

LINEAR REGRESSION MODEL FOR ESTIMATING PERCENT BODY FAT IN YOUNG ADULT MEDICAL STUDENTS: FINDINGS FROM A CROSS-SECTIONAL STUDY

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Abstract

Objectives: To identify factors associated with percent body fat (PBF) and to develop a predictive model in healthy young adult medical students. **Methods:** A cross-sectional study was conducted among 76 medical students aged 22 - 24 years. Body composition was assessed using multi-frequency bioelectrical impedance analysis (BIA). Dietary intake was collected using three non-consecutive 24-hour dietary recalls, and physical activity was assessed using the International Physical Activity Questionnaire - Short Form (IPAQ-SF) with total activity expressed as MET-min/week. Block-wise multivariable linear regression was applied to determine independent predictors of PBF. **Results:** PBF was correlated positively with fat mass and visceral fat area, and negatively with skeletal muscle mass, skeletal muscle index, and phase angle. In the final multivariable model, sex, height, waist-to-hip ratio (WHR), lipid intake (g/kg/day), and physical activity (MET-min/week) were independently associated with PBF. The model equation was: $PBF (\%) = 53.80 - 7.02 \times \text{sex (male = 1)} - 0.2 \times \text{height (cm)} + 18.24 \times \text{WHR} - 5.53 \times \text{lipid intake (g/kg/day)} - 0.001 \times \text{physical activity (MET-min/week)}$. **Conclusion:** In young adult medical students, a simple linear model incorporating WHR, sex, height, lipid intake, and physical activity may help estimate PBF and support screening of adiposity patterns in similar student populations. Given the cross-sectional, single-center design, self-reported measures, and lack of validation, larger multicenter studies are needed.

Keywords: Percent body fat; Body composition; Young adults; Medical students.

INTRODUCTION

Changes in lifestyle, dietary habits, and physical activity levels have contributed to an increasing risk of metabolic disorders among young adults, even in individuals

whose body mass index (BMI) remains within normal ranges. In this context, percent body fat (PBF) has emerged as a critical indicator that more directly reflects adipose tissue accumulation and

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latent health risks, and particularly effective in identifying central fat distribution and visceral adiposity, which are strongly associated with cardiometabolic risk [1, 2].

Although numerous studies have assessed nutritional status and body composition, data on the relationship between lifestyle factors, specifically dietary intake and physical activity, and PBF among young adults in Vietnam remain limited, especially studies adopting a multifactorial approach. Emerging evidence suggests that, in young populations, physical activity may be more closely associated with PBF and body composition than BMI, while sex-related differences in dietary energy distribution may also influence fat accumulation and therefore warrant consideration in analytical models [3].

Advances in multi-frequency BIA have enabled rapid, non-invasive, and feasible assessment of body composition in community-based research, providing valuable indices such as percent body fat, skeletal muscle mass, visceral fat, and phase angle. BIA has been widely applied in both research and clinical practice, demonstrating acceptable accuracy when compared with reference methods such as dual-energy X-ray absorptiometry (DEXA) under standardized measurement conditions [4, 5].

Therefore, the present study aimed to: *Determine estimate percent body fat and to identify associated factors, including anthropometric characteristics,*

dietary intake, and physical activity levels among young adults. The findings are expected to contribute to national scientific evidence and to inform early lifestyle-oriented interventions targeting unfavorable fat accumulation in this population.

MATERIALS AND METHODS

1. Subjects

A total of 76 fourth-year civilian medical students undertaking clinical rotations at Military Hospital 103 were enrolled between June 2022 and March 2023.

** Inclusion criteria:* Participants were required to be fourth-year medical students with a stable health status during the study period.

** Exclusion criteria:* Individuals with conditions affecting metabolism; those who were pregnant, or those engaged in professional athletic training were excluded from the study.

2. Methods

** Study design:* This study was conducted using an analytical cross-sectional design to describe body composition among medical students and to examine the associations between PBF and anthropometric characteristics, physical activity, and lifestyle-related factors.

** Sample size and selection:* Convenience sampling was applied. All eligible participants who met the inclusion criteria and none of the exclusion criteria were enrolled in the study.

** Study variables and measurements:* The dependent variable was percent body fat (PBF, %). Independent variables included perinatal characteristics, age, sex, body mass index (BMI), anthropometric measures, physical activity (MET-minutes/week), and dietary intake variables.

Body weight (kg) and height (cm) were measured using a calibrated scale and stadiometer, respectively with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight/height^2 (kg/m²). Waist circumference (WC) was recorded with a non-elastic measuring tape at the midpoint between the lowest rib margin and the iliac crest at the end of a normal expiration. Hip circumference (HC) was assessed at the level of the greatest posterior protuberance of the buttocks. Each circumference measurement was performed at least twice; if the two measurements differed by more than 0.5 cm, a third measurement was taken, and the mean of the closest two values was used. Waist-to-hip ratio (WHR) was calculated as WC/HC.

