identify the best indicators of obesity to accurately identify at risk individuals. **Purpose:** The purpose of this study was to examine the relationship between various anthropometric and body composition measures to determine if BMI is a reliable indicator of body fatness in college freshmen. **Methods:** Within the first three weeks of arriving on campus, first year college students (n=101; age 18.1 ±0.3 yr; 22 M, 79 F) were screened for height, weight, and waist girth (waist); BMI was calculated as kg·m⁻². Body composition (% fat) was determined using bioelectrical impedance analysis (BIA) and air-displacement plethysmography (ADP by BODPOD) following standard recommendations for each instrument. Correlation coefficients were calculated between waist, BMI, and the two % fat measures for all subjects. **Results:** Correlations between body composition measures were as follows: BIA vs. waist (r=0.657), BMI (r=0.671), and ADP (r=0.920); ADP vs. waist (r=0.651) and BMI (r=0.621); BMI vs. waist (r=0.922)( p<0.01 for all). When comparing our participants to accepted screening values, 19% were categorized as overweight or obese when using BMI (23.3±5.7 kg·m⁻²) while 12% were identified with a waist circumference (M: 30.7±3.1; F: 31.6±4.9 in) as a positive risk factor. Twenty-three % were categorized as having excess to risky
high levels of body fat as measured by ADP (M: 13.3±4.8; F: 28.4±8.5%). **Conclusion:** While significant correlations existed for all measures of body composition the relationships between estimates of % fat (i.e., BIA and ADP) were much stronger than those between % fat and risk factor indicators (i.e., waist and BMI). In addition, % fat identified more individuals at risk for poor health. Therefore, BMI and waist should only be utilized as screening tests when measures of % fat are not available. Identification of those at risk for poor health due to excess levels of body fat should be a primary goal of clinicians, therefore, standard measures of % fat are recommended over waist girth and BMI.
APPENDIX B DEMOGRAPHIC QUESTIONNAIRE

Name: ____________________________
Subject ID: _______________________
Visit Date: _______________________

SCREENING AND DEMOGRAPHIC QUESTIONNAIRE

Please circle TRUE or FALSE for the following questions.

TRUE  FALSE  1. I am not pregnant or planning a pregnancy.
TRUE  FALSE  2. I am not claustrophobic.
TRUE  FALSE  3. I do not have a pacemaker or artificial electrical medical device(s)/electrical system(s).
TRUE  FALSE  3. I am willing to attend 5 test visits lasting about 35 minutes each.
TRUE  FALSE  4. I am willing to answer questions about my diet.
TRUE  FALSE  5. I am willing to answer questions about my physical activity.
TRUE  FALSE  6. I am willing to have my blood pressure measured.
TRUE  FALSE  7. I am willing to have my weight measured.
TRUE  FALSE  8. I am willing to have my height measured.
TRUE  FALSE  9. I am willing to have my waist size measured.
TRUE  FALSE 10. I am willing to wear a swimsuit or tight shorts with a sports bra (if applicable) to have my muscle and body fat measured.

Please fill-in or circle your answers to the following questions.

11. Sex: ______ male; ______ female
12. Age: ______ years
13. Birthday (month/day/year): __________________________
14. Ethnic/racial Background
   a. White/Caucasian (non-Hispanic)
   b. Asian/Pacific Islander
   c. Hispanic
   d. Black/African American
   e. American Indian/Alaskan
   f. Other (name): __________________________
   g. Prefer not to answer
15. Height: ______ inches
16. Weight: ______ pounds
17. Major: __________________________
18. Phone Number: _______________________
19. Email: __________________________
20. Residence Hall
   a. Centennial
   b. Conklin
   c. Falcon Heights
   d. Founders
   e. Harshman Anderson
   f. Harshman Bromfield
   g. Harshman Chapman
   h. Harshman Dunbar
   i. Kreischer Batchelder
   j. Kreischer Compton
   k. Kreischer Darrow
   l. Kohn
   m. McDonald East
   n. McDonald North
   o. McDonald West
   p. Offenhauer East
   q. Offenhauer West
   r. Other (name): ____________________________
   s. I do NOT live on campus

21. Residential Learning Communities
   a. Arts Village
   b. Global Village
   c. Honors Learning Community
   d. La Comunidad
   e. La Maison Francaise
   f. Natural and Health Sciences Residential Community
   g. Other (name): ____________________________
   h. I do NOT participate in a Residential Learning Community

22. Residential Theme Communities
   a. Army ROTC
   b. Aviation
   c. Batchelder Music Community
   d. Construction Management
   e. Fraternity and Sorority Life
   f. Wellness
   g. SEARCH
   h. Other (name): ____________________________
   i. I do NOT participate in a Residential Theme Community

23. Preferred T-shirt Size
   a. Small
   b. Medium
   c. Large
   d. Extra Large
   e. Other (name): ____________________________

Thanks for completing the screening and demographic questionnaire!
APPENDIX C INFORMED CONSENT DOCUMENT

Informed Consent for "Freshman Health Study"

Introduction: You are being invited to participate in the "Freshman Health Study." This project is collaboration between Dr. Mary-Jon Ludy, an assistant professor of clinical nutrition, Dr. Amy Morgan, an associate professor of kinesiology, and Ryan Leone, a graduate student completing dual master's degrees in food and nutrition and kinesiology. We are interested in the health habits of first year college students who live on campus.

