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Intensity of Physical Activity and Body Composition: A Cross-Sectional Analysis of Young Adult Women

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A thesis submitted to the faculty of
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Master of Science

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ABSTRACT

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Purpose: The purpose of this study was to assess the relationship between intensity of physical activity and body composition in 239 young adult women.

Methods: This study was cross-sectional. Participants were recruited from October 2009 to December 2011 and included women from 36 different states and 6 different countries. Physical activity was objectively measured using accelerometers worn for seven days. Body composition was measured using the BOD POD. Height, weight, and circumferences were assessed.

Results: Participant's mean age was 20.6±1.6 years. Their mean BMI was 22.6±3.0 kg/m^2 and mean body fat percentage was 26.4±6.3 %. Average total activity counts per day were 387,560 ± 172,000, with 61.6±22.5 min per day spent in MVPA, 169.4±43 min per day in light activity, 55.6±19 min per day in moderate activity, and 6±9.2 min per day in vigorous activity. Total activity counts per day were inversely correlated with body fat (r = -0.17, p = 0.007). Light activity was positively correlated with both BMI (r = 0.17, p = 0.007) and waist circumference (r = 0.15, p = 0.0164). Moderate activity was inversely associated with body fat (r = -0.18, p = 0.0051) and hip circumference (r = -0.12, p = 0.0459). MVPA was inversely associated with body fat (r = -0.19, p = 0.0026) and hip circumference (r = -0.14, p = 0.0291). Vigorous physical activity was inversely related to body fat (r = -0.20, p = 0.0023). Using stepwise regression, the best predictor of body fat was time spent in vigorous PA (F = 9.45, p = 0.0024). The best predictor of BMI was light activity per day, which was positively correlated with BMI (F = 7.5, p = 0.0066) followed by moderate activity per day which was negatively correlated (F = 4.25, p = 0.0403). Young adult women who spent no time performing vigorous PA had significantly higher body fat percentages than women who performed some vigorous PA. Young adult women who spent less than 30 minutes per day in MVPA had significantly higher body fat percentages and BMIs than those who obtained more than 30 minutes per day. For every 10 minutes spent in MVPA per day, the odds of being obese by body fat decreased by 33%.

Conclusion: Vigorous PA and MVPA appear to be the most important aspects of PA associated with lower body fat and BMI levels. Young adult women should be encouraged to obtain at least 30 minutes of MVPA per day.

Keywords: body composition, physical activity, body fat, accelerometer

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Introduction

Preventing obesity and its associated health risks is a growing problem [1-3]. Central to diminishing the prevalence of obesity includes identifying the critical periods where excess weight tends to be gained or unhealthy habits established. According to the Behavioral Risk Factor Surveillance System, the greatest increase in the rate of obesity occurs among 18-29 year-olds who have some college education [4-5]. The college years are therefore a critical time in which to prevent excess weight gain.

During the freshman year of college alone, a weight gain of 1.7 to 4.2 kilograms is commonly seen in men and women [6]. Increases in percent body fat during the freshman year tend to be around two percentage points [7]. Multiple factors play into this weight gain including dietary habits and physical activity [8].

It has been shown that physical activity tends to decline in the transition from high school to college [8]. What is less understood is the actual relationship between the intensity of physical activity and body composition in university students. Though not always a straightforward relationship, physical activity has been shown to be significantly associated with percent body fat during the college years [9-11]. However, all but one of these studies that have looked at this relationship have used subjective measures of physical activity and the intensity of activity has not been well evaluated. The one study that used accelerometers to evaluate physical activity was limited by sample size and was not able to comprehensively evaluate the relationship between intensity of physical activity and body composition [10].

A better understanding of the relationship between intensity of physical activity and body composition can aid in preventing obesity. Profiling physical activity, intensity of physical activity and body composition in young adult women will increase our understanding of the level and intensity of physical activity that tends to be more favorable for lower adiposity. It may also help universities to establish wellness goals or requirements for their students in order to prevent excess weight gain during college. The purpose of this study was to identify associations between physical activity levels and body composition among young adult women, with specific emphasis on intensity and time spent in sedentary, light, moderate, and vigorous activity. A secondary purpose was to evaluate the impact of potential confounding factors, such as age and season of assessment, on these relationships.

Methods and Procedures

Design

This study used a cross-sectional design to assess 249 college women. Data was collected beginning in the fall semester of 2009 and continued through the fall semester of 2011.

Participants

Participants included young adult women ages 17-30 yrs. In order to join the study, participants had to be found healthy as determined by a health history questionnaire and able to participate in moderate to vigorous activity without limitations. Participants were non-smokers. Those who had a baby in the past six months or were pregnant were excluded from the study. Women taking any medications that alter metabolism were also excluded from the study.

Recruitment for the study was done using posters, flyers, a Facebook group, and word of mouth. Those interested in participating filled out a screening form to ensure the inclusion criteria were met. Prior to participating in the assessment, all participants signed an informed consent form approved by the university's Institutional Review Board.

Procedures

Participants who met the inclusion criteria were asked to participate in two appointments separated by seven full days. At the first assessment height and weight were measured. Body composition was assessed using the BOD POD (Life Measurement, Inc., Concord, CA). Participants were given a belt with the ActiGraph GT3X accelerometer (ActiGraph, Pensacola, FL) attached and instructed on how to properly wear the belt. A physical activity form was sent home with the participants on which they logged exercise activities performed, any times the belt was removed, and the activities performed while the belt was off (e.g. swimming).

During the seven days of activity monitoring, each participant was contacted once to ensure she was properly wearing the activity monitor. Following the seven days of activity monitoring participants came in for the second appointment. At this point participants returned the activity monitor. Activity monitor data was downloaded and checked to make sure that the data was complete. If the participant forgot to wear the monitor or the data was unusable (as a result of a monitor malfunction) the participant was asked to wear the monitor again.

Following completion of the study, participants were given their body composition results and received a $15 cash incentive for participating.

Instrumentation and Measurement Methods

Body Weight and Height. Body weight was measured on a digital scale (Tanita Corporation, Japan; modified by Life Measurement, Inc., Concord, CA) to the nearest 0.005 kg. In order to standardize the assessment, participants were weighed while wearing a standard one-piece swimsuit. The scale was calibrated every two weeks. Height was measured using a wall-mounted stadiometer (Seca, Chino, CA) and recorded to the nearest 0.1 cm. Body mass index was calculated by dividing a participant's mass in kilograms by their height in meters squared.

Body Composition. Waist and hip circumferences were measured in triplicate and the average of three measurements was used for analysis. Using a spring loaded Gulick measuring tape (Fitness Wholesale, Stow, OH), waist circumference was assessed at the narrowest portion of the abdomen and hip circumference was assessed at the widest portion of the buttocks.

