AlMasud et al. Journal of Health, Population and Nutrition (2025) 44:64
https://doi.org/10.1186/s41043-025-00795-5

Journal of Health, Population and Nutrition

RESEARCH

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Relationship of fat mass index and fat free mass index with body mass index and association with sleeping patterns and physical activity in Saudi young adults women

Alaa A. AlMasud[1], Shaima A. Alothman[2*], Nada Benajiba[3], Seham Alqahtani[1,2*], Afnan A. Alatr[4], Anfal A. Alshatowy[4], Ghadah E. Alenezy[4], Ghaida M. Alshahrani[5], Laylas A. Alhussain[5], Noha I. Alnashwan[4], Norah A. Alshimali[4], Nourah A. Alneghamshi[4], Nashmia M. Aljasser[4] and Mashael A. Huwaikem[5]

Abstract

Aim To analyze the association between Fat Mass Index (FMI), Free Fat Mass Index (FFMI), Free Fat Mass/Fat Mass (FFM/FM), and Body Mass Index (BMI) among young adult Saudi women and to explore how these body composition indices are associated with sleep and physical activity patterns.

Methods A total of 1,741 university female students participated in this cross-sectional study. Body composition was measured using the InBody 270 body composition analyzer. FMI, FFMI, and FM/FFM were classified into tertiles (T1, T2, T3), with T1 classified as the lowest and T3 as the highest tertile. Sleep quality and duration were assessed using the Pittsburgh Sleep Quality Index, while physical activity was measured using an exercise vital sign tool.

Results BMI increased significantly from Tertile 1 to Tertile 3 across all groups for FMI and FFMI ($p < 0.001$), while a decrease in FM/FFM was observed across tertiles ($p < 0.001$). Conversely, FFM was highest in the third tertile of FFMI ($p < 0.001$). No significant associations were found between sleep duration or quality and body composition indices, even after adjusting for age and BMI. However, significant associations were observed between physical activity frequency and duration and body composition, particularly FFMI and FMI. These associations became more pronounced after adjusting for age and BMI.

Conclusion The findings highlight a strong association between physical activity patterns and body composition indices, particularly FFMI and FMI, among young adult Saudi women. While sleep patterns did not show significant relationships with body composition, the results emphasize the importance of regular physical activity in maintaining

*Correspondence:
Shaima A. Alothman
Shaalothman@pnu.edu.sa
Seham Alqahtani
seham.alqahtani@gmail.com

Full list of author information is available at the end of the article

healthy body composition. These insights underline the need for targeted interventions promoting physical activity to support optimal health and well-being in this population.

Keywords Fat mass index, Free fat mass index, Free fat mass/Fat mass, Body mass index, Young adults, Women, Saudi Arabia

Introduction

Understanding body composition is essential for accurately assessing health outcomes, as it provides a more nuanced perspective on an individual's health status compared to traditional metrics such as weight or Body Mass Index (BMI) alone [1]. Body composition analysis differentiates between lean mass (e.g., muscles, organs, and bones) and fat mass, offering valuable insights into the distribution of these components within the body [2]. Recent research has increasingly moved beyond BMI to explore more specific body composition indices that provide deeper understanding of their associations with health outcomes. Among these, Fat Mass Index (FMI), Fat-Free Mass Index (FFMI), and the fat mass-to-fat-free mass ratio (FM/FFM) have emerged as significant tools in body composition research [3].

FMI is calculated as the ratio of fat mass to height squared (kg/m^2), serving as an indicator of total body fat relative to body size. Studies have shown that FMI provides a more precise measure of adiposity and is more strongly associated with health risks such as hypertension, type 2 diabetes, and cardiovascular disease compared to BMI alone [4, 5]. Similarly, FFMI, which measures the proportion of lean body mass (including muscles, bones, and organs) relative to height squared, is an important marker for assessing muscle mass. Increased FFMI is linked to better physical fitness, higher metabolic rate, and improved overall health outcomes. On the other hand, the FM/FFM ratio, which reflects the relationship between fat mass and fat-free mass, has garnered attention for its role in understanding fat distribution patterns. Research has demonstrated that a higher FM/FFM ratio—indicating a greater proportion of fat mass relative to lean mass—is associated with poor health outcomes, even among individuals with a normal BMI [6, 7]. This underscores the importance of examining not only total fat and lean mass, but also their relative proportions in predicting health risks that may not be captured by BMI alone. Taken together, these indices seem to offer a more comprehensive and accurate assessment of an individual's body composition, shedding light on the subtle differences that can influence metabolic health, physical fitness, and disease risk. Therefore, exploring the potential association between BMI and these measures will help providing crucial insights for both clinical practice and public health interventions.

