American Journal of Sports Science and Medicine, 2017, Vol. 5, No. 4, 64-68
Available online at http://pubs.sciepub.com/ajssm/5/4/1
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DOI:10.12691/ajssm-5-4-1

A Canonical Correlation Analysis of Physical Activity Parameters and Body Composition Measures in College Students

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Abstract The aim of this study was to examine the multivariate associate between physical activity (PA) parameters and body composition (BC) measures in college students. A total of N=60 college students who completed a PA questionnaire and had their BC assessed were included in this study. Three variables were used to measure the PA construct: VO2max (ml/kg/min), minutes of moderate PA (MMPA) (min/week), and muscle strengthening activity (MSA) (days/week). Three variables were used to measure the BC construct: percent body fat (PBF) (%), body mass index (BMI) (kg/m^2), and waist circumference (WC) (cm). Three different statistical software packages were used to ensure consistent canonical correlation analysis (CCA) findings: SAS, SPSS, and R. Two variates presented useful in the CCA. The first variate showed 77.8% explained variance and a large canonical correlation (r_c = .512). The second variate showed 21.8% explained variance and a modest canonical correlation (r_c = .301). All communalities (h^{2}s) were large for PA variables. However, h^{2}s were only large for PBF and BMI in the BC construct. Results from this study indicate that PA and BC constructs are correlated with each other in college students. Of particular note, is the contribution of MSA, MMPA, PBF, and BMI to the first variate. As well, the contribution of VO2max, MSA, and BMI to the second variate. These findings may suggest two different relationships between PA and BC: 1) a general PA behavior and BC relationship and 2) an exercise and BC relationship.

Keywords: *multivariate analysis, physical activity, physical fitness, body composition*

Cite This Article: Peter D. Hart, "A Canonical Correlation Analysis of Physical Activity Parameters and Body Composition Measures in College Students." *American Journal of Sports Science and Medicine*, vol. 5, no. 4 (2017): 64-68. doi: 10.12691/ajssm-5-4-1.

1. Introduction

Physical activity (PA) is an important health behavior that is commonly promoted on college campuses [1]. Body composition (BC) is a fitness trait that often reflects a student's participation in PA [2]. Although many tests are available which yield measured variables representing the traits of PA and BC, there is no single measured variable that is considered a perfect indicator of these traits. A latent trait is an unmeasured characteristic that can be estimated from other measured variables [3,4].

In epidemiological and public health research, often questionnaires and/or examinations are administered resulting in several measured variables representing such traits. Furthermore, in multivariate statistical analysis, a latent variable (or construct) also serves as a means of data reduction – allowing, for example, the use of a single latent variable as opposed to the use of several observed variables [5]. Therefore, in a multivariate context, the extent to which the constructs of PA and BC are related in college student populations is not well understood. Therefore, the purpose of this study was to examine the multivariate association between PA parameters and BC measures in college students.

2. Methods

Data for this research came from a cross-sectional measurement study conducted at a rural public university. A total of N=60 college students who completed a PA questionnaire and had their BC assessed were included in the analysis. All study components were reviewed and approved by the university's institutional review board (IRB).

PA measures were assessed using the BRFSS PA rotating core questionnaire [6]. Using this tool, three PA measures were derived. Maximal oxygen consumption (VO2max [ml/kg/min]) was computed using sex-specific prediction equations for males (VO2max = [60 – 0.55 * age in years]) and females (VO2max = [48 – 0.37 * age in years]). Minutes of moderate PA (MMPA [per week]) was derived from a series of steps, beginning with VO2max. First, participant VO2max scores were divided by 3.5 to yield maximal metabolic equivalent (METmax) scores.

Second, METmax values were multiplied by 0.60 (60%) to determine a cutoff value for vigorous-intensity PA. Activities above this cutoff value were considered vigorous for that participant. Activities with MET values between 3.0 and the vigorous-intensity cutoff value were then considered moderate in intensity for that participant. Third, each reported activity was cross-referenced with the 2011 Compendium of Physical Activities and classified as being either "moderate", vigorous", or "neither", in terms of intensity [7]. The final step also involved combining the reported frequency (number of days per week) and duration (minutes that each activity lasted) responses to quantify MMPA. In this computation, vigorous-intensity minutes were doubled to convert to a common moderate-intensity minutes scale. Finally, muscle strengthening activity (MSA [days per week]) was assessed from a single question asking participants how many times per week (during the past month) they performed physical activities or exercises specifically to strengthen their muscles such as yoga, sit-ups, push-ups, weight machines, free weights, or elastic bands.