The BOD POD was used to determine body fat percentage. The BOD POD has been shown to produce reliable and valid measurements of body composition in comparison to Dual Energy X-ray Absorptiometry (DEXA) [12]. When comparing the measurements between the DEXA and the BOD POD, results have shown a Pearson correlation of 0.94 ($p < 0.001$) and an intraclass correlation of 0.97 ($p < 0.001$) [13]. Thoracic volume was measured twice to make sure readings were within 0.300 ml of each other. The average of the two readings was used to calculate body fat percentage.

Physical Activity. The ActiGraph GT3X accelerometer was used to objectively measure physical activity. Accelerometers have shown good correlations ($r = 0.74$ to 0.95) to energy expenditure during walking, running, and other defined activities [14-18]. The accelerometer was worn on the right side of the body at the level of the umbilicus and above the anterior superior iliac spine. Participants wore the belt continually for seven consecutive days, removing it for water activities only. Participants were asked to log any times the belt had to be removed for water activities.

A day's data was considered complete if the participant wore the monitor 75% of the time between 7 a.m. to 11 p.m. Non-wear time was conservatively defined as twenty or more minutes of consecutive zeros [19]. Data was collected in 60 second epochs. Physical activity intensity levels were categorized using the cut-points established by Troiano et. al [20]: vigorous activity (>5999 counts/min), moderate activity (2020-5999 counts/min), light activity (250-2019 counts/min), and sedentary (0-249 counts/min).

Data Analysis

The purpose of this study was to assess the relationship between physical activity intensity and body composition. The criterion variable was body fat percentage and the predictor variable was intensity of physical activity. Descriptive statistics (mean, standard deviation, etc.) were reported for all variables of interest. Vigorous physical activity was log transformed for data analysis. Pearson product-moment correlations were used to measure bivariate relationships. The general linear model was used to detect differences between groups for variables of interest. Contrast coding was used when comparing groups of differing amounts of time spent in both vigorous and moderate to vigorous physical activity (MVPA). The best predictors for outcomes of interest were identified through stepwise regression. Logistic regression was used to assess the probability of having excess body fat (≥ 32 %) given the amount of time spent in MVPA per day [21]. Appropriate controls (age and season of assessment) were added to the statistical models to account for potentially confounding variables. Seasons were developed by grouping three months with similar temperatures together into winter, spring, summer and fall seasons. The SAS® system 9.3 (Cary, NC) was used to compute all statistical analyses. The level of significance was set at 0.05.

Results

A total of 249 women were recruited to participate in the study. Of those 249 women, 239 had complete body composition and activity data. All women included in the analysis had at least 2 complete weekend days and 3 complete weekdays of physical activity observation. The means number of days observed was 6.7 ± 0.7 days.

The characteristics of the 239 women are reported in Table 1. Participants were primarily Caucasian (88.2%), with the remaining women including Asian, Hispanic, African-American, and other. The participants in the study represented 36 different states and 6 different countries. The mean age of participants was 20.6 ± 1.6 years and the average daily activity count was 387,560 ± 172,000. Using BMI, 5% of the women were underweight (< 18.5 kg m^{-2}), 76% were normal weight (18.5-24.9 kg m^{-2}), 15% were overweight (24-29.9 kg m^{-2}), and 3% were obese (≥30 kg m^{-2}). Furthermore, 16% of women had a body fat level classified as "Athletic" (10-20%), 30% had a body fat classified as "Fitness" (20-24%), 36% had a body fat classified as "Average" (25-31%), and 18% of women had a body fat level classified as "Obese" (≥32%) [21]. The top three reported activities among participants were jogging, sports, and weight lifting. The percentages of women who participated in the reported activities at least once during their week of observation are included in Figure 1.

Pearson-r correlations were calculated between activity levels and the outcome variables of body fat, BMI, waist circumference, hip circumference, and waist-to-hip ratio (Table 2). Total activity counts per day were inversely associated with body fat (r = -0.17, p = 0.007). Time spent in sedentary activity was not significantly correlated with any outcome variables. Light activity was positively correlated with both BMI (r = 0.17, p= 0.007) and waist circumference (r = 0.15, p = 0.0164). Moderate activity was inversely associated with body fat (r = -0.18, p = 0.0051) and hip circumference (r = -0.12, p = 0.0459). MVPA was inversely associated with body fat (r = -0.19, p = 0.0026) and hip circumference (r = -0.14, p = 0.0291). Vigorous physical activity was inversely related to body fat (r = -0.20, p = 0.0023).

Stepwise regression indicated that the best predictor of body fat was time spent in vigorous physical activity per day (F = 9.45, p = 0.0024). This relationship was not altered by controlling for age or season. The best predictor of BMI was light activity per day, which was positively correlated with BMI (F = 7.5, $p = 0.0066$) followed by moderate activity per day which was negatively correlated (F = 4.25, $p = 0.0403$). Controlling for age had little impact on the relationship between BMI and light activity but weakened the relationship between BMI and moderate activity, which resulted in a non-significant relationship (F = 2.22, $p = 0.1374$).

When women were divided into groups based on time spent in vigorous physical activity (0 min/day, 0-5 min/day, 5-10 min/day, and >10 min/day), there was a significant difference across categories for body fat (F = 17.43, $p < 0.0001$) (Table 4). Women who spent no time performing vigorous physical activity had significantly higher body fat than did women who performed some vigorous physical activity per day. This relationship was independent of age and season, although controlling for age weakened the relationship by 23.6% (F = 13.56, $p = 0.0003$). A significant difference was also found across all categories for BMI (F = 7.54, $p = 0.0065$). Women who spent no time performing vigorous physical activity had significantly higher BMIs than did women who performed some vigorous physical activity per day. Controlling for season had little impact on this relationship but controlling for age weakened the relationship by 37.8% (F = 4.81, $p = 0.0293$).

When participants were divided into groups based on time spent in MVPA (0-29 min/day, 30-59 min/day, 60-89 min/day, and ≥90 min/day), body fat differed significantly across categories (F = 4.67, $p = 0.0316$) (Table 3). Those women in the group which spent less than 30 minutes per day in MVPA had significantly higher body fat percentages than those women who obtained more than 30 minutes per day. Controlling for age weakened the relationship by 37.4% (F = 2.98, $p = 0.0855$) to the point where there was no longer a significant relationship. However, controlling for season strengthened the relationship by 126.8% (F = 10.77, p =

0.0012). When controlling for both age and season, the relationship was strengthened by 52.8% and remained significant (F = 7.35, p = 0.0072). BMI also differed significantly across categories (F = 4.33, p = 0.0385). Similar to body fat percentage, BMI was significantly higher among those in the group which spent less than 30 minutes in MVPA. Controlling for age weakened the relationship by 40.9% to the point where it was no longer significant (F = 2.61, p = 0.1072). Similar to body fat however, controlling for season strengthened the relationship by 49.1% (F = 8.51, p = 0.0039). When controlling for both age and season, the relationship was strengthened by 20.3% and therefore remained significant (F = 5.29, p = 0.0224).