The rising prevalence of obesity and its associated health complications worldwide among young adults [8], particularly young women in Saudi Arabia, represents a significant public health challenge. In recent decades, shifts in lifestyle—including increased sedentary behavior, poor dietary habits, sleep pattern changes and evolving cultural norms—have contributed to a sharp rise in obesity rates among adults globally, including young adult Saudi women [9–13]. While Body Mass Index (BMI) is widely utilized in research examining obesity within this population [14–17], there is a notable gap in the literature regarding the assessment of more specific body composition indices, such as FMI, FFMI, and the FM/FFM ratio, and their correlation with BMI in this demographic. Furthermore, little is known about how these body composition indices are influenced by or interact with lifestyle factors such as sleep quality and physical activity in young Saudi women.

This research gap is particularly concerning given the unique lifestyle factors in Saudi Arabia, where sedentary behavior, irregular sleep patterns, and low levels of physical activity are prevalent [18–20]. As such, understanding the interplay between body composition indices (FMI, FFMI, and FM/FFM) and lifestyle factors is crucial for developing a more accurate understanding of obesity-related health risks in this population. Despite the potential implications for public health and clinical interventions, no studies have yet comprehensively examined how these body composition measures relate to factors such as sleep quality, level of physical activity among young adult Saudi women. Therefore, the aim of the present study is to analyse the association between FMI, FFMI and FFM/FM, and BMI among young adult Saudi women. Additionally, the study seeks to explore how these body composition indices are associated with sleep and physical activity patterns. By investigating these associations, this research will provide a better understanding of the interplay between body composition and lifestyle factors and could inform more effective strategies for managing obesity and promoting healthier lifestyle behaviours within this population.

Methods

Study design and subject

This cross-sectional study was conducted during 2023/2024 academic year at Princess Nourah bint Abdulrahman University (PNU) (Riyadh, KSA). All students enrolled at PNU were invited to participate through an advertisement sent via email. The inclusion criteria consisted of students aged 18 years and older who provided consent to participate in the study. Exclusion criteria included pregnant or breastfeeding students, as well as individuals with severe infections or medical conditions that could affect their normal lifestyle. Participants with implanted medical devices were also excluded. Ethical approval for the study was granted by the Institutional Review Board (IRB) of PNU (IRB Log number 24–0024). Informed consent was obtained from participants by their indication of agreement to use their data for research purposes. All data collected was kept confidential and anonymous, ensuring that it was used solely for the purposes of the study.

Sampling technique and sample size calculation

The sampling technique adopted in this study was convenient sampling technique. Sample size calculation was based on population proportions $(n = z^2pq)/d^2)$ where ($p = 0.50$), confidence level of 99%, and a margin of error of 5%. Then, an additional 15% of participants were added to account for the clustered design effect, nonresponses, and missing data. Thus, the minimum sample size needed was 766 students. All interested students were included in final analysis.

Data collection

Anthropometric measurements and body composition analysis and age

Anthropometric measurements were conducted by a trained researcher following established protocols. Height was measured to the nearest 0.1 cm and weight to the nearest 50 g using calibrated medical scales (Seca, Germany). Participants were asked to stand without shoes and in minimal clothing during the measurements. BMI was calculated by dividing weight (in kilograms) by height (in meters) squared (Kg/m^2). Categorization of participants according to their BMI was performed according to the WHO recommendations: Underweight (<18.5), Normal (18.5–24.9), Overweight 25-29.9) and Obese (>30 kg/m^2) [21]. Additionally, participants' age was recorded in years.

Body composition data were collected using the InBody 270 body composition analyzer, which utilizes a constant high-frequency current of 100 mA at a frequency of 20 kHz. The measurements obtained included Waist-Hip Ratio (WHR) Percentage of Body Fat (PBF%), Fat Mass (FM) in kilograms, Visceral Fat Level (VFL), Fat-Free Mass (FFM) in kilograms, Total Body Water (TBW) in litre, and Skeletal Muscle Mass (Kg), along with Basal Metabolic Rate (BMR) (Kcal). Additionally, the following indices were calculated: Fat Mass Index (FMI), which is a ratio expressing the amount of fat mass relative to an individual's height squared (kg/m^2); the Fat-Free Mass Index (FFMI), which measures the proportion of lean body mass (muscles, bones, organs, etc.) relative to height squared; and the Fat Mass to Fat-Free Mass Ratio (FM/FFM), which compares the amount of fat mass to fat-free mass in the body. FMI, FFMI and FM/FFM were classified into tertiles (T1, T2, T3) with T1 classified as lowest and T3 highest tertile respectively. The skeletal Mass Index was also calculated in kg/m^2.

