Physical Activity is Associated with Percent Body Fat and Body Composition but not Body Mass Index in White and Black College Students

MICHAEL ZANOVEC†[1], ANANTHA P. LAKKAKULA†[1], LISA G. JOHNSON‡[2], GEORGIANNA TURRI‡[1]

[1]School of Human Ecology, Louisana State University Agcenter, Baton Rouge, LA, USA; [2]Department of Kinesiology, Louisana State University, Baton Rouge, LA, USA

†Denotes graduate student author, ‡denotes professional author

ABSTRACT

Int J Exerc Sci 2(3): 175-185, 2009. The objective of this study was to examine the association of self-reported physical activity (PA) with body composition in 290 college students (49% male, 60% White) 18-25 years of age. Outcome measures included: self-reported PA levels calculated in MET-hrs·wk^{-1} from the International Physical Activity Questionnaire (IPAQ); body mass index (BMI; in kg·m^{-2}); and body composition variables estimated by dual-energy X-ray absorptiometry (DXA). Mean activity levels of the sample were 39.8 ± 23.8 MET-hrs·wk^{-1}. Participants were divided into quartiles of PA levels: ≥0 to <24.0, ≥24.0 to <34.0, ≥34.0 to <51.25, and ≥51.25 MET-hrs·wk^{-1} and body composition variables were compared by group. Chi-square analyses revealed a significant difference for gender by PA quartile [$x^2_{(3, N=290)}$ = 32.42, p < 0.0001], and for gender by race by PA quartile [$x^2_{(9, N=290)}$ = 37.82, p < 0.0001]. MET-hrs·wk^{-1} was inversely correlated with %BF (r = -0.40, p < 0.0001) but not BMI (r = 0.05, p = 0.43). When comparing body composition variables across PA quartiles, no significant differences were observed for BMI; however, subjects in the highest quartile of PA had a lower percent body fat (%BF) and fat mass (FM), and a higher lean-tissue mass (LTM) compared to subjects in the other three groups. In this cohort of young adults, participants in the highest activity group had a more fit body composition profile (e.g., lower %BF, lower FM, and higher LTM) which was not reflected in BMI and was independent of gender and race.

KEY WORDS: Physical activity, body composition, college students, IPAQ, DXA, BMI, body fat, race, ethnicity

INTRODUCTION

The prevalence of obesity has tripled among adolescents in the past three decades (28), coinciding with the steepest decline in physical activity (PA) levels observed between the ages of 13 and 18 years (30). The World Health Organization (WHO) identified the transition from high school to college as a critical period for the development of obesity (38). Furthermore, data from cross-sectional and prospective studies indicates that participation in

exercise decreases significantly between adolescence and adulthood, the age range of most university students (19, 21).

Obesity is defined as excessive fat accumulation to the extent that health may be impaired (38). Prevalence estimates of overweight and obesity are currently based on cut-points of body mass index (BMI; in $kg \cdot m^{-2}$), a proxy measure calculated as body weight adjusted for height (35). Many studies have shown that BMI is a reasonable measure of adiposity in healthy adults (7, 13, 14, 35); however, the use of BMI assumes that after adjusting weight for height, all individuals have the same relative body fatness independent of age, gender, and race (13), and therefore a BMI value of 30 $kg \cdot m^{-2}$ is considered obese in all adults aged 20 to 74 (35). For instance, percent body fat (%BF) increases with age (6) and is higher in females than males (13), but these differences may not be detected by BMI (2, 37). Moreover, there is substantial evidence to suggest that the relationship between BMI and %BF is dependent upon other factors including race/ethnicity (4, 8), body build (5), and level of PA (20, 23, 40). Consequently, the main limitation of using BMI as an index of obesity is that it fails to account for the composition of body weight (17), which is comprised mainly of fat, lean-tissue, and bone mineral (38).

The inherent limitations of using BMI to classify obesity are particularly exemplified when examining young adults with varying levels of physical activity. Physical activity has been shown to affect body composition and weight favorably by promoting fat loss while maintaining or increasing lean-tissue mass (11, 32, 34). Self-reports are the most

common method of obtaining PA levels at the population level. However, lack of a standardized instrument to measure PA has limited the capacity to make comparative inferences across different samples. A specific recommendation made by the World Health Organization in 2004 (39) is that more attention be given to national and international monitoring and surveillance of PA.