Differences in body fat were examined according to time spent at varying intensity levels (Table 5). For a given amount of time, as the minimum intensity level increased, body fat levels tended to decrease. For a given intensity level, as time spent at that intensity level increased, body fat levels tended to decrease.

Logistic regression revealed that for every 10 minutes spent in MVPA per day, the odds of being obese (≥ 32% body fat) decreased by 33% (Figure 2). The probability of being obese for a woman who obtained only 10 minutes per day of MVPA was 0.49, whereas the probability for a woman who obtained 120 minutes was 0.02.

Odds ratios revealed that the odds of being obese by body fat for those who did not obtain at least 30 minutes per day of MVPA were 3.2 (95% CI: 1.5-6.9) times greater than those who obtained 30 minutes or more per day. The odds of being overweight by BMI (≥ 25) for those who did not obtain at least 30 minutes per day of MVPA were 3.5 (95% CI: 1.6-7.4) times greater than those who obtained 30 minutes or more per day.

Discussion

A major finding of this study is the important inverse associations between body fat percentage and both vigorous physical activity and MVPA in young adult women. Among all activity levels, vigorous PA had the strongest inverse correlation with body fat percentage. MVPA had a similarly strong relationship to body fat.

The 2008 Physical Activity Guidelines for Americans sets the vigorous physical activity recommendation at 75 minutes per week [22]. Although this recommendation was not developed for weight management our results support the recommendation as we found improved body composition with increasing amounts of vigorous physical activity. Not only was vigorous physical activity found to be inversely correlated with body fat, but a significant association was also found with body fat when vigorous physical activity was examined by groups of differing amounts of vigorous physical activity. Assuming a causal relationship, these findings underscore the importance of getting at least some vigorous activity as those women who did not get any vigorous activity had the highest body fat. Based off of energy balance principles it makes sense that more time spent in vigorous activity would increase energy expenditure and thus lead to improved body fat.

The relationship between moderate activity and healthy weight management in these young adults is a little less clear. Time spent in moderate activity was significantly correlated with body fat percentage. However, once vigorous physical activity was controlled, moderate activity was no longer significantly associated with body fat. Similarly, moderate activity was initially correlated with BMI but when age was controlled the relationship was no longer significant. From the results of our study it seems that the role that moderate physical activity plays in healthy weight management in young adult women is complex and more research is needed to examine this relationship further.

Combining time in vigorous activity with time spent in moderate activity does seem to have some utility as this was predictive of body fat. When examining the relationship between MVPA and body fat according to time spent in MVPA, obtaining more than 30 minutes per day was associated with lower body fat levels among young adult women. This same relationship held true for BMI. Interestingly, both age and season of assessment had significant impacts on these relationships. Controlling for age weakened the relationship between MVPA and body composition but controlling for season strengthened the relationship. This highlights the importance of accounting for these variables when evaluating physical activity and body composition in young adult women.

Perhaps the most interesting finding of this study is the reduction in odds of being obese when examining varying amounts of time spent in MVPA. The probability of being obese for a young woman who spent only 10 minutes per day in MVPA was 0.49, whereas the probability for a woman who spent 120 minutes per day in MVPA was 0.02. Our results support the recommendation from the 2008 Physical Activity Guidelines for Americans of obtaining at least 30 minutes per day of moderate activity [22]. Furthermore, results supported the Physical Activity Guideline's statement that greater health benefits are achieved when moderate physical activity is increased beyond 300 minutes per week [22].

One surprising finding was that sedentary time had no relationship with body composition and time in light activity was actually predictive of higher BMIs. Some research has suggested that decreased time spent in sedentary behaviors, such as TV viewing, and increased time in light activity will correlate with better body composition outcomes in women [23]. While our study does not refute this theory, our results do not support this argument. The 2008 Physical Activity Guidelines for Americans refer to light activity as "baselines activities" and states that it is unclear whether doing more baseline activities would result in health benefits [22]. Our study does not indicate that higher amounts of light activity are associated with better body composition outcomes.

It is interesting to point out that a correlation between an activity level and body fat did not necessarily mean that the same activity level would also be correlated with BMI. Of the four variables which were significantly correlated with body fat (total activity counts, moderate PA, vigorous PA, and MVPA), none were significantly correlated with BMI. The only variable that was significantly associated with BMI was light activity (which was a positive correlation). This emphasizes the importance of examining body fat in addition to BMI when examining weight management in young adult women. While BMI and body fat are highly correlated, there seems to be a meaningful difference between the two constructs. This difference can change the outcome of the study and possibly alter the final conclusions.

In a similar study conducted by Den Hoed and Westerterp (2008), physical activity was measured in 80 college women of the Netherlands for two weeks using an accelerometer. They found that total physical activity explained about 4% ($R^2 = 0.79$, SEE = 3.7%, $P < 0.001$) of the variance in body composition, which is similar to the findings of our study [10]. Similar to our study, they also found that low intensity physical activity was positively correlated with body fat and moderate and high intensity physical activity were negatively correlated with body fat. However because of the limited sample size they were unable to expand these relationships beyond just the simple correlations. Our study provides support to their findings and better evaluates the nuances of the relationship between intensity of physical activity and both body weight and composition. It provides support for higher intensity activity and emphasizes the potential negative impact on body weight and adiposity from not meeting current physical activity guidelines.

There are a few limitations to our study. A primary limitation of this study is its cross-sectional design, which does not allow us to determine the direction of the relationship. Secondly, although accelerometers provide objective measurements of physical activity, they cannot be worn while performing water activities, such as swimming. However, of the 239 participants in our study, only 26 reported swimming at some point during their week of assessment.

While there are some limitations to our research, the findings from this study make some significant contributions to the existing literature on intensity of physical activity and body composition among young adult women. To date studies evaluating this relationship have relied primarily on subjective measurements of physical activity. The use of accelerometers allowed us to not only draw conclusions about physical activity in general, but provided a deeper understanding of the roles that varying intensity levels play in body composition in this population of women. Our study supports the general finding in the literature that there is a relationship between total physical activity and body fat, however our study highlights in particular the important association between both MVPA and vigorous activity and lower body fat among young adult women.

In conclusion, vigorous PA and MVPA appear to be the most important aspects associated with lower body fat and BMI levels. Assuming a causal relationship, young adult women should be encouraged to obtain at least 30 minutes of MVPA per day. Furthermore, increasing amounts of MVPA beyond 30 minutes is associated with even lower odds of having elevated body fat. Further research should continue to explore the relationship between intensity of physical activity and body composition in both longitudinal and experimental designs.

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Table 1 Descriptive data for all participants (n = 239).