Physical activity frequency and duration

Physical activity was measured using the Exercise Vital Sign tool [22]. Two questions were asked to assess relative intensity: (1) "How many days a week do you engage in moderate and vigorous physical activity, such as brisk walking?" and (2) "On average, how many minutes per day do you exercise at this level?". These questions were designed to capture both the frequency and the daily duration of physical activity participants engaged in.

Sleep quality and duration

Referring to previous large-scale research focusing on sleep quality, Sleep quality and duration were assessed using the Pittsburgh Sleep Quality Index (PSQI) [23], a validated 19-item questionnaire designed to evaluate various aspects of sleep. The PSQI generates a global sleep quality score that ranges from 0 to 21, with higher scores indicating poorer sleep quality. For this study, the Arabic version of the PSQI, which was tested for its validity and reliability by Suleiman et al. (2011), was utilized [24]. This version has been shown to be a reliable tool for assessing sleep quality in Arabic-speaking populations.

Statistical analysis

Categorical variables were presented as frequencies, while continuous variables were reported as means ± standard deviations. The Chi-squared test with Bonferroni correction was applied to determine the significance between categorical variables. For continuous variables, One-Way ANOVA with the Tukey test and Welch ANOVA with the Games-Howell test were used, depending on the assumption of homogeneity of variance. Subgroup analyses were performed based on BMI categories, as well as on frequency and duration of physical activity. FMI, FFMI, and FM/FFM were used as predictor variables (categorized into tertiles) in linear regression models for sleep (both duration and quality) as continuous outcomes, and in generalized linear models for physical activity (both frequency and duration) as categorical outcomes. Normality assumption was met for all continuous outcomes. In both types of analysis, the models were first run without any adjustments, followed by adjustments for age and BMI, as an explorative analysis. Statistical significance was set at $p < 0.05$.

Results

A total of 1,741 participants were included in this study. Table 1 provides a summary of their demographic, body composition, physical activity, and sleep characteristics. The average age of the participants was 20.24 ± 2.87 years, with a mean BMI of 23.16 ± 5.05 (Kg/m^2). The mean WHR was 0.86 ± 0.05. BFM averaged 22.46 ± 9.59 kg, while the FMI had a mean value of 8.94 ± 3.74 (Kg/m^2). FFM averaged 35.76 ± 5.19 kg, and the FM/FFM ratio had a mean of 1.82 ± 0.65. Additional body composition metrics include Skeletal Muscle Mass (SMM) with a mean of 19.00 ± 3.10 kg and the SMI with a mean value of 5.53 ± 0.81 (Kg/m^2). Regarding sleep patterns, participants reported an average sleep duration of 7.17 ± 2.35 h, with a mean total PSQI-total of 7.51 ± 3.37. In terms of physical activity, 36.82% of participants reported no exercise, while 30.26% engaged in physical activity 1–2 times per week. Regarding exercise duration, 34.02% of participants reported no physical activity, and 43.94% engaged in less than or equal to 30 min of exercise per session.

Table 1 General characteristics of the study population ($N = 1741$)

Parameter	Mean ± SD
Age (years)	20.24 ± 2.87
Hight (cm)	158.37 ± 5.62
Weight (kg)	58.23 ± 13.65
BMI (kg/m^2)	23.16 ± 5.05
WHR	0.86 ± 0.05
FM (Kg)	22.46 ± 9.59
FMI (kg/m^2)	8.94 ± 3.74
PBF (%)	37.17 ± 7.67
FFM (kg)	35.76 ± 5.19
FFMI (kg/m^2)	14.23 ± 1.65
FFM/FM	1.82 ± 0.65
SMM (kg)	19.00 ± 3.10
VFL	10.65 ± 4.81
TBW (L)	26.14 ± 3.79
SMI (kg/m^2)	5.53 ± 0.81
BMR (Kcal)	1142.55 ± 112.15
Sleep duration (hr)	7.17 ± 2.35
PSQI-total	7.51 ± 3.37
	N (%)
Physical activity frequency ($n = 1738$)	
No exercise	640 (36.82)
1–2 times /week	526 (30.26)
3 times / week	283 (16.29)
> 3 times / week	289 (16.63)
Duration of physical activity ($n = 817$)	
No exercise	278 (34.02)
≤ 30 min	359 (43.94)
> 30 min	180 (22.04)

WHR: Waist-to-Hip ratio, BFM: Body Fat Mass, FMI: Fat Mass Index, PBF: Percent of Body Fat, FFM: Free Fat Mass, FFMI: Free Fat Mass Index, SMM: Skeletal Muscle Mass, VFL: Visceral Fat Level, TBW: Total Body Water, SMI: Skeletal Muscle Index, BMR: Basal Metabolism Rate, PSQI: Pittsburgh Sleep Quality Index