The International Physical Activity Questionnaire (IPAQ) was developed in 1998 by an international group of PA assessment experts in an effort to provide a valid instrument suitable for surveillance of health-enhancing PA (HEPA) levels among 15- to 65-yr.-olds within and between countries (3). The IPAQ has undergone extensive reliability and validity testing and is recommended for use by public health officials to monitor entire populations and to allow for international comparisons (3). Several studies (3, 9, 10, 12, 15, 31) have examined the criterion validity of the IPAQ compared with data from accelerometers, and one study (12) examined the validity of the IPAQ against fitness measures. Results from the 12-country reliability and validity study of the IPAQ reported the criterion validity of the short version against CSA accelerometers to be comparable to most other self-reports (N = 781, median ρ = 0.30, 95% CI: 0.23-0.36).

Using DXA to measure body composition and the IPAQ to assess PA levels, the purpose of this study was to examine the association of PA with BMI and body composition in a sample of White and Black college students.

METHOD

Recruitment and Data Collection

Participants were recruited during the 2006-2007 academic school year from undergraduate kinesiology and nutrition courses, fraternities and sororities, and flyers posted on-campus. Inclusion criteria were: 1) apparently healthy; 2) White and Black males and females; and 3) aged 18-25 yr. Race/ethnicity was self-reported. Exclusion criteria were: 1) subjects over 6 feet 4 inches tall and/or weighing over 250 pounds due to height and weight limits of the DXA device; and 2) individuals that reported race/ethnicity as Hispanic, Asian, or other. There were ten subjects excluded based on self-reported race/ethnicity; two subjects were older than 25 yr; two subjects were taller than six feet 4 inches; and one subject weighed over 250 lbs. A total of 290 (49% male, 60% White) students participated and were included in the analysis. Descriptive information of the sample were as follows: age 20.5 ± 1.6 y, BMI 24.6 ± 4.1 kg·m^{-2}, and %BF 24.4 ± 9.5. The research protocol was approved by the Louisiana State University institutional review board, and all subjects provided written informed consent.

All measurements were collected by one trained investigator (MZ) during a single laboratory session that lasted approximately one hour. Appointments were scheduled via e-mail, and subjects were advised to refrain from exercising on the day of testing and to not eat at least three hours prior. Subjects were also asked to wear lightweight, loose-fitting clothing free of metal and to remove all jewelry, hair clips, and shoes during measurements. Standing height was measured without shoes to the nearest 0.5 cm using a portable stadiometer (Shorr Inc., Olney, MD) with the subject's head positioned in the Frankfurt horizontal plane. Body mass was assessed to the nearest 0.1 kg with a digital scale (Seca, Model 880, Hanover, MD) calibrated daily using a 5-kg weight. Body mass index (BMI) values were calculated as weight in kilograms divided by height in meters squared.

Measures

DXA. Body composition estimates, including total percent body fat (%BF), fat mass (FM), lean-tissue mass (LTM), and bone mineral content (BMC) were obtained using a full-size Lunar Prodigy Pro (GE Lunar Corporation, Madison, WI) densitometer in conjunction with Encore 2004 software (version 8.10.027). The Prodigy Pro is a narrow-angle (4.5°) transversely scanning fan beam densitometer that uses a cadmium-zinc-telluride detector to directly convert x-rays into an electronic signal. The DXA machine was calibrated daily against a standard calibration block supplied by the manufacturer. The instrument automatically altered scan depth (standard or thick) based on the thickness of the subject as estimated from height and weight. All subjects were scanned in a supine position with the midline of the body centered on the table, arms by their side with palms face down, and feet held together by a Velcro strap. Approximate scan times were six and ten minutes for standard and thick modes, respectively. The *in-vivo* precision error for the Prodigy Pro given by the manufacturer is less than 1%. The *in-vitro* precision error of the phantom measurements used to calibrate the machine daily is 0.23%. In several

reviews of studies comparing DXA estimates of %BF to estimates obtained using a multi-component molecular model, Lohman determined the precision of %BF$_{DXA}$ to be within 1-3% BF (17, 22, 23).

Physical activity. The IPAQ short form was administered using an interview probe-type format to assess subjects' total health-enhancing PA during the previous seven days (www.ipaq.ki.se). Participants completed the short self-administered IPAQ version using an interview format directed by the researcher. A probe protocol similar to the one used by Rzewnicki et al. (29) was used to minimize the potential for over-reporting. Details regarding the questions asked and the procedures used have been reported elsewhere (40). Briefly, participants were asked to recall the frequency (days per week), duration (minutes) and level of intensity (vigorous, moderate, and walking) of PA undertaken during the previous 7 d within four domains: leisure-time PA, work-related PA, transport-related PA, and domestic and gardening (yard) activities. During the interview, respondents were asked to explain their responses, and to give more detailed reports of all activities. Attention was given to the explicit criteria used in the IPAQ scoring protocol such as breathing cues and the minimum duration of 10 minutes for individual bouts of physical activity.