Dietary intake was assessed using repeated 24-hour dietary recalls on three non-consecutive days, including two weekdays and one weekend day. Trained investigators conducted face-to-face interviews using a structured multiple-pass approach to improve recall accuracy. Portion sizes were estimated using standard household

measures and food portion aids when available. Daily intakes were converted to nutrients using food composition references/software routinely applied at the study site, and protein intake was additionally expressed in g/kg/day based on measured body weight. The average intake calculated across the three recall days was used for analysis

Body composition parameters, including PBF (%), were measured using a multi-frequency bioelectrical impedance analyzer (BWA 2.0, InBody Co., Ltd, Korea). Measurements were performed under standardized conditions: Participants were assessed in the morning after an overnight fast, having voided their bladder and refrained from vigorous physical activity, alcohol, and caffeine for at least 12 hours, and with light clothing and bare feet to minimize hydration-related measurement variability [5].

Physical activity was assessed using the International Physical Activity Questionnaire - Short Form (IPAQ-SF). Physical activity levels were quantified using standard MET values [2].

** Data analysis:* Statistical analyses were performed using IBM SPSS Statistics 26.0. Variables significant in univariate analyses and those with biological relevance were entered into block-wise multivariable linear regression models (anthropometric/biological, dietary, physical activity, and final integrated

models). Model fit was assessed using adjusted R^2 and $p < 0.05$ was considered statistically significant.

3. Ethics

The study protocol was approved by the Scientific Council of the Military Medical University (Decision No. 2091, dated June 29th, 2022). The study was

conducted in accordance with the Declaration of Helsinki and the regulations of Military Hospital 103. Written informed consent was obtained from all participants. Data use and publication were authorized by Military Hospital 103, and all data were anonymized prior to analysis. The authors declare no conflicts of interest.

RESULTS

Table 1. General, anthropometric, physical activity, and dietary characteristics.

Variables	Female (n = 35)	Male (n = 41)	Total (n = 76)	p
Age (years)	22.09 ± 0.45	22.29 ± 0.64	22.20 ± 0.57	0.113 ^a
Birth weight (kg)	3.15 ± 0.28	3.21 ± 0.36	3.18 ± 0.33	0.439 ^a
Gestational age (weeks)	37.6 ± 1.46	38.2 ± 1.28	37.9 ± 1.39	0.071 ^a
Height (cm)	157.2 ± 4.3	171.0 ± 6.1	164.6 ± 8.7	< 0.001 ^a
Body weight (kg)	49.3 ± 6.1	64.3 ± 8.9	57.4 ± 10.7	< 0.001 ^a
BMI (kg/m ²)	19.9 ± 1.8	22.0 ± 2.7	21.0 ± 2.6	< 0.001 ^a
MUAC (cm)	22 (21 - 25)	27 (25.5 - 33)	25 (22.25 - 29)	< 0.001 ^b
Calf circumference (cm)	33 (31 - 36)	39 (35 - 45.5)	36 (32.25 - 41)	0.005 ^b
Waist circumference (cm)	66.9 ± 5.0	79.2 ± 8.0	73.5 ± 9.1	< 0.001 ^a
Hip circumference (cm)	88.6 ± 4.8	93.2 ± 6.6	91.1 ± 6.3	0.001 ^a
Waist-to-hip ratio	0.76 ± 0.05	0.85 ± 0.06	0.81 ± 0.07	< 0.001 ^a
Physical activity (MET-min/week)	1794 (1230 - 2754)	1710 (1152 - 2232)	1731 (1203 - 2503)	0.395 ^b
Energy intake (kcal/day)	1782 ± 326	2016 ± 400	1908 ± 384	0.007 ^a
Energy (kcal/kg/day)	36.7 ± 8.35	32.0 ± 7.90	34.2 ± 8.39	0.015 ^a
Protein (g/day)	82.6 (72.7 - 108.9)	98.0 (82.5 - 115.1)	92.1 (77.8 - 110.2)	0.025 ^b
Protein (g/kg/day)	1.70 (1.50 - 2.14)	1.56 (1.24 - 1.87)	1.62 (1.37 - 1.91)	0.019 ^b
Lipid (g/kg/day)	1.28 ± 0.43	1.01 ± 0.34	1.13 ± 0.40	0.003 ^a
Carbohydrate (g/day)	212 (182 - 238)	255 (212 - 319)	229.9 (188.6 - 291.1)	0.002 ^b
Dietary fiber (g/1000 kcal)	5.49 (3.69 - 6.53)	3.71 (2.81 - 5.12)	4.64 (3.36 - 5.77)	0.009 ^b

(Data are presented as $\bar{X} \pm SD$ or median (IQR); ^a Independent-samples T-test; ^b Mann-Whitney U test; MUAC: Mid-upper arm circumference.