In Table 2 are presented the results of the anthropometric and body composition characteristics, as well as sleep and physical activity patterns, across three tertiles of body composition indices: FMI, FFMI, and FM/FFM. The WHR exhibited a clear increased trend across tertiles of FMI, FFMI, and decrease across the tertile of FM/FFM ($p < 0.001$), indicating a more centralized fat distribution in higher FMI and lower FFMI tertiles. Similarly, BMI increased significantly from Tertile 1 to Tertile 3 in all groups ($p < 0.001$), reflecting the well-established association between higher body fat and elevated BMI. Both FM and FMI demonstrated significant increases with higher tertiles ($p < 0.001$), highlighting the association between higher FMI and greater fat mass accumulation. In contrast, FFM and SMM were found to be highest in the third tertile of FFMI ($p < 0.001$), underscoring the positive relationship between lean mass and FFMI.

Regarding sleep patterns, the analysis indicated that Tertile 3 of FM/FFM was associated with significantly fewer hours of sleep compared to Tertile 1 and Tertile 2 ($p = 0.048$). However, no significant differences in sleep quality were observed across tertiles ($p = 0.789$), indicating that factors other than body composition might influence sleep quality.

In terms of physical activity, there were no significant differences in physical activity frequency across tertiles of FMI and FM/FFM, yet significant variations were observed in the FFMI groups ($p < 0.001$), with more frequent physical activity reported in higher FFMI tertiles. Additionally, the analysis of physical activity duration revealed significant differences in FFMI ($p < 0.001$), with longer durations of physical activity associated with higher FFMI levels.

The body composition by BMI stratification is summarized in Table 3. The results highlight significant differences in anthropometric measures, body composition, sleep patterns, and physical activity across four groups based on body weight classification (underweight, normal, overweight, and obese). Regarding anthropometric and body composition measures, significant differences were observed across the groups for all variables ($p < 0.001$). The obese group exhibited the highest values in BFM, BFMI, PBF, and VFL, while the underweight group had the lowest values. Similarly, FFM, SMM, and TBW increased progressively from the underweight to the obese group. The FFMI was lowest in the obese group, indicating a lower proportion of lean mass relative to fat mass. The WHR was higher in the normal and overweight groups compared to the underweight and obese groups. In terms of sleep, there were no significant differences in sleep duration or quality between the groups ($p > 0.05$). For physical activity, although the frequency of exercise showed no significant differences ($p = 0.141$), the duration of physical activity was significantly different

Table 2 Anthropometric, body composition characteristics, sleep, and physical activity patterns across three tertiles of body composition indices: FMI, FFMI, and FM/FFM ($N = 1741$)