BC measures were assessed in a laboratory using American College of Sports Medicine (ACSM) protocol [8]. Percent body fat (PBF [%]) was measured using the skinfold technique and the sum of skinfold thicknesses from chest, abdomen, and thigh for males and triceps, suprailiac, and thigh for women. The Siri equation was then used to convert predicted body density to PBF for each participant. Waist circumference (WC [cm]) was measured the same for all participants using an elastic tape at the most narrow section of the torso between the umbilicus and xyphoid process. Finally, body mass index (BMI [kg/m^2]) was measured the same for all participants using a wall mounted stadiometer to measure height (cm) and an electronic floor scale to measure weight (kg).

Means, standard errors (SEs), and independent t statistics, were reported to describe the sample. Pearson correlation coefficients were reported for all study variables in the form of a correlation matrix. A canonical correlation analysis (CCA) was used to determine the extent of the relationship between a set of PA variables serving as the PA construct and a set of BC variables serving as the BC construct (see Figure 1). Three different statistical software packages were used to ensure consistent CCA findings: SAS, SPSS, and R [9,10,11].

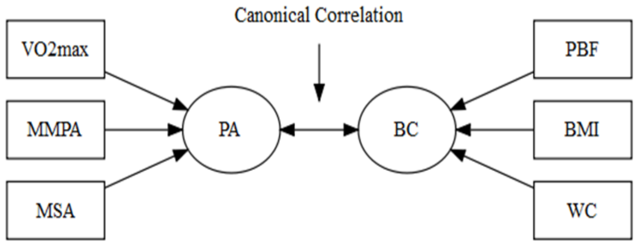

Figure 1. Graphical representation of a canonical correlation analysis of BC and PA constructs (*Note.* The graph represents a single canonical variate)

3. Results

Table 1 contains descriptive statistics for all study and related variables by sex. Mean values of weight, height, BMI, WC, and VO2max were significantly higher (p's<.05) for males than for females. However, mean PBF was significantly lower ($p<.001$) for males than for females. Table 2 displays Pearson bivariate correlations between all observed variables. PBF had the strongest correlations with the PA measures. PBF was significantly (p's<.05) and negatively correlated with MSA ($r=-.427$), VO2max ($r=-.683$), and MMPA ($r=-.570$). VO2max had the strongest correlations with the BC measures. VO2max was significantly (p's<.05) and positively correlated with BMI ($r=.323$) and WC ($r=.475$).

Table 3 contains results from the overall CCA and displays the standardized coefficients, structure coefficients (r_s), squared structure coefficients (r_s^2), communalities (h^2) and the canonical correlation coefficients (r_c). Two variates presented useful in this CCA. The first variate showed 77.8% explained variance and a large r_c of .512. The second variate showed 21.8% explained variance and a modest r_c of .301. All h^2s were large for PA variables. However, h^2s were only large for PBF and BMI in the BC construct. Structure coefficients for the first variate were large for MSA ($r_s=.603$), MMPA ($r_s=.964$), PBF ($r_s=-.891$), and BMI ($r_s=-.538$). Structure coefficients for the second variate were large for MSA ($r_s=.539$), VO2max ($r_s=.814$), and BMI ($r_s=.411$).

Table 1. Descriptive statistics for study and descriptive observed variables

	Male		Female			
Variable	*M*	*SE*	*M*	*SE*	*t*	*p*
Age (years)	21.8	0.44	21.3	0.84	-0.59	.558
Weight (kg)	87.9	2.14	72.8	2.13	-4.86	<.001
Height (cm)	180.3	1.35	171.6	1.69	-4.07	<.001
BMI (kg/m^2)	27.0	0.59	24.7	0.66	-2.59	.012
PBF (%)	12.6	0.86	23.8	1.44	7.03	<.001
WC (cm)	87.7	1.41	77.1	1.84	-4.66	<.001
MSA (days/wk)	3.8	0.27	3.1	0.41	-1.39	.171
$VO2_{max}$ (ml/kg/min)	48.0	0.24	40.1	0.31	-20.17	<.001
MMPA (min/wk)	946.1	109.53	634.0	109.42	-1.96	.055

Note. *M* = mean, *SE* = standard error, *t* = independent t statistic.