Based on the responses, each subject's total physical activity level was calculated and recorded in MET-minutes per week (MET-min·wk^{-1}) according to the IPAQ scoring protocol (18). The MET levels derived from the IPAQ validity and reliability study (3) were 8.0, 4.0, and 3.3 for vigorous-intensity, moderate-intensity, and walking activities, respectively. MET-min·wk^{-1} were computed as: MET level x minutes of activity/day x days per week. These values were re-coded into MET-hours per week (MET-hrs·wk^{-1}) by dividing MET-min·wk^{-1} by sixty minutes. A detailed description of the IPAQ scoring protocol including the criteria for truncating extreme values is provided on-line (www.ipaq.ki.se).

Statistical Analysis

Data were examined using SAS (v. 9.1.3; SAS Institute, Inc., Cary, NC). Mean activity for the total sample was 39.8 ± 23.8 MET-hrs·wk^{-1}, with a range of 0-107.3. Participants were divided into quartiles of PA levels: ≥0 to <24.0, ≥24.0 to <34.0, ≥34.0 to <51.25, and ≥51.25 MET-hrs·wk^{-1}. Body composition variables were determined for each group. The percentages of participants in physical activity quartile groups were calculated by gender and race. Chi-square analyses were used to examine the frequency distributions of gender and race between IPAQ quartiles. Pearson correlation coefficients were computed for physical activity analyzed as a continuous variable (MET-hrs·wk^{-1}) and BMI and body composition. Mixed model analysis of variance using the SAS PROC MIXED procedure was utilized to calculate least-square means (LSM) and standard errors (SE) of the association between body composition variables and physical activity. In all models, IPAQ quartile was the grouping variable, and gender and race were included as covariates. All interactions were considered in the models. *Post-hoc* analyses with a Tukey-Kramer adjustment of the least-square means were used to compare differences between IPAQ categories. Significance was set at an alpha level of $P < 0.05$.

Table 1. Percentage of participants in physical activity quartiles by gender and race (N = 290)

| Gender/Race Group | Total sample | Quartiles of Physical Activity | | | |
| | | Q1 | Q2 | Q3 | Q4 |
	n (%)	n (%)	n (%)	n (%)	n (%)
Gender[1]					
Male	142 (49%)	20 (7%)	29 (10%)	40 (14%)	53 (18%)
Female	148 (51%)	52 (18%)	43 (15%)	33 (11%)	20 (7%)
Race					
White	175 (60%)	38 (13%)	40 (14%)	48 (17%)	49 (17%)
Black	115 (40%)	34 (12%)	32 (11%)	25 (9%)	24 (8%)
Gender x Race[1]					
White Female	85 (29%)	25 (8.6%)	24 (8.3%)	22 (7.6%)	14 (4.8%)
Black Female	63 (22%)	27 (9.3%)	19 (6.6%)	11 (3.8%)	6 (2.1%)
White Male	90 (31%)	13 (4.5%)	16 (5.5%)	26 (9.0%)	35 (12.1%)
Black Male	52 (18%)	7 (2.4%)	13 (4.5%)	14 (4.8%)	18 (6.2%)

[1] $P < 0.05$ between groups (χ^2 analysis).

RESULTS

Table 1 shows the percentages of participants by gender and race in the physical activity quartile groups. A total of 290 healthy university students aged 18-25 were included in the study. There were 142 males (90 White and 52 Black) and 147 females (85 White and 63 Black). Chi-square analyses revealed a significant difference in the frequency distribution of gender by IPAQ quartile [$\chi^2_{(3, N=290)}$ = 32.42, p < 0.0001], and for gender by race across activity categories [$\chi^2_{(9, N=290)}$ = 37.82, p < 0.0001].

The correlation coefficients between the body composition variables and MET-hrs·wk^{-1} are shown in table 2. MET-hrs·wk^{-1} was inversely correlated with %BF ($r = -$ 0.40, $p < 0.0001$) but not BMI ($r = 0.05$, $p = 0.43$). In addition, MET-hrs·wk^{-1} was significantly related to all three DXA-measured body composition components, FM, LTM, and BMC ($p < 0.05$ for all).

Table 3 presents a comparison of the adjusted body composition variables across PA quartiles. There were no significant differences in mean height [$F_{(3,284)} = 0.89$, $p = 0.45$], weight [$F_{(3,284)} = 0.62$, $p = 0.60$], or BMI [$F_{(3,284)} = 0.97$, $p = 0.41$] across activity quartiles. However, %BF was significantly different across activity categories [$F_{(3,284)} = 6.04$, $p < 0.001$]. Furthermore, FM and LTM were significantly different across PA quartiles [$F_{(3,284)} = 3.98$, $p = 0.008$; and $F_{(3,284)} = 3.41$, $p = 0.018$], and BMC approached significance [$F_{(3,284)} = 2.53$, $p = 0.06$].