	Fat Mass Index (FMI) Fat-Free				Fat Free Mass Index (FFMI)				Fat Mass/ Fat-Free Mass (FM/FFM)			
	Tertile 1	**Tertile 2**	**Tertile 3**	***P*-value**	**Tertile 1**	**Tertile 2**	**Tertile 3**	***P*-value**	**Tertile 1**	**Tertile 2**	**Tertile 3**	***P*-value**
Anthropometric and Body composition												
WHR	0.81 ± 0.03	0.85 ± 0.03	0.91 ± 0.05	< 0.001	0.82 ± 0.03	0.85 ± 0.04	0.89 0.06	< 0.001	0.90 ± 0.05	0.85 ± 0.04	0.81 ± 0.03	< 0.001
BMI (Kg/m^2)	18.57 ± 1.66	22.18 ± 1.55	28.71 ± 4.30	< 0.001	19.12 ± 2.22	22.38 ± 2.70	27.97 ± 4.91	< 0.001	28.20 ± 4.77	22.29 ± 2.44	19.00 ± 2.11	< 0.001
BMI Categories												
Underweight	275 (47.5)	1 (0.17)	0 (0.00)	< 0.001	237 (40.86)	39 (6.74)	0 (0.00)	< 0.001	1 (0.17)	25 (4.31)	250 (43.03)	< 0.001
Normal	304 (52.5)	555 (95.7)	83 (14.26)		331 (57.07)	439 (75.82)	172 (29.55)		145 (25.00)	472 (81.38)	325 (55.94)	
Overweight	0 (0.00)	24 (4.14)	329 (56.53)		12 (2.07)	100 (17.27)	241 (41.41)		267 (46.03)	80 (13.79)	6 (1.03)	
Obese	0 (0.00)	0 (0.00)	170 (29.21)		0 (0.00)	1 (0.17)	169 (29.04)		167 (28.79)	3 (0.52)	0 (0.00)	
BFM (Kg)	13.56 ± 2.70	20.60 ± 2.52	33.17 ± 8.06	< 0.001	16.24 ± 5.06	20.94 ± 6.47	30.17 ± 10.39	< 0.001	28.20 ± 4.77	22.29 ± 2.44	19.00 ± 2.11	< 0.001
FMI (kg/m^2)	5.42 ± 1.02	8.21 ± 0.82	13.17 ± 3.07	< 0.001	6.54 ± 2.00	8.37 ± 2.58	11.89 ± 4.05	< 0.001	32.78 ± 8.46	20.77 ± 3.39	13.85 ± 3.09	< 0.001
PBF (%)	29.02 ± 4.06	37.02 ± 2.69	45.43 ± 4.22	< 0.001	33.54 ± 6.52	36.5 ± 7.1	41.40 ± 7.21	< 0.001	32.78 ± 8.46	20.77 ± 3.39	13.85 ± 3.09	< 0.001
FFM (Kg)	32.96 ± 3.78	35.09 ± 4.15	39.22 ± 5.38	< 0.001	31.26 ± 2.73	35.15 ± 2.65	40.85 ± 4.44	< 0.001	38.17 ± 5.70	35.27 ± 4.57	33.85 ± 4.20	< 0.001
FFMI (Kg/m^2)	13.15 ± 1.10	13.97 ± 1.16	15.54 ± 1.63	< 0.001	12.58 ± 0.62	14.01 ± 0.37	16.07 ± 1.21	< 0.001	15.16 ± 1.80	14.02 ± 1.39	13.48 ± 1.24	< 0.001
FFM/FM	5.42 ± 1.02	8.21 ± 0.82	13.16 ± 3.07	< 0.001	2.10 ± 0.66	1.85 ± 0.63	1.49 ± 0.49	< 0.001	1.20 ± 0.17	1.71 ± 0.14	2.54 ± 0.55	< 0.001
SMM (Kg)	17.33 ± 2.57	18.58 ± 2.48	21.07 ± 3.21	< 0.001	16.28 ± 1.60	18.63 ± 1.54	22.07 ± 2.62	< 0.001	20.43 ± 3.41	18.69 ± 2.73	17.87 ± 2.51	< 0.001
VFL	5.60 ± 1.52	10.08 ± 1.67	16.23 ± 2.69	< 0.001	7.77 ± 3.39	10.14 ± 4.11	14.02 ± 4.58	< 0.001	16.19 ± 2.73	10.14 ± 1.76	5.61 ± 1.53	< 0.001
TBW (L)	24.11 ± 2.77	25.63 ± 3.03	28.66 ± 3.94	< 0.001	22.85 ± 1.99	25.69 ± 1.92	29.87 ± 3.24	< 0.001	27.89 ± 4.18	25.76 ± 3.34	24.76 ± 3.07	< 0.001
SMI (Kg/m^2)	4.98 ± 0.56	5.40 ± 0.58	6.21 ± 0.74	< 0.001	4.76 ± 0.42	5.44 ± 0.32	6.39 ± 0.59	< 0.001	6.05 ± 0.83	5.43 ± 0.68	5.31 ± 0.64	< 0.001
Sleep												
Sleeping hours	7.27 ± 2.42	7.34 ± 2.42	6.91 ± 2.18	0.153	7.24 ± 2.39	7.23 ± 2.24	7.05 ± 2.42	0.68	6.83 ± 2.15	7.40 ± 2.42	7.28 ± 2.43	0.048
Quality of sleep	7.40 ± 3.55	7.52 ± 3.37	7.63 ± 3.18	0.789	7.18 ± 3.35	7.59 ± 3.32	7.83 ± 3.43	0.151	7.61 ± 3.07	7.48 ± 3.52	7.46 ± 3.49	0.90
Physical activity												
Frequency												
No exercise	210 (36.46)	222 (38.28)	208 (35.74)	0.911	254 (43.95)	204 (35.29)	182 (31.27)	< 0.001	231 (39.83)	207 (35.69)	202 (34.95)	0.070
1–2 times /week	173 (30.04)	173 (29.83)	180 (30.93)		173 (29.93)	189 (32.7)	164 (28.18)		174 (30.00)	188 (32.41)	164 (28.37)	
3 times / week	92 (15.97)	89 (15.35)	102 (17.53)		77 (13.32)	98 (16.96)	108 (18.56)		96 (16.55)	92 (15.86)	95 (16.44)	
> 3 times / week	101 (17.54)	96 (16.55)	92 (15.81)		74 (12.80)	87 (15.05)	128 (21.99)		79 (13.62)	93 (16.03)	117 (20.24)	
Duration												
No exercise	97 (35.27)	91 (34.21)	90 (32.61)	0.880	114 (39.58)	86 (33.08)	78 (29.00)	< 0.001	100 (36.50)	87 (31.41)	91 (34.21)	0.708
≤ 30 min	123 (44.73)	114 (42.86)	122 (44.20)		137 (47.57)	107 (41.15)	115 (42.75)		119 (43.43)	123 (44.40)	117 (43.99)	
> 30 min	55 (20.0)	61 (22.93)	64 (23.19)		37 (12.85)	67 (25.77)	76 (28.25)		55 (20.07)	67 (24.19)	58 (21.81)	