Purpose: The purpose of this study is to explore diet and exercise habits of college freshmen. In general, the study will help to assess the need for campus-wide program to help students stay healthy, especially during the freshman year. Benefits of being a participant include:

- A small reward at the end of each visit. For example, $5 BG Bucks that can be used on- and off-campus or a spirit item (such as: a thermal mug, a water bottle, or a t-shirt).
- Access to results and expert feedback after data is collected. This will include:
  - Your testing results, which would cost approximately $200 at a health club,
  - A health-based information session during spring finals week, and
  - If applicable, early detection of risk factors related to health and disease.

Procedure:
Screening (15 minutes):

1. Arrive at laboratory.
   a. You will arrive at Epler South 104 at least 2 hours after exercise and eating/drinking anything other than water.

2. Sign informed consent document.
   a. You will read the informed consent document.
   b. You will ask any questions about participating in this study.
   c. After all your questions have been answered, you will have the option of:
      i. Signing the informed consent (meaning that you agree to participate in this study), or
      ii. Deciding not to participate.

3. Screening and demographic questionnaire:
   a. You will complete a questionnaire asking about:
      i. Your sex, age, ethnic/racial background, height, weight, major, phone number, email, residence hall, and residential learning/theme community (if applicable), as well as
      ii. Whether you are pregnant or planning a pregnancy, claustrophobic, and willing to participate in study activities.
   b.
Researchers will determine if eligibility criteria are met.

i. If you are eligible, you will receive $5 BG Bucks, the screening visit will end, and visit 1 will begin immediately.
ii. If you are not eligible, you will receive $5 BG Bucks and the screening visit will end.

Testing Visits
You will be scheduled for 5 study visits. Each study visit will last approximately 35 minutes.

Test Visit Schedule (5 study visits)
1. Visit 1 will occur during the first 2 weeks of the fall semester (August 20-31, 2012).
2. Visit 2 will occur during the 2 weeks before Thanksgiving break (November 5-16, 2012).
3. Visit 3 will occur during the first 2 weeks of the spring semester (January 7-18, 2013).
4. Visit 4 will occur during the 2 weeks before spring break (February 18 – March 1, 2013).
5. Visit 5 will occur during the 2 weeks before spring finals week (April 15-26, 2013).

Test Visit Procedures (35 minutes each)
1. You will arrive at Eppler South 104 at least 2-hours after exercise and eating/drinking anything other than water.
2. You will sit while completing diet, physical activity, and alcohol questionnaires (10 minutes).
3. Your blood pressure will be measured by placing a cuff around your upper arm (2 minutes).
4. You will dress in a swimsuit or tight shorts with sports bra (if applicable), swim cap, and nose plugs for your body composition measurements (5 minutes).
5. You will have your waist circumference measured by placing a measuring tape around your waist (2 minutes).
6. You will have your height measured while standing against the wall (2 minutes).
7. You will have your weight measured while standing on an electronic scale (2 minutes).
8. You will have your body composition measured using 2 methods (10 minutes).
   a. Method 1 (BOD POD): You will sit in an airtight chamber for 2-3 brief measurements lasting approximately 45 seconds. You should not participate in this measurement if you are claustrophobic.
   b. Method 2 (bioelectrical impedance): You will stand on an electronic scale and place your hands around handgrips. You should not participate in this measurement if you have a pacemaker or other artificial electrical medical device/electrical system.
9. You will dress in your own clothes (2 minutes).
10. You will receive a small reward, such as $5 BG Bucks or a spirit item (thermal mug, water bottle, t-shirt, etc).
After Final Data Collection (Following All 5 Visits to the Laboratory)

You will have access to your testing results and expert feedback.

1. Your testing results will be available to you.
2. You will have the chance to attend a group-based education event led by graduate nutrition and exercise physiology students. This will occur during spring finals week (April 29 – May 3, 2013).

Voluntary nature: Your participation is completely voluntary. You are free to withdraw at any time. You may decide to skip questions (or not do a particular task) or discontinue participation at any time without penalty. Deciding to participate or not will not affect your relationship with Bowling Green State University.

Confidentiality: Your participation in this study will remain confidential. Hard copies of all data will be stored in a locked filing cabinet. The principal investigator, co-investigators, and undergraduate student assistants will be the only people with access to the data. The hard copies will be retained for 3 years after the project ends, after which they will be destroyed by shredding. Electronic files will be stored on a computer in password-protected documents and will not be destroyed. The study will not be anonymous because it will be necessary to identify participants before each test, as well as track and analyze results. Your name will be used when signing consent forms, at the screening visit, and when entering data into computer hardware for body composition testing. You will receive a “subject ID” number, which will be used on all paper documents after screening.