Variable	M	SD	Range
Age	20.6	1.6	17.7-26.1
Height (cm)	165.9	7.0	147.2-183.5
Weight (kg)	62.3	9.5	42.9-95.6
BMI[a] (kg m^{-2})	22.6	3.0	17.1-34.8
Waist (cm)	73.0	6.8	62-110.1
Hip (cm)	97.7	7.4	67.9-123.7
WHR[b]	0.75	0.04	0.64-0.92
Body fat (%)	26.4	6.3	9.5-44
Sedentary counts per day	1203.7	51.9	1036.1
Activity counts per day[c]	387.6	127.2	138.8-940.2
MVPA[d] (min/day)	61.6	22.5	6-136.7
Light activity (min/day)	169.4	43.0	83.1-337.3
Moderate activity (min/day)	55.6	19.0	6.0-126.0
Vigorous activity (min/day)	6.0	9.2	0-65.3

[a] BMI, body mass index

[b]WHR, waist-to-hip ratio

[c]Counts divided by 1000

[d]MVPA, moderate to vigorous physical activity

Table 2 Correlations (n =239).

	Body fat	BMI	Waist	Hip	WHR
Activity counts per day	-0.17[a]	-0.05	-0.05	-0.08	0.03
Sedentary (min/day)	0.06	-0.08	-0.07	-0.03	-0.06
MVPA[b] (min/day)	-0.19[a]	-0.11	-0.11	-0.14[a]	0.02
Light activity (min/day)	0.02	0.17[a]	0.15[a]	0.09	0.11
Moderate activity (min/day)	-0.18[a]	-0.12	-0.11	-0.12[a]	0.00
Vigorous activity (min/day)	-0.20[a]	-0.03	-0.03	-0.07	-0.05

[a]$P \leq 0.05$

[b]MVPA, moderate to vigorous physical activity

Table 3 Body composition and time spent in MVPA.

	Group 1		Group 2		Group 3		Group 4			
	0-29 min/day n=16		30-59 min/day n=103		60-89 min/day n=92		≥90 min/day n=28			
	M	SD	M	SD	M	SD	M	SD	F	*p*
Body fat (%)	28.2[a]	6.9	26.7[b]	6.2	25.6[b]	5.9	24.3[b]	5.4	7.35	0.0072
BMI* (kg/m^2)	23.5[a]	3.9	22.6[b]	3.0	22.5[b]	2.9	21.8[b]	2.3	5.29	0.0224

Means with a superscript letter that is the same as the letter of another mean in the same row are not significantly different ($p > 0.05$). F and p values reflect comparisons against the group of women who had 0-29 min of MVPA per day after controlling for season of assessment and age.

*BMI, body mass index

Table 4 Body composition and time spent in vigorous activity.

	Group 1		Group 2		Group 3		Group 4			
	0 min/day		>0 and <5 min/day		>5 and <10 min/day		≥10 min/day			
	n = 28		n = 135		n = 30		n =28			
	M	SD	M	SD	M	SD	M	SD	F	*p*
Body fat (%)	30.9[a]	7.0	25.9[b]	6.2	25.1[b]	6.0	25.4[b]	5.7	17.43	< 0.0001
BMI* (kg/m^2)	24.1[a]	3.2	22.4[b]	2.9	22.1[b]	3.5	22.5[b]	2.9	7.54	0.0065

Means with a superscript letter that is the same as the letter of another mean in the same row are not significantly different ($p > 0.05$). F and p values reflect comparisons against the group of women who had no vigorous activity.

*BMI, body mass index

Table 5 Differences in body fat across levels of activity duration at various intensity levels.

Intensity (activity counts)	0-29 min/day	30-119 min/day	≥120 min/day	F	*p*
≥ 3,000	37.2 ± 4.8[a] (n =3)	28.6 ± 6.4[a] (n = 22)	26.0 ± 6.1[b] (n = 213)	4.6	0.0010
≥ 4,000	28.9 ± 6.7[a] (n = 25)	27.2 ± 6.5[a] (n = 92)	25.2 ± 5.8[b] (n = 121)	3.4	0.0343
≥ 5,000	27.9 ± 6.8[a] (n = 87)	25.5 ± 5.7[b] (n = 106)	25.4 ± 6.1[b] (n = 44)	3.9	0.0259
≥6, 000	27.2 ± 6.5[a] (n = 142)	25.4 ± 5.8[b] (n = 70)	24.9 ± 5.7[a] (n = 24)	3.1	0.0498
≥7, 000	26.7 ± 6.7[a] (n = 174)	26.0 ± 4.2[a] (n = 45)	24.5 ± 6.7[a] (n = 15)	1.0	0.4810

Means with a superscript letter that is the same as the letter of another mean in the same row are not significantly different ($p > 0.05$).

F and *p* reflect comparisons between categories after age and season of assessment were statistically controlled.

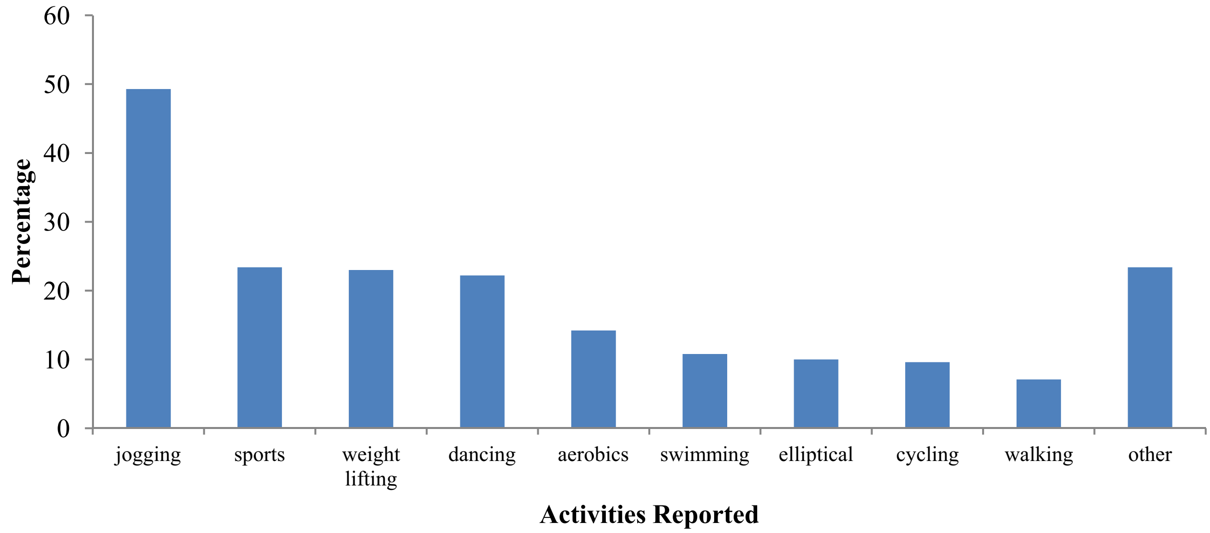

Figure 1 Percent of women who participated in reported activities at least one time during the observation week