Table 2. Pearson correlations of body composition and physical activity

Variable	Correlations between variables*				
	%BF	FM	LTM	BMC	MET-hrs·wk⁻¹
BMI (kg·m⁻²)	0.34	0.72	0.52	0.53	0.05
Percent fat (%BF)		0.86	-0.54	-0.30	-0.40
Fat mass (FM)			-0.08	0.12	-0.26
Lean-tissue mass (LTM)				0.85	0.38
Bone mineral content (BMC)					0.30

* Correlations greater than 0.11 are significant at $P < 0.05$.

Table 3. Comparison of variables between quartiles of self-reported physical activity

Variable[1]	Quartiles of self-reported physical activity (MET-hrs·wk⁻¹)			
	Q1 (0 – 23.99) LSM ± SE[2]	Q2 (24.0 – 33.99) LSM ± SE	Q3 (34.0 – 51.24) LSM ± SE	Q4 (≥ 51.25) LSM ± SE
Height (cm)	169.7 ± 0.8	169.7 ± 0.8	171.2 ± 0.8	170.9 ± 0.9
Weight (kg)	71.6 ± 1.4	73.3 ± 1.4	73.2 ± 1.4	71.2 ± 1.4
BMI (kg·m⁻²)	24.8 ± 0.4	25.3 ± 0.4	24.8 ± 0.4	24.2 ± 0.5
%BF	25.8 ± 0.9ᵃ	26.0 ± 0.9ᵃ	24.8 ± 0.9ᵃ	21.3 ± 0.9ᵇ
FM (kg)	18.7 ± 0.9ᵃ	19.1 ± 0.9ᵃ	18.3 ± 0.9ᵃᵇ	14.9 ± 0.9ᵇ
LTM (kg)	50.0 ± 0.8ᵃ	51.3 ± 0.7ᵃᵇ	51.9 ± 0.7ᵃᵇ	53.5 ± 0.8ᵇ
BMC (kg)	2.95 ± 0.06	3.02 ± 0.06	3.15 ± 0.06	3.12 ± 0.06
MET-hrs·wk⁻¹	14.9 ± 1.2ᵃ	28.9 ± 1.1ᵇ	41.8 ± 1.1ᶜ	72.6 ± 1.2ᵈ

[1] Covariates included gender and race.
[2] LSM ± SE, least-square mean ± standard error.
Means not sharing an alphabetic character differ significantly, $P < 0.05$ (Tukey-Kramer adjustment).
Abbreviations: BMI = body mass index; %BF = percent body fat; FM = fat mass; LTM = lean-tissue mass; BMC = bone mineral content; MET-hrs·wk⁻¹ = physical activity score calculated from the IPAQ.

Post-hoc analyses revealed significant differences in %BF among those in the highest activity category compared to the other three groups. Fat mass was significantly higher in the first two quartiles compared with the last two activity categories. Lean-tissue mass significantly higher in the highest activity group compared to the lowest quartile. There was no difference in BMC between any of the groups. Finally, as expected, MET-hrs ·wk⁻¹

was significantly different across each of the four quartiles.

DISSCUSSION

In this study, we examined the association of body composition variables with physical activity in young adults. We found that participants in the highest quartile of self-reported physical activity had a lower %BF, lower fat mass, and higher lean-tissue mass compared to those in the lower three groups. Additionally, these findings were independent of gender and race, and were not observed in height, weight, or body mass index.

Physical inactivity is considered a global health concern and long-term insufficient PA is a prevalent and preventable leading risk factor for chronic disease and death (39). Public health officials have identified college-age individuals as a neglected but important population for initiatives addressing lifestyle changes to decrease health risks. In fact, increasing PA and prevention of obesity are listed as the top two priority health indicators of the Healthy Campus 2010 initiative, a national campaign established in 2000 by the USDHHS which parallels the objectives of the Healthy People 2010 agenda (1).

While the use of BMI has shown to be a reasonable measure of adiposity in adults, some research suggests that BMI may be a poor indicator of body fatness in certain population subgroups, such as racial/ethnic minorities (4), college aged athletes and non-athletes (27), and individuals with a large body build (5). For example, in a previous analysis of the same study sample used in this investigation, we

determined through multiple linear regression that in both groups (Whites and Blacks), the combination of gender, BMI, and MET-hrs·wk^{-1} contributed significantly to the explained variance in percent body fat (40). However, the model adjusted R^2 value for Blacks was 0.87 (RMSE = 3.72), as compared to 0.78 (RMSE = 3.97) for Whites. Furthermore, BMI contributed 30% of the variance in percent fat in Whites versus 50% in Blacks. These results provide further evidence of the apparent differences in body composition among racial/ethnic groups; however, the findings do not confirm whether physical activity and/or body build help partially explain the variations observed.