Data are presented as *n* (%) for BMI categories and physical activity, and as mean ± SD for the other parameters

WHR: Waist-to-Hip ratio, BFM: Body Fat Mass, FMI: Fat Mass Index, PBF: Percent of Body Fat, FFM: Free Fat Mass, FFMI: Free Fat Mass Index, SMM: Skeletal Muscle Mass, VFL: Visceral Fat Level, TBW: Total Body Water, SMI: Skeletal Muscle Index. One-Way ANOVA with Tukey test and Welch ANOVA with Games-Howell was applied for anthropometric, body composition and sleep. Chi-squared test was applied for physical activity

Table 3 Body composition by BMI stratification

	Underweight	Normal	Overweight	Obese	*P*-value
Anthropometric and Body composition	*n* = 276	*n* = 942	*n* = 353	*n* = 170	
WHR	0.8 ± 0.0	0.9 ± 0.0	0.9 ± 0.1	0.8 ± 0.0	< 0.001
BFM (Kg)	11.8 ± 2.4	19.3 ± 4.0	29.5 ± 4.0	42.8 ± 7.5	< 0.001
FMI (Kg/m^2)	4.7 ± 0.9	7.7 ± 1.5	11.7 ± 1.4	16.9 ± 2.8	< 0.001
PBF (%)	27.3 ± 4.5	35.5 ± 4.7	43.4 ± 4.1	49.3 ± 3.5	< 0.001
FFM (Kg)	31.3 ± 3.2	34.6 ± 3.7	38.5 ± 4.3	43.6 ± 5.2	< 0.001
FFMI (Kg/m^2)	12.5 ± 0.8	13.8 ± 1.0	15.3 ± 1.1	17.2 ± 1.3	< 0.001
FFM/FM	2.8 ± 0.7	1.9 ± 0.4	1.3 ± 0.2	1.0 ± 0.2	< 0.001
SMM (kg)	16.3 ± 1.9	18.3 ± 2.2	20.6 ± 2.6	23.7 ± 3.1	< 0.001
VFL	4.9 ± 1.5	9.2 ± 2.7	15.0 ± 2.5	19.1 ± 1.4	< 0.001
TBW (L)	22.9 ± 2.3	25.3 ± 2.7	28.1 ± 3.1	31.9 ± 3.8	< 0.001
SMI (Kg/m^2)	4.7 ± 0.5	5.3 ± 0.5	6.1 ± 0.5	6.9 ± 0.6	< 0.001
Sleep	*n* = 106	*n* = 295	*n* = 128	*n* = 47	
Sleeping hours	7.2 ± 2.3	7.3 ± 2.5	6.9 ± 2.2	7.0 ± 2.2	0.416
Quality of sleep	7.2 ± 3.5	7.4 ± 3.4	8.0 ± 3.4	7.3 ± 2.8	0.248
Physical activity					
	n = 273	*n* = 942	*n* = 353	*n* = 170	
Frequency					
No exercise	121 (44.3)	341 (36.2)	115 (32.6)	63 (37.1)	0.141
1–2 times /week	83 (30.4)	278 (29.5)	116 (32.9)	49 (28.8)	
3 times / week	36 (13.2)	155 (16.5)	62 (17.6)	30 (17.6)	
> 3 times / week	33 (12.1)	168 (17.8)	60 (17.0)	28 (16.5)	
	n = 131	*n* = 437	*n* = 172	*n* = 77	
Duration					
No exercise	59 (45.0)	142 (32.5)	52 (30.2)	25 (32.5)	0.021
≤ 30 min	57 (43.5)	190 (43.5)	81 (47.1)	31 (40.3)	
> 30 min	15 (11.5)	105 (24.0)	39 (22.7)	21 (27.3)	

Data are presented as *n* (%) for physical activity, and as mean ± SD for the other parameters

WHR: Waist-to-Hip ratio, BFM: Body Fat Mass, FMI: Fat Mass Index, PBF: Percent of Body Fat, FFM: Free Fat Mass, FFMI: Free Fat Mass Index, SMM: Skeletal Muscle Mass, VFL: Visceral Fat Level, TBW: Total Body Water, SMI: Skeletal Muscle Index. One-Way ANOVA with Tukey test and Welch ANOVA with Games-Howell was applied for anthropometric, body composition and sleep. Chi-squared test was applied for physical activity

($p = 0.021$). The obese group had the lowest proportion of individuals (40.3%) engaging in physical activity for less than 30 min, while the overweight groups had the highest percentage (47.1%).