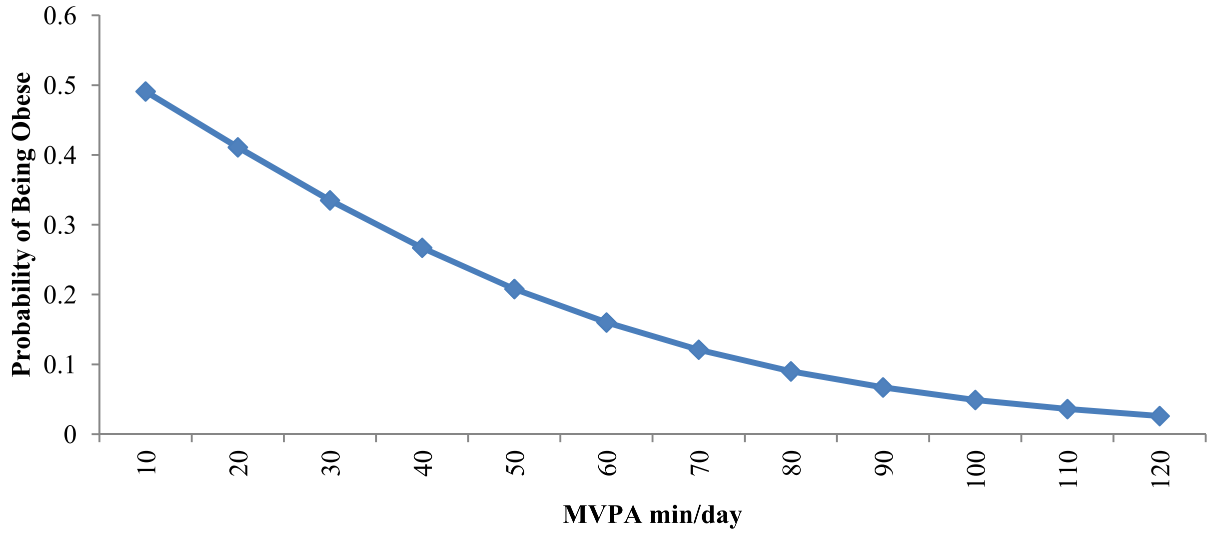

Figure 2 Probability of being obese (>32% body fat) by time spent in MVPA
Note: The logistic regression that was used for this figure: Y = X*0.0324 – 0.2897

Prospectus

Intensity of Physical Activity and Body Composition: A Cross-Sectional Analysis of Young Adult Women

Pamela Borup

Chapter 1

Introduction

The growing prevalence of obesity over the past few decades is alarming. In the United States nearly 68 percent of the population is overweight or obese (Flegal, Carroll, Ogden, & Curtin, 2010). It is estimated that in the U.S. over 147 billion dollars are spent each year on the direct and indirect costs associated with obesity (Finkelstein, Trogdon, Cohen, & Dietz, 2009). Preventing these high obesity rates and the health risks associated with them is a growing problem in the United States (Main, Rao, & O'Keefe, 2010).

There are numerous health risks associated with obesity. Heart disease, type 2 diabetes, and certain types of cancers have been shown to be significantly associated with obesity. These three conditions are among the top 7 causes of death in the United States (Xu, Kochanek, Murphy, & Tejada-Vera, 2010). By preventing an accumulation of excess body weight, the prevalence of these diseases may be reduced (Main, et al., 2010).

A central component of diminishing the prevalence of obesity includes identifying the critical periods where excess weight tends to be gained or unhealthy habits established. According to the Behavioral Risk Factor Surveillance System, the greatest increase in the rate of obesity occurs among 18-29 year-olds who have some college education (Mokdad, et al., 1999; Orr, et al., 2008). The college years are therefore a critical time period in which to prevent excess weight gain.

During the freshman year of college alone, a weight gain of about 1.7 to 4.2 kilograms is commonly seen in men and women (Cluskey & Grobe, 2009). Increases in percent body fat during the freshman year tend to be around two percentage points (Hajhosseini, et al., 2006). Multiple factors play into this weight gain including dietary habits and physical activity (Wengreen & Moncur, 2009).

It has been shown that physical activity tends to decline in the transition from high school to college (Wengreen & Moncur, 2009). What is less understood is the actual relationship between the intensity of physical activity and body composition in university students. Though not always a straightforward relationship, physical activity has been shown to be significantly associated with percent body fat during the college years (den Hoed & Westerterp, 2008). Intensity of physical activity has also been shown to have a significant role in body fat regulation (B. W. Bailey, Tucker, Peterson, & LeCheminant, 2007), though it has not yet been adequately studied among college aged individuals.

A better understanding of the relationship between intensity of physical activity and body composition will aid in preventing obesity. Profiling the intensity of physical activity associated with healthy body compositions in young adult women may increase our understanding of the intensity of physical activity college women should participate in to promote a healthy level of body fat. It may also help universities to establish wellness goals or requirements for their students in order to fight the obesity epidemic.

Statement of the Problem

The proposed cross-sectional study will examine the relationship between intensity of physical activity and body composition in approximately 125 undergraduate women.

Research Questions

1. To what extent is total physical activity associated with body fat in young adult women?
2. To what extent is each activity level (sedentary, light, moderate, and vigorous) associated with body fat in young adult women
3. Which activity levels are the best predictors of body fat?

Limitations

Although an objective method will be used to assess physical activity, human error can still be present. Less accurate measurements may be obtained if participants fail to properly wear the accelerometer. In addition, causality cannot be established based on the cross-sectional nature of the study.

Delimitations

Participants will be delimited to currently enrolled undergraduate healthy women between the ages of 17-30 yrs. Participants will be single or married but will be excluded if they have had a baby in the past 6 months or are planning on having a baby in the next year. Participants will also be excluded if they are not able to perform moderate to vigorous physical activity or are taking medications that alter metabolism.

Operational Definitions

Sedentary- 0-249 counts per minute

Light intensity- 250-2019 counts per minute

Moderate intensity- 2020- 5999 counts per minute

Vigorous intensity- more than 5999 counts per minute (Troiano, et al., 2008)

Chapter 2

Review of the Literature

The prevalence of obesity has dramatically increased over the past few decades. In the United States nearly 68 percent of the population is overweight or obese (Flegal, et al., 2010). The rise in obesity rates has been attributed in part to the overall decrease in energy expenditure resulting from the sedentary lifestyle associated with the technology and culture of today (Ball, Owen, Salmon, Bauman, & Gore, 2001).

According to the Behavioral Risk Factor Surveillance System, the greatest increase in the rate of obesity occurs among 18-29 year-olds who have some college education (Mokdad, et al., 1999; Orr, et al., 2008). The college years have been identified as a critical period for weight gain and therefore may be a key time to implement obesity and weight gain prevention programs (Anderson, Shapiro, & Lundgren, 2003; Mokdad, et al., 1999). An important component of weight gain prevention is energy expenditure though physical activity.