Unique to this study was the use of self-reported physical activity to compare body composition variables. The IPAQ was chosen because it assesses all activities performed during the previous week across multiple domains. The inclusion of activities involved in occupation, transport, and housework in addition to leisure-time physical activity has been shown to improve the accuracy of assessment, which has led to more meaningful relationships with health outcomes being described (1). The IPAQ has been shown to be a valid and reliable instrument for self-reporting physical activity levels across a wide range of age groups and country of origin. Several studies (5, 10, 15) have examined the criterion validity of the IPAQ compared with data from accelerometers, and one study (11) examined the validity of the IPAQ against fitness measures. Results from the 12-country reliability and validity study of the IPAQ reported the criterion validity of the short version against CSA accelerometers to be comparable to most

other self-reports (N = 781, median ρ = 0.30, 95% CI 0.23-0.36). Similar results have been reported by Dinger et al. (9) in college students (N = 123, ρ = 0.23, 95% CI: 0.06, 0.40) for total counts/day, by Ekelund et al. (10) for total physical activity (MET-min·day^{-1}) against MTI Actigraph accelerometers (counts·min^{-1}) (N = 185, r = 0.34, p < 0.001), and by Hagstromer et al. (15) (N = 46, ρ = 0.55, p < 0.001). Fogelholm et al. (12) compared the IPAQ to measures of cardiorespiratory and muscular fitness in adult males and found that those that were classified as in the high activity group based on the IPAQ scoring protocol had superior fitness levels as assessed by maximal oxygen uptake and total number of sit-ups, push-ups, and repeated squats. The IPAQ short form has also been shown to have high intraclass reliability (ICC = 0.86, 95% CI: 0.80, 0.91) when administered two weeks apart in college students (9).

The relationship between %BF and MET-hrs·wk^{-1} in this study was -0.40. Several studies (24, 25, 33) have examined the relationship between percent fat and physical activity, and all have observed similar findings. In adolescent girls, Lohman et al. (24) reported significant inverse relationships between percent fat and various levels of accelerometry-determined physical activity (r = -0.17 for MET-weighted MVPA). Similarly, Tudor-Locke et al. (33) reported a significant correlation of -0.27 between pedometer-determined steps/day and percent fat predicted from bioelectrical impedance in healthy Caucasian and African American adults. Furthermore, a prospective study conducted with 140 young adult male conscripts observed that percent fat from

DXA, but not BMI, was significantly related to running performance (25).

The findings of the present study are further strengthened by the use of DXA to estimate body composition. Although the DXA method assumes a constant hydration of 0.73 for lean-tissue mass, several investigators have found that DXA measurements are relatively unaffected by fluctuations in total body water (± 2%) in normal healthy adults (16, 26, 36). Lohman and colleagues theorized that a 5% change in the water content of the FFM would be likely to affect DXA %BF estimates by only 1% to 2.5%BF (23). In a review of studies using DXA, Lohman (1996) determined the precision of %BF$_{DXA}$ to be around 1% BF (17). Moreover, when compared to a 6-C chemical model, the prediction error of the DXA method for estimating fat-mass ranges between 1.7 – 2.0 kg (36).

The limitations of this study include its cross-sectional design with a convenience sample of young adult volunteers and the use of self-reported information to make comparative inferences in body composition. Therefore, statements regarding cause-and-effect cannot be made. Furthermore, due to the use of a narrow age range, unequal gender race group representation, and exclusion of other race/ethnic groups, the results reported herein may not be generalized to other populations. Self-reports of physical activity are prone to bias and low reliability. In the present study, however, a standardized instrument (IPAQ) with a probe-type protocol was used to maximize the potential for acquiring accurate responses. Therefore, the results may be more reflective of the study population

than if the survey had been administered freely without assistance from the investigator. Additional prospective studies using the IPAQ in combination with objective measures of PA are needed to confirm the findings of this study.

The aim of this study was to examine the association of physical activity with body composition variables in a biracial group of college students. The findings indicate that participants with the highest self-reported level of physical activity had a more fit body composition profile as estimated by DXA, independent of gender and race, and that these results were not reflected by BMI. Health professionals and coaches should be aware of the limitations of using BMI when using this information to determine health status or eligibility to compete in athletic events.

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