Table 2. Correlation coefficient matrix of study and descriptive observed variables (n = 60)

Observed Variables	Sex	Age	Athlete	Weight	Height	BMI	PBF	WC	MSA	VO2max	MMPA
Sex (1=male, 0=female)	1.0	-	-	-	-	-	-	-	-	-	-
Age (years)	.077	1.0	-	-	-	-	-	-	-	-	-
Athlete (1=yes, 0=no)	.168	**-.315**	1.0	-	-	-	-	-	-	-	-
Weight (kg)	**.538**	-.006	**.310**	1.0	-	-	-	-	-	-	-
Height (cm)	**.471**	-.027	**.446**	**.600**	1.0	-	-	-	-	-	-
BMI (kg/m^2)	**.322**	.012	.022	**.782**	-.023	1.0	-	-	-	-	-
PBF (%)	**-.678**	.081	**-.391**	-.167	**-.415**	.100	1.0	-	-	-	-
WC (cm)	**.522**	.126	.144	**.846**	**.332**	**.813**	-.113	1.0	-	-	-
MSA (days/wk)	.179	-.192	<u>.220</u>	.123	**.271**	-.079	**-.427**	-.066	1.0	-	-
VO2$_{max}$ (ml/kg/min)	**.936**	**-.273**	**.278**	**.533**	**.462**	**.323**	**-.683**	**.475**	<u>.243</u>	1.0	-
MMPA (min/wk)	<u>.249</u>	-.073	**.480**	.075	**.384**	-.203	**-.570**	-.011	**.394**	**.266**	1.0

Note. Bolded values significant at the .05 level. Underlined values significant at the .10 level.

Table 3. Overall canonical correlation analysis of BC and PA constructs (n = 60)

	Canonical Variate 1				Canonical Variate 2			
Constructs	*Coef*	r_s	r_s^2	r_c	*Coef*	r_s	r_s^2	r_c
BC Variables								
PBF	-.865	-.891	.794		-.523	-.162	.026	
BMI	-.369	-.538	.289		1.781	.411	.169	
WC	-.101	-.303	.092		-1.621	-.113	.013	
				.512				.301
PA Variables								
MSA	.274	.603	.363		.555	.539	.291	
VO2$_{max}$	.038	.184	.034		.737	.814	.662	
MMPA	.858	.964	.930		-.487	-.208	.043	
Explained Variance (%)		77.8				21.8		
Wilk's Lambda (*F*, *p*-value)				.670 (2.62, .008)				

Note. *Coef* = standardized coefficients, r_s = structure coefficients, r_s^2 = squared structure coefficients, r_c = canonical correlation coefficients, h^2 = communality coefficients (%). The last canonical variate was not reported due to low explained variance (< 1%). Explained variance is based on eigenvalues. Each variable is T-score transformed.

Table 4. Male-specific canonical correlation analysis of BC and PA constructs (n = 35)

	Canonical Variate 1				Canonical Variate 2				
Constructs	*Coef*	r_s	r_s^2	r_c	*Coef*	r_s	r_s^2	r_c	h^2
BC Variables									
PBF	-1.248	-.592	.350		.386	.645	.416		76.6
BMI	.083	.296	.088		1.073	.955	.911		99.9
WC	.972	.244	.059		-.366	.747	.558		61.8
				.555				.492	
PA Variables									
MSA	.305	.581	.337		.088	-.156	.024		36.2
VO2$_{max}$	.821	.916	.839		.341	.277	.077		91.6
MMPA	.193	.368	.135		-.989	-.929	.864		99.9
Explained Variance (%)		58.1				41.6			99.7
Wilk's Lambda (*F*, *p*-value)				.523 (2.40, .020)					

Note. *Coef* = standardized coefficients, r_s = structure coefficients, r_s^2 = squared structure coefficients, r_c = canonical correlation coefficients, h^2 = communality coefficients (%). The last canonical variate was not reported due to low explained variance (< 1%). Explained variance is based on eigenvalues. Each variable is T-score transformed.