This review of current literature will examine the research surrounding the relationship between physical activity and body composition and more specifically how it applies to university students. The research will be divided based on subject characteristics: General Adult Population and University Adult Population.

General Adult Population

Among the general adult population the studies involving physical activity and body composition tend to assess a wide range of ages. It is known that body fat tends to increase with age, but the association between physical activity and the body fat is less understood (Williamson). Much of the research surrounding physical activity deals with the Body Mass

Index (BMI) rather than a more precise measurement of body fat. Though studies assessing BMI and physical activity tend to find significant associations between the two variables, studies dealing with BMI are not included in this literature review so as to allow the focus to be placed on body fat. The following research is categorized according to research design: Cross-Sectional, Longitudinal, and Experimental.

Cross-Sectional

A cross-sectional approach to examining physical activity and body composition among the general adult population is effective for evaluating the relationship between the two variables without considering their interaction over time. Of the following studies, two suggest that an association exists in both genders, two found an association in men only, and four studies found an association in women only.

Tremblay et al. (1990) studied the association between intensity of physical activity and subcutaneous body fat in adults ranging in age from 20 to 49 years. The participants included 1366 women and 1257 men. Intensity of physical activity was estimated through a questionnaire similar to the Minnesota Leisure Time Activity Questionnaire and body fat was measured by the sum of five skinfolds. Results showed that among women, those participants in the high (reported activities ≥9 METs for ≥6 months in the past year) and moderate (≥7 METs and <9 METs for ≥6 months in the past year) groups had significantly lower subcutaneous body fat measurements than those in the sedentary group (reported no activities ≥5 METs for ≤6 months in the past year). Among men, those participants in the high intensity group had significantly lower subcutaneous body fat measurements than those in the sedentary group. Even when total energy expenditure from leisure-time physical activity was controlled, among both men and women the highest intensity groups still had significantly lower subcutaneous body fat than the sedentary group.

Klesges, Eck, Isbell, Fulliton, and Hanson (1991) examined the relationship between physical activity and body composition in 221 men and 221 women ranging from 23-52 years old (average age of 34.7). Three physical activity questionnaires were administered, specifically the Paffenbarger scale, the Baecke physical activity questionnaire, and the SCAN Energy Balance Questionnaire. Body fat was determined through three skinfold sites. The results indicated that increased time spent in aerobic and leisure activities correlated negatively to body composition in both men and women. Women who participated in aerobic leisure time physical activity had a correlation coefficient of -0.29 ($P<0.001$) and men who participated in aerobic leisure time physical activity had a correlation coefficient of -0.26 ($P<0.001$).

In a study by Ball, Owen, Salmon, Bauman, and Gore (2001) the association between physical activity and body composition was further examined in a larger number of both men and women. A cross-sectional analysis of 1,302 men and women ages 18-78 years was performed. Data from the Pilot Survey of the Fitness of Australians was used. Participants were shown a survey containing a list of physical activities and asked to recall the type, frequency, duration, and intensity of each activity performed during the past two weeks. Body composition was calculated using the sum of six skinfold measures. Subjects were considered to be in the "lower" body fat category if the sum of the six skinfolds was below the gender-specific median. Results showed increased odds of having lower body fat for women with moderate (OR 2.36; CI 1.31-4.23) and high (OR 2.92; CI 1.55-5.52) amounts of leisure time physical activity. Unlike the study by Klesges et al. however, no significant association was found among men.

Westerterp and Goran (1997) also studied the differences among men and women as related to physical activity and body composition. Participants included 146 Caucasian women and 144 Caucasian men ranging in age from 18-49 years old. Energy expenditure was measured through the doubly labeled water method and percent body fat was measured with hydrodensitometry or with isotope dilution. Contrary to the findings of Ball et al. (2001), a higher amount of physical activity was related to a lower percent body fat in men (r=-0.35, P<0.01), but the study showed no relationship between physical activity and body composition in women.

In a study limited specifically to middle-aged African-American women, Hornebuckle, Bassett, and Thompson (2005) examined the relationship between body composition and physical activity as measured by pedometers. Body composition was measured in the Bod Pod and pedometers were worn for seven consecutive days. A significant inverse association was found between average steps per day and body fat percentage in these African-American women. Body fat percentage and average walking volume had a Pearson correlation of -0.506 ($p < .001$). After controlling for age and energy intake, the relationship remained moderately strong with a partial correlation of -0.4267 ($p < .001$).

In a very similar study performed a year earlier, Thompson, Rakow, and Perdue (2004) found a strong inverse association between steps per day and body fat percentage among middle-aged women. Results showed a Pearson correlation of -0.713 ($p < .0001$). When divided into three groups (low, moderate, high) based on average steps per day, the body fat percentages were significantly different between the three groups. Those in the low steps group had the highest average body fat percentage, followed by the moderate steps group, and finally the high steps group had the lowest average body fat percentage. Along with the study by Hornebuckle et al., these studies show that among middle-aged women, physical activity as measured by step counts is inversely associated with body fat.

Paul, Novotny, and Rumpler (2004) also studied energy expenditure and body composition in men and women and went on to examine the importance of energy intake to this relation. Subjects consisted of 47 women and 44 men. The doubly labeled water method was used to assess total energy expenditure. Energy intake was measured using two 24-hour dietary recalls. Similar to the results found by Westerterp and Goran (1997), there was a significant but weak relationship between energy expenditure and percent body fat in men (r=-0.34, P<0.03), but not in women. More active men tended to have a lower percent body fat but the same was not true for women. The authors suggested that a possible explanation for the difference could be due to the carbohydrate and fat intake by women.

Tucker and Peterson (2003) also accounted for energy intake in a study examining the association between duration and intensity of physical activity and body composition in women. Accelerometers were worn for seven days in order to measure physical activity and body composition was measured in the Bod Pod. Findings showed that beyond the lowest intensity category, the leanest women participated in the longest durations of physical activity and the fattest women participated in the shortest duration in each intensity category. Controlling for energy intake strengthened the relationship by 14%. Controlling for total physical activity weakened the relationship by 30%, however in each intensity category the relationship remained significant.

In the above cross-sectional studies, the lack of unanimity may be due to the methods used to assess physical activity. The three studies which used questionnaires had conflicting results, whereas both studies which used the doubly labeled water method found an association between physical activity and body composition to exist only in men. The three studies which objectively measured physical activity in women through the use of accelerometers and pedometers found a significant association to exist.

Longitudinal

A longitudinal research design facilitates the observation of changes and relationships over time in the same subjects. The following longitudinal designs found physical activity to play an important role in weight and body fat control.

Weinsier et al. (2002) studied the free-living energy expenditure and physical activity of premenopausal women who were successful and unsuccessful at maintaining a normal body weight over the course of a year. Participants included 61 white or black premenopausal women ages 20-46. Energy expenditure was measured using the doubly labeled water method and body composition was determined by dual-energy X-ray absorptiometry. This study measured subjects one year from their original measurement and found that women who were successful at maintaining a normal body weight maintained higher levels of free-living energy expenditure and physical activity than those who were unsuccessful in maintaining their weight ($p < 0.02$). The activity energy expenditure was 44% higher (by 212 kcal/d) across time in the maintainers group than in the gainers group.