Risks: Risk may be encountered during body composition assessments and alcohol reporting.

1. BOD POD: There is a risk that participants will experience anxiety and/or uneasiness when placed in the confined windowed chamber. This procedure, involving 2-3 measurements of approximately 45 seconds, will be monitored by laboratory staff and can be discontinued at any point as necessary. The BOD POD also has a “panic button” that the subject may press at any point during the assessment to stop the test. To minimize this risk, potential participants reporting claustrophobia will be excluded at screening.
2. Bioelectrical impedance analysis: There is a risk that the small electrical signal transmitted through bioelectrical impedance analysis (to measure resistance of body tissues to the electrical flow, and thus estimate body fat and muscle mass) will interfere with implanted electrical devices. To avoid this risk, potential participants who report having a pacemaker or other artificial electrical medical device/electrical system will be excluded at screening.
3. Alcohol questionnaires: There is a risk that a breach of confidentiality will lead to disclosure of self-reported alcohol use. To safeguard data, particularly for those under the legal drinking age of 21, identifying information will be removed from questionnaires. Data will be kept strictly confidential and tracked using an ID number, rather than your name.
Contact information: If you have any questions about this research or your participation in this research, please contact the study investigators.

Principal Investigator:    Co-Investigator:    Co-Investigator:
Dr. Mary-Jon Ludy        Dr. Amy Morgan        Ryan Leone
Assistant Professor      Associate Professor      Graduate Student
School of FCS            School of HMSI5          Schools of FCS and HMSI5
mludy@bgsu.edu           amorgan@bgsu.edu       rleone@bgsu.edu
419-372-6461             419-372-0596         440-856-6835

You may also contact the Chair, Human Subjects Review Board at 419-372-7716 or hrsb@bgsu.edu, if you have any questions about your rights as a participant in this research.

Thank you for your time.

I have been informed of the purposes, procedures, risks and benefits of this study. I have had the opportunity to have all my questions answered and I have been informed that my participation is completely voluntary. I agree to participate in this research.

________________________________________
Participant Signature
DATE: June 25, 2012

TO: Mary-Jon Ludy, PhD

FROM: Bowling Green State University Human Subjects Review Board

PROJECT TITLE: [342745-2] Patterns and Composition of Weight Change in College Freshmen

SUBMISSION TYPE: Revision

ACTION: APPROVED

APPROVAL DATE: June 25, 2012

EXPIRATION DATE: June 7, 2013

REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 7

Thank you for your submission of Revision materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk-benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The final approved version of the consent document(s) is available as a published Board Document in the Review Details page. You must use the approved version of the consent document when obtaining consent from participants. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

You have been approved to enroll 250 participants. If you wish to enroll additional participants, you must seek approval from the HSRB.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on June 7, 2013. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hsrb@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board’s records.
DATE: May 28, 2013

TO: Mary-Jo Ludy, PhD
FROM: Bowling Green State University Human Subjects Review Board

PROJECT TITLE: [342745-4] Patterns and Composition of Weight Change in College Freshmen
SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: June 8, 2013
EXPIRATION DATE: June 7, 2014
REVIEW TYPE: Expedited Review
REVIEW CATEGORY: Expedited review category # 7

Thank you for your submission of Continuing Review/Progress Report materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The final approved version of the consent document(s) is available as a published Board Document in the Review Details page. You must use the approved version of the consent document when obtaining consent from participants. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

You have been approved to enroll 250 participants. If you wish to enroll additional participants you must seek approval from the HSRB.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on June 7, 2014. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hrsb@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board’s records.
DATE: May 21, 2014

TO: Macy-Jon Ludy, PhD

FROM: Bowling Green State University Human Subjects Review Board

PROJECT TITLE: [342745-10] Patterns and Composition of Weight Change in College Freshmen

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED

APPROVAL DATE: May 19, 2014

EXPIRATION DATE: May 18, 2015

REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 7

Thank you for your submission of Continuing Review/Progress Report materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The final approved version of the consent document(s) is available as a published Board Document in the Review Details page. You must use the approved version of the consent document when obtaining consent from participants. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

You have been approved to enroll 250 participants. If you wish to enroll additional participants you must seek approval from the HSRB.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on May 18, 2015. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hrsb@bgus.edu. Please include your project title and reference number in all correspondence regarding this project.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.
April 6, 2015

To Whom It May Concern:

We, the undersigned, hereby grant Ryan J. Leone permission to use all content to include data, text, and graphs in the document titled *Patterns and Composition of Weight Change in College Freshmen*.

James H. Albert
Mary A. Lody
Amy L. Morgan
Robin M. Tucker