Male participants were significantly taller and heavier, with higher BMI and larger anthropometric measurements than females ($p < 0.01$). Physical activity levels did not differ between sexes. Males had higher total energy and absolute protein and carbohydrate, whereas females showed higher intakes of energy, protein, and lipid intakes when normalized to body weight as well as higher dietary fiber density.

Table 2. Body composition characteristics.

Variables	Female (n = 35)	Male (n = 41)	Total (n = 76)	p-value
ICW (L)	16.55 ± 1.79	23.91 ± 3.21	20.52 ± 4.54	< 0.001 ^a
ECW (L)	10.21 ± 1.12	14.30 ± 1.80	12.42 ± 2.55	< 0.001 ^a
BFM (kg)	12.72 ± 2.87	12.66 ± 5.05	12.69 ± 4.16	0.956 ^a
PBF (%)	25.65 ± 3.98	19.15 ± 5.37	22.14 ± 5.76	< 0.001 ^a
VFA (cm ²)	46.7 (39.1 - 60.3)	42.3 (31.7 - 62.2)	45.4 (34.65 - 61.27)	0.239 ^b
SMM (kg)	19.58 ± 2.34	29.18 ± 4.20	24.76 ± 5.93	< 0.001 ^a
ECW/TBW	0.382 ± 0.0045	0.375 ± 0.0058	0.378 ± 0.0063	< 0.001 ^a
BMR (kcal/day)	1159 ± 85	1495 ± 149	1340 ± 209	< 0.001 ^a
SMI (kg/m ²)	5.87 ± 0.57	7.58 ± 0.70	6.79 ± 1.07	< 0.001 ^a
Phase angle (°)	5.68 ± 0.47	6.94 ± 0.75	6.36 ± 0.90	< 0.001 ^a

(Intracellular Water: ICW; Extracellular Water: ECW; Body Fat Mass: BFM; Percent Body Fat: PBF; Visceral Fat Area: VFA; Skeletal Muscle Mass: SMM; Total Body Water: TBW; Ratio of Extracellular Water to Total Body Water: ECW/TBW; Basal Metabolic Rate: BMR; Skeletal Muscle Index: SMI. Note: Data are presented as $\bar{X} \pm SD$ or median (IQR). ^a Independent-samples t-test; ^b Mann-Whitney U test).

Male participants exhibited significantly higher levels of ICW, ECW, SMM, SMI, and BMR than females (all $p < 0.001$), indicating a greater lean mass component. In contrast, females exhibited a significantly higher PBF than males ($p < 0.001$), despite no difference in absolute body fat mass between sexes ($p = 0.956$). The ECW/TBW ratio was lower and phase angle was higher in males ($p < 0.001$).

Table 3. Correlations between PBF and parameter group.

Parameter group	Variables	ρ (Spearman)	p-value
Perinatal and anthropometric characteristics	Birth weight	0.083	0.478
	Gestational age (weeks)	-0.104	0.37
	Age (years)	-0.332**	0.003
	Current height (cm)	-0.492**	< 0.001
	Body weight (kg)	-0.188	0.104
	Waist-to-hip ratio (WHR)	-0.243*	0.035
	BMI	0.170	0.143
Daily dietary intake (g/kg/day)	Protein (g/kg/24h)	-0.049	0.672
	Lipid (g/kg/24h)	-0.186	0.108
	Carbohydrate (g/kg/24h)	-0.162	0.163
Body composition (BIA)	ICW (L)	-0.461**	< 0.001
	ECW (L)	-0.431**	< 0.001
	BFM (kg)	0.802**	< 0.001
	SMM (kg)	-0.461**	< 0.001
	VFA (cm ²)	0.813**	< 0.001
	SMI (kg/m ²)	-0.442**	<0.001
	Phase angle (°)	-0.592**	<0.001
Physical activity	MET-minutes/week	-0.079	0.500

(ρ denotes Spearman's rank correlation coefficient between PBF and each variable. $p < 0.05$; ** $p < 0.01$).

PBF was inversely correlated with age, height, and BIA-derived lean mass indices, including SMM, SMI, and phase angle (all $p < 0.05$), while showing strong positive correlations between body fat mass and visceral fat area ($p < 0.001$). No significant correlations were observed with dietary intake normalized by body weight or physical activity level.

Table 4. Comparison of linear regression models predicting PBF.