Bailey, Tucker, Peterson, and LeCheminant (2007) also assessed premenopausal women, but analyzed the relationship between intensity of physical activity and changes in adiposity. Participant's physical activity was measured using accelerometers worn for seven days at a time and body composition was measured in the Bod Pod. Measurements were taken at a baseline and follow-up appointment separated by 20 months. At each appointment, the intensity of physical activity for each participant was categorized based on 10- minute epoch counts. After the follow-up appointment, change in intensity levels were analyzed and participants were classified as having increased intensity, maintained intensity, or decreased intensity. Body composition changes were also categorized as having increased in body fat, maintained body fat, or decreased in body fat. The cross-sectional results from both the baseline and follow-up testing periods showed women in the vigorous intensity category to have significantly lower body fat percentages than those women in the low ($p < .0001$) and moderate ($p=.0006$) intensity categories. There was no difference in body fat between the low and moderate intensity groups. At follow-up, significantly more women who decreased physical activity intensity had a higher body fat percentage than those women who maintained or increased physical activity intensity ($p <.05$). Sixty-five percent of those women who decreased intensity had a higher body fat percentage at follow-up. In contrast, only 48% of women who maintained intensity and 46% of women who increased intensity had a higher body fat percentage at follow up. The results of this prospective study indicated that women who maintain or increase physical activity over time are at reduced risk of body fat gains. The cross-sectional results demonstrated that those women who participated in vigorous physical activity were the leanest.

In both of these longitudinal studies, higher levels of physical activity were associated with less body fat gain.

Experimental

Experimental research is perhaps the best for identifying meaningful cause-and-effect data. The following experimental studies found physical activity to play a significant role in the reduction of body fat.

Slentz et al. (2004) conducted a randomized controlled trial to determine the effects of different amounts and intensities of physical activity on body composition and measures of central obesity. A total of 120 men and post-menopausal women age 40-65 years-old participated. All subjects were classified as sedentary and overweight and were randomly assigned to one of three intervention groups: high amount/vigorous intensity (caloric equivalent of approximately 20 miles of jogging per week), low amount/vigorous intensity (equivalent to approximately 12 miles of jogging per week), and low amount/moderate intensity (equivalent to approximately 12 miles of walking per week). Body composition was assessed via four skinfolds at the beginning and end of the eight month trial period. Results showed a significant dose-response relationship ($p < 0.05$) between the amount of physical activity and fat loss. The high volume of activity resulted in the largest loss of body fat at the abdominal and suprailiac skinfold sites compared with the two lower volume groups, which in turn had larger reductions than the control group. The effect of the exercise intensity on body fat loss was concluded to be nonsignificant, whereas the exercise duration had a much clearer effect on the reduction of body fat in middle-age men and post-menopausal women.

Kemmler et al. (2010) conducted a randomized controlled trial to assess the effects of a multipurpose exercise program on body fat in postmenopausal white women ages 65-80 years old. Over the course of the 18 month study, the 115 participants in the experimental group participated in two supervised weekly group sessions and two at-home autonomous training sessions while the 112 participants in the control group participated in a wellness program that focused on well-being. The group exercise session included twenty minutes of aerobic dancing at 70-85% of the maximum heart rate. The at-home training sessions focused mainly of resistance training. Body fat was measured with dual-energy x-ray absorptiometry. At the end of the study it was found that both abdominal and total body fat decreased significantly (p=.001) among the exercise group. In the control group abdominal fat did decrease significantly (p=.001), however total body fat did not decrease significantly. It was concluded that a multipurpose exercise program of high-intensity can reduce abdominal and total body fat among postmenopausal women.

In conclusion, the studies surrounding physical activity and body composition in men and women of the general population have shown some conflicting results. Some studies show a significant association between physical activity and body composition in both men and women, while others have shown that there is only a significant association among one of the genders. Seven of the above studies measured physical activity objectively whereas others relied on surveys, which tend to be more conducive to studying large numbers of participants but are prone to self-report error. The subjects of these studies also varied dramatically in age. The majority focused on middle aged subjects, yet others had a much larger age range.

University Adult Population

The college years are an important time period in which excess weight tends to be gained (Mokdad, et al., 1999). During the freshman year of college alone, weight gains of 1.7 to 4.2 kilograms are common (Cluskey & Grobe, 2009). Hajhosseini et al. (2006) reported that on average percent body fat significantly increases from 30.1 ± 1.1 at the beginning of the freshman year to 32.2 ± 1.3 while lean body mass decreases from 69.9 ±1.2 to 67.8 ±1.3 at the end of the freshman year (p=0.001). Narrowing in on the college age group may be crucial to understanding the factors associated with the weight gain that commonly continues well into adulthood. The following literature examines body fat among university students. Much of the research surrounding physical activity in college deals with BMI rather than body fat percentage. Because BMI does not specifically measure body fat, the studies reviewed are limited to those that measured body composition. The studies are organized according to research design: Cross-Sectional, Longitudinal, and Experimental.

Cross-Sectional

Den Hoed and Westerterp (2008) cross-sectionally studied whether body composition is related to physical activity in university aged men and women. They studied 80 women (age 21 ±2 years) and 42 men (age 22.0 ±2.4). Physical activity was measured for two weeks through the use of a triaxial accelerometer. Body composition was measured by underwater weighing and deuterium dilution according to Siri's three-compartment model. Among women, body mass and height accounted for 41% of the variation in body fat percentage. Adding physical activity into the model increased the explained variation by 17% (R^2=0.58, SEE=3.3%, $P<0.001$). Among men, body mass and height accounted for 46% of the variation in body fat percentage. Adding physical activity into the model did not significantly improve the model unless seasonality was factored into the analysis (R^2=0.52 $p<0.05$).

Longitudinal

In a study limited to women only, Butler, Black, Blue, and Gretebeck (2004) examined changes in physical activity and body composition over the first 5 months of the freshman year. Physical activity was assessed though the Baecke Questionnaire of Habitual Physical Activity at the beginning of the freshman year and again 5 months later. Body composition changes were tracked using a 3-site skinfold assessment. Despite a significant reduction in mean caloric intake over the course of the study (measured by the Block Food Frequency Questionnaire), a significant increase in body fat occurred among the women. The fat gain was therefore believed to be associated with the significantly reduced physical activity levels of the participants (from 9.51 ± 2.03 to 8.75 ± 1.73, p=.05).