The results from the unadjusted and adjusted linear regression models exploring the relationships between body composition indices (FMI, FFMI, FM/FFM), sleep quality, and sleep duration, as well as their association with BMI are presented in Table 4. Overall, the findings suggest that sleep duration and quality are not significantly associated with body composition indices (FMI, FFMI, FM/FFM) in this sample, even after adjusting for age and BMI. The B-coefficients across all models are relatively small and non-significant, confirming the weak associations between sleep hours, sleep quality, and body composition variables.

The unadjusted and adjusted generalized linear models evaluating the relationships between physical activity frequency, duration, and body composition indices (FMI, FFMI, FM/FFM), as well as their association with BMI (adjusted for age), are presented in Table 5. These analyses highlight the significant associations between both physical activity frequency and duration with body composition, particularly with FFMI and FMI, with effects becoming more pronounced after adjusting for age and BMI.

Regarding FMI, the unadjusted model revealed no significant relationship; however, after adjustment, a significant negative association emerged (B = -0.242, $p < 0.001$), indicating that higher physical activity frequency is linked to a lower FMI. FFMI, in contrast, showed a significant positive relationship with physical activity frequency in both unadjusted (B = 0.090, $p < 0.001$) and adjusted models (B = 0.243, $p < 0.001$), suggesting that more frequent physical activity is associated with an increase in fat-free mass. For the FM/FFM ratio, a significant positive relationship was observed only in the adjusted model (B = 0.217, $p < 0.001$), indicating that higher physical activity frequency is associated with a higher FM/FFM ratio.

When considering the duration of physical activity, the unadjusted model for FMI again showed no significant

Table 4 Unadjusted and adjusted linear regression models of FMI, FFMI and FM/FFM by sleep quality / sleeping hours and association with BMI (adjusted for age and BMI)

Predictor variable		Model type	R^2	Standard Error	B-coefficient (95% CI)	*P*-value
	Sleep hours					
FMI		Unadjusted	0.001	0.026	-0.031 (-0.070–0.031)	0.451
		Adjusted	0.004	0.113	0.068 (0.373–0.709)	0.570
FFMI		Unadjusted	0.002	0.057	-0.04 (-0.166–0.058)	0.342
		Adjusted	0.004	0.037	-0.005 (-0.267–0.176)	0.565
FM/FFM		Unadjusted	0.000	0.153	0.002 (-0.293–0.309)	0.959
		Adjusted	0.005	0.234	-0.062 (-0.687–0.234)	0.422
	Sleep quality					
FMI		Unadjusted	0.001	0.037	0.027 (− 0.048–0.095)	0.523
		Adjusted	0.007	0.16	-0.281 (-0.564–0.006)	0.267
FFMI		Unadjusted	0.005	0.081	0.070 (-0.023–0.296)	0.093
		Adjusted	0.007	0.16	0.129 (-0.062–0.568)	0.258
FM/FFM		Unadjusted	0.000	0.219	-0.017 (-0.518–0.341)	0.686
		Adjusted	0.003	0.335	0.034 (-0.478–0.839)	0.608

FM: Fat Mass, FFM: Free Fat Mass, FMI: Fat Mass Index, FFMI: Free Fat Mass Index

Table 5 Unadjusted and adjusted regression generalized linear models of FMI, FFMI and FM/FFM by physical activity frequency / duration and association with BMI (adjusted for age and BMI)

Predictor variable		Model type	X^2	Standard Error	B-coefficient (95% CI)	*P*-value
	Frequency					
FMI		Unadjusted	0.017	0.007	0.000 (-0.014–0.013)	0.904
		Adjusted	83.302	0.030	-0.242 (-0.034–0.002)	< 0.001
FFMI		Unadjusted	38.56	0.016	0.090 (0.060–0.121)	< 0.001
		Adjusted	83.713	0.03	0.243 (0.185–0.301)	< 0.001
FM/FFM		Unadjusted	1.279	0.04	0.042 (-0.037–0.120)	0.298
		Adjusted	22.784	0.06	0.217 (0.100–0.335)	< 0.001
	Duration					
FMI		Unadjusted	0.869	0.007	0.008 (-0.005–0.021)	0.208
		Adjusted	15.608	0.029	-0.141 (-0.199: − 0.083)	< 0.001
FFMI		Unadjusted	10.622	0.015	0.066 (0.037–0.095)	< 0.001
		Adjusted	15.651	0.03	0.141 (0.083–0.199)	< 0.001
FM/FFM		Unadjusted	0.247	0.041	-0.027 (-0.107–0.052)	0.502
		Adjusted	5.028	0.062	0.104 (-0.018–0.225)	0.027