Table 5. Female-specific canonical correlation analysis of BC and PA constructs (n = 25)

	Canonical Variate 1				Canonical Variate 2				
Constructs	*Coef*	r_s	r_s^2	r_c	*Coef*	r_s	r_s^2	r_c	h^2
BC Variables									
PBF	1.149	.930	.864		-.170	-.264	.070		93.4
BMI	-.682	.379	.143		-.673	.366	.134		27.7
WC	.650	.293	.086		1.412	.851	.724		80.9
				.873				.585	
PA Variables									
MSA	-.511	-.804	.646		-.715	-.452	.204		85.1
$VO2_{max}$	-.128	-.291	.085		-.515	-.548	.300		38.5
MMPA	-.636	-.868	.753		.835	.473	.224		97.7
Explained Variance (%)		86.0				13.9			99.9
Wilk's Lambda (*F*, *p*-value)				.156 (5.91, < .001)					

Note. *Coef* = standardized coefficients, r_s = structure coefficients, r_s^2 = squared structure coefficients, r_c = canonical correlation coefficients, h^2 = communality coefficients (%). The last canonical variate was not reported due to low explained variance (< 1%). Explained variance is based on eigenvalues. Each variable is T-score transformed.

Table 4 contains results from the male-specific CCA. As well, two variates presented useful with 58.1% and 41.6% explained variance and r_c=.555 and r_c=.492 seen in the first and seconds variates, respectively. Structure coefficients for the first variate were large for male MSA (r_s=.581), VO2max (r_s=.916), and PBF (r_s=-.592). Structure coefficients for the second variate were large for male MMPA (r_s=-.929), PBF (r_s=.645), BMI (r_s=.955), and WC (r_s=.747).

Table 5 contains results from the female-specific CCA. Similarly to males, two variates presented useful with 86.0% and 13.9% explained variance and r_c=.873 and r_c=.585 seen in the first and seconds variates, respectively. Structure coefficients for the first variate were large for female MSA (r_s=.603), MMPA (r_s=.964), and PBF (r_s=-.891). Structure coefficients for the second variate were large for female VO2max (r_s=-.548), MSA (r_s=-.452), MMPA (r_s=.473), and WC (r_s=.851).

4. Discussion

The aim of this study was to examine the multivariate relationship between measures of PA and BC in college students. The major findings showed that a moderately strong relationship did indeed exist between the PA and BC constructs and remained so even after sex-specific analyses were performed. There are no currently published studies that support these findings in terms of the multivariate relationship between latent constructs of PA and BC. Nonetheless, many studies support these findings at the univariate level. One study of 7 to 10 year old children used a cross-sectional design to examine the relationship between PA, cardiorespiratory fitness, and BC [12]. Results of this study showed an inverse relationship between cardiorespiratory fitness and both BMI and WC. The authors of this study also showed that these relationships existed in both male and female children. In a similar study of college-aged men and women, PA was assessed by pedometer and examined for its correlations with BC measures [13]. Results of this study showed significant relationships between PA and BMI, WC, PBF, as well as hip circumference. These relationships, however, were only seen among the female participants. A final study worth noting also examined similar relationships among young adults but used a cardiorespiratory measure derived from an incremental cycle ergometer test [14]. This study showed findings consistent with the others, with an inverse correlation between maximal oxygen uptake and PBF.

The results of this current study should be considered along with its limitations. For example, data for this study were collected at one point in time, with participants self-reporting their PA at the same time point as their BC assessment. Generalizations from cross-sectional data are obviously incapable of purporting cause-and-effect relationships. Future studies may consider a longitudinal design where change (gain) scores could serve as indicator variables for the PA and BC constructs. Another limitation of this study was its use of sex-specific prediction equations for VO2max. While a laboratory- or field-based maximal cardiorespiratory test may had provided more confidence in the VO2max measures used in this study, the prediction equation procedure was the same as that used by the CDC to estimate VO2max in their continuous BRFSS annual survey of adults [6].

5. Conclusions

Results from this study indicate that PA and BC constructs are correlated with each other in college students. Of particular note, is the contribution of MSA, MMPA, PBF, and BMI to the first variate. As well, the contribution of VO2max, MSA, and BMI to the second variate. These findings suggest two different and unique relationships between PA and BC. One relationship may be considered a PA and BC association. The other relationship may be considered an exercise and BC association.

Acknowledgements

No financial assistance was used to assist with this project.

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