Edmonds et al. (2008) performed a similar study also limited to 116 freshman women only. Physical activity was measured using questions adapted from the National Longitudinal Survey of Children and Youth and the National Youth Risk Behavior Survey. Body fat was measured using bioelectrical impedance. Over the course of this 5 month study, body fat significantly increased from $23.8 \pm .5$ to $25.6 \pm .55$ ($P < .03$). Since no significant increase in dietary intake occurred (based on 3-day dietary records), the body fat gain was thought to be associated with the physical activity habits of the participants. A multiple regression model found a decrease in moderate physical activity to significantly predict weight gain at the end of the study (p=0.01).

Among these longitudinal studies of university women, both found body fat to significantly increase over the length of the study. Physical activity was assessed subjectively through questionnaires in both studies.

Experimental

Randomized controlled trials examining physical activity and body composition in university students is limited. Donnelly et al. (2003) tracked body composition changes throughout a 16-month exercise program. The intervention group ramped up their exercise duration from 20 minutes at baseline to 45 minutes at 6 months and their exercise intensity from 60% of heart rate reserve to 75% at 6 months. The exercise duration and intensity were then maintained throughout the rest of the study. Controls were instructed to maintain their usual physical activity patterns. Both groups maintained ad libitum diets. Results showed that the exercising men lost a significant amount of fat mass (4.9 ± 4.4 kg) in comparison to the controls. Among women, the exercisers maintained their fat mass whereas the controls significantly increased their fat mass (2.1 ± 4.8 kg).

In summary, research surrounding college students has shown that body fat gains occur specifically during the first year at a university. Relatively few studies performed on college students have focused on actual body composition, instead most tend to deal with body mass. Of the reviewed studies, one objectively measured physical activity through the use of accelerometers while the others relied on questionnaires. Results showed that specifically among women, physical activity and body composition are significantly associated. The cross-sectional study which also studied men found a significant association only when seasonality was factored in to the analysis.

Conclusions

Research has shown conflicting results about the relationship between physical activity and body composition in men and women. Some studies have shown that in non-university adult women there is no significant relationship between physical activity and body composition while others have demonstrated a relationship. A potential explanation for these varying results is the method used to assess physical activity. Questionnaires are prone to bias and self-report error. Specifically, women tend to underestimate their time spent in physical activity while men tend to overestimate time spent in physical activity (Klesges, et al., 1990). For this reason physical activity needs to be further assessed objectively through methods such as doubly labeled water or accelerometers.

Among university adults research shows that weight gains of about 1.7 to 4.2 kilograms occur during the freshman year. Those studies which have addressed body composition have shown an increase in percent body fat among men and women. Future research that objectively measures physical activity will improve our understanding of the relationship between physical activity and body composition among university students. The relationship between body fat and physical activity seems to differ between men and women, thus further research needs to be performed to independently examine body composition and it's relation to physical activity in men and women.

A better understanding of the role physical activity plays in body composition among university students is important in preventing the weight gain that can lead to obesity. By preventing excess weight gain, many of the problems and diseases associated with obesity can be avoided.

Chapter 3

Methods

Design

The proposed study will use a cross-sectional design following approximately 125 young adult women over the course of a year. Measurements began during the 2009-2010 academic year and will continue through the 2010-2011 academic year.

Participants

Participants include university women ages 17-30 yrs who were recruited during the 2009-2010 academic year and those that will be recruited during the 2010-2011 academic year. In order to join the study, participants have to be found healthy as determined by a health history questionnaire and able to participate in moderate to vigorous activity without limitations. Participants are non-smokers. Those who had a baby in the past six months or are planning on having a baby sometime in the next year are excluded from the study. Women taking any medications that alter metabolism are also excluded from the study.

Recruitment for the study took place and will continue to take place on the campus of Brigham Young University primarily through posters, flyers, a Facebook group, and word of mouth. Those interested in participating will fill out a screening form to ensure the inclusion criteria are met. Prior to participating, all participants will sign an informed consent form approved by the university's Institutional Review Board. All participant information and results will be kept confidential in a locked filing cabinet and password-protected computer.

Procedures

Participants who meet the inclusion criteria will be asked to participate in a seven day assessment period. At the first appointment height and weight will be measured and body composition will be assessed using the Bod Pod (Life Measurement, Inc., Concord, CA). Participants will be given a belt with the Actigraph GT3X accelerometer (Actigraph, Pensacola, FL) attached and instructed on how to properly wear the belt. A physical activity form will be sent home with the participants on which they are to log any times the belt was removed and the activities performed while the belt was off (e.g. swimming).

During the seven days of activity monitoring, each participant will be contacted once to ensure she is properly wearing the activity monitor. Following the seven days of activity monitoring participants will come in for the second appointment. At this point participants will return the activity monitor. Activity monitor data will be downloaded and checked to make sure that the data is complete. If the participant forgot to wear the monitor or the data is unusable (as a result of a monitor malfunction) the participant will be asked to wear the monitor again.

Following their week of assessment, participants will receive their body composition results as well as a $15 cash incentive for participating.

Instrumentation and Measurement Methods

Body Weight and Height. Body weight will be measured on a digital scale to the nearest 0.005 kg. In order to standardize the assessment, participants will be weighed while wearing a BYU issued swimsuit. The scale will be calibrated every two weeks. Height will be measured using a wall-mounted stadiometer and recorded to the nearest 0.1 cm.

Body Composition. The Bod Pod will be used to determine body composition. The Bod Pod has been shown to produce reliable and valid measurements of body composition in comparison to Dual Energy X-ray Absorptiometry (B W. Bailey, Tucker, Peterson, & LeCheminant, 2001). Thoracic volume will be measured twice to make sure readings are within

0.300 ml of each other. The average of the two readings will be used to calculate body composition.

Physical Activity. The Actigraph GT3X accelerometer will be used to objectively measure physical activity. The Actigraph accelerometer has been validated against the doubly labeled water method (Plasqui & Westerterp, 2007) for assessing physical activity. The accelerometer will be worn on the right side of the body at the level of the umbilicus and above the anterior superior iliac spine. Participants will wear the belt continually for seven consecutive days, removing it for water activities only. Participants will log any times the belt had to be removed for water activities.

A day's data will be considered complete if the participant wore the monitor 75% of the time between 7 a.m. to 11 p.m. Non-wear time is conservatively defined as twenty or more minutes of consecutive zeros (Masse, et al., 2005). Seven full days of data will be included in the analysis. Physical activity intensity levels will be categorized using the cut-points established by Troiano et. al: vigorous activity (>5999 counts/min), moderate activity (2020-5999 counts/min), light activity (250-2019 counts/min), and sedentary (0-249 counts/min) (2008).

Variables

The criterion variable will be body fat percentage and the predictor variable will be intensity of physical activity.

Data Analysis

The purpose of this study is to assess the relationship between physical activity intensity and body composition. Regression analysis using the general linear model will be used to measure the association between body composition and each intensity level. Partial correlation will be used to control for potential confounding variables. Pearson product-moment correlations will be used to measure bivariate relationships. The SAS® system (Cary, NC) will be used to compute all statistical analyses.

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