Variables	Model 1 <i>B</i> (p)	Model 2 <i>B</i> (p)	Model 3 <i>B</i> (p)	Model 4 <i>B</i> (p)
Demographics				
Sex (male = 1, female = 0)	-6.72 (0.001)	-7.16 (< 0.001)	-7.00 (< 0.001)	-7.02 (< 0.001)
Current height (cm)	-0.15 (0.150)	-0.22 (0.023)	-0.13 (0.202)	-0.21 (0.024)
Waist-to-hip ratio	23.87 (0.017)	23.14 (0.016)	22.46 (0.023)	18.24 (0.039)
Early life factors:				
Birth weight (kg)	1.68 (0.348)	-	-	-
Gestational age (weeks)	-0.01 (0.983)	-	-	-
Nutritional intake				
Protein (g/kg/day)	-	1.19 (0.396)	-	-
Lipid (g/kg/day)	-	-6.00 (0.001)	-	-5.53 (< 0.001)
Carbohydrate (g/kg/day)	-	-0.32 (0.434)	-	-
Dietary fiber (g/1000 kcal)	-	-0.18 (0.511)	-	-
MET-minutes/week	-	-	-0.001 (0.137)	-0.001 (0.054)
Constant	26.4	50.8	30.3	53.8
Adjusted R ²	0.356	0.468	0.376	0.501
Durbin-Watson	1.690	1.713	1.574	1.637
Variance inflation factor	< 3.5	< 3.7	< 3.3	< 3.3

Across the linear regression models, male sex and waist-to-hip ratio were consistently associated with percent body fat. The final integrated model (Model 4) showed the best fit (adjusted R² = 0.501), retaining sex, height, waist-to-hip ratio, and lipid intake were identified as significant predictors. Additionally, physical activity showed a borderline inverse association with PBF.

DISCUSSION

This study demonstrated clear sex-related differences in body composition among healthy young adults, with males exhibiting greater height and lean mass, while females had significantly higher PBF, consistent with sex-specific physiological fat distribution reported in large population studies [6]. These findings support PBF as a more sensitive indicator of adiposity-related risk than BMI in young populations.

PBF was strongly and positively associated with body fat mass and visceral fat area, while showing an inverse association with musculoskeletal and metabolic markers (SMM, SMI, BMR) as well as phase angle. This underscores the antagonistic relationship between adiposity, muscle mass and the relevance of cellular integrity in body composition assessment [1, 7]. This aligns with evidence from BIA- and DEXA-based studies identifying visceral adiposity as a key determinant of metabolic risk [1].

In multivariable analyses, the final model explained 50.1% of the variance in PBF, identifying sex, height, waist-to-hip ratio (WHR), and dietary lipid intake (g/kg/day) as independent predictors. The inverse bivariate correlation between WHR and PBF in the pooled sample may reflect sex-based confounding. Males tended to have higher WHR but lower PBF than females. After adjusting for sex and height in multivariable regression,

WHR showed a positive independent association with PBF, suggesting that central adiposity captured by WHR relates to higher fat percentage when major confounders are accounted for. Future studies should consider sex-stratified analyses and external validation. The consistent significance of WHR across models reinforces its value as a marker of central adiposity and metabolic risk, particularly in individuals with normal BMI [2]. Sex remained an essential covariate, reflecting inherent biological differences in body composition [8, 9].

Dietary lipid intake showed an inverse association with PBF, which should be interpreted as a reflection of broader dietary patterns and energy balance rather than a causal protective effect [10]. Previous studies indicate that overall dietary quality and macronutrient balance, rather than isolated nutrient intake, are central to adiposity regulation. The borderline association between physical activity and PBF may stem from self-reported assessment tools in capturing true activity-body composition relationships. Perinatal factors were not associated with PBF, likely due to the homogeneous and relatively small study sample.

Overall, these findings highlight the combined roles of sex, central fat distribution, muscle-related indices, and dietary patterns in shaping PBF among young adults while supporting the

practical utility of multi-frequency BIA in body composition research.

Strengths and limitations: The strengths of this study include the application of multi-frequency BIA and a block-wise regression approach to examine the incremental contributions of anthropometric, dietary, and lifestyle factors to PBF. Dietary intake was assessed using three non-consecutive 24-hour recalls (two weekdays and one weekend day). However, limitations include the cross-sectional design, modest sample size, and convenience sampling from a single-center, relatively homogeneous student population, which may restrict generalizability of the findings. In addition, diet and physical activity were self-reported (24-hour recalls and IPAQ-SF), introducing potential recall/reporting bias. Body composition was measured by BIA rather than DEXA, and the developed multivariable model was neither internally nor externally validated; therefore, predictive performance beyond this sample remains uncertain.

CONCLUSION

In fourth-year medical students, PBF exhibited significant associations with anthropometric indices, and a simple multivariable model including sex, height, WHR, lipid intake, and physical activity explained a substantial proportion of PBF variability within this sample. These findings suggest that easily obtained measures, particularly WHR, may help

approximate adiposity patterns in similar student settings, although validation in larger and more diverse populations is needed.

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