FM: Fat Mass, FFM: Free Fat Mass, FMI: Fat Mass Index, FFMI: Free Fat Mass Index

relationship. However, after adjustment, a significant negative association was found (B = -0.141, $p < 0.001$), suggesting that longer durations of physical activity are associated with a reduction in FMI. FFMI was positively associated with physical activity duration in both unadjusted (B = 0.066, $p < 0.001$) and adjusted models (B = 0.141, $p < 0.001$), indicating that longer activity durations contribute to a higher fat-free mass. Finally, for FM/FFM, the unadjusted model showed no significant association, while the adjusted model revealed a significant positive relationship (B = 0.104, $p = 0.027$), suggesting that longer physical activity durations are linked to a higher FM/FFM ratio.

Discussion

The primary objective of this study was to investigate the relationships between key body composition indices FMI, FFMI and FM/FF, and BMI in young adult Saudi women. Additionally, the study aimed to explore how these body composition measures correlate with sleep patterns and physical activity behaviors. By examining these associations, the research seeks to deepen our understanding of how body composition interacts with lifestyle factors, with the potential to inform more effective, tailored strategies for managing obesity and promoting healthier behaviors within this population. To our knowledge, this is the first study of its kind, as most existing research on obesity in Saudi women relies primarily on BMI as a screening tool—despite its well-documented limitations [25].

The findings from this study highlight the important relationship between body composition indices and fat distribution patterns. Specifically, the WHR was found to increase significantly across tertiles of FMI, indicating a more centralized fat distribution (i.e., greater abdominal fat) in individuals with higher FMI. This is a notable observation, as abdominal or visceral fat has long been recognized as a key risk factor for a range of metabolic and cardiovascular diseases [26, 27]. The study further observed that as FM/FFM increased, WHR decreased, suggesting that individuals with a higher proportion of fat-free mass (lean tissue such as muscle and bone) relative to their fat mass may indicating a more favorable fat distribution. These findings contribute to the growing body of evidence that highlights the importance of considering both fat and lean mass when assessing body composition, as different ratios of fat and lean tissue can have distinct implications for health [28, 29]. The significant increase in BMI from Tertile 1 to Tertile 3 across all groups is in line with the well-established association between higher fat mass and elevated BMI [30]. This supports the continued use of BMI as a useful screening tool for obesity, however, it also underscores the limitations of relying solely on BMI as a measure of health. For instance, individuals with a higher FMI may have a higher risk of developing obesity-related comorbidities due to greater abdominal fat, even if their BMI does not place them in the "obese" category. Conversely, those with higher FFMI may benefit from better metabolic health, as lean mass, particularly muscle mass, is associated with a lower risk of metabolic syndrome, improved insulin sensitivity, and better overall physical function [31].

The results from the linear regression models accounting for potential confounders like age and BMI, indicate that sleep duration and quality are not significantly associated with the body composition indices (FMI, FFMI, FM/FFM) in this sample of young adult Saudi women. This lack of significant association suggests that factors other than body composition might play a more prominent role in determining sleep quality and duration in this population. Even if some research has suggested that higher levels of body fat (e.g., greater FMI) can contribute to sleep disturbances or shorter sleep duration due to conditions like obstructive sleep apnea [32], the complexity of sleep regulation is well documented involving other common factors among university students like stress levels [33] and academic pressure [34].

The regression models in this study suggest several important associations between physical activity and body composition indices, specifically FMI, FFMI, and FM/FFM. The use of adjusted models reveals in terms of duration, the positive B-value for FFMI (0.243) shows that more frequent physical activity contributes to increased lean mass. First, the analysis indicates that higher physical activity frequency is associated with a lower FMI. This is an intriguing finding, as it suggests that individuals who engage in more frequent physical activity tend to have a lower Fat Mass Index (FMI), which could imply a reduction in body fat accumulation. The relationship between physical activity and lower FMI aligns with existing literature that suggests regular physical activity, particularly aerobic and strength training exercises, plays a critical role in reducing fat mass and improving overall fat distribution as well as to an increase in lean body mass, particularly muscle [35]. In addition to physical activity frequency, the positive B-value for FFMI (0.141) highlights that prolonged physical activity also promotes lean mass gain, further supporting the benefits of extended exercise for muscle development and in shaping body composition, specifically the FM/FFM ratio (B-value = 0.217). The adjusted regression models suggest that longer physical activity durations are associated with a higher FM/FFM ratio (B-value = 0.104). Taken together, these findings are consistent with research indicating that both the duration and intensity of physical activity contribute to improvements in body composition, promoting lean mass preservation while reducing fat [36]. These findings suggest that public health interventions should prioritize both increasing the frequency and extending the duration of physical activity to improve health outcomes in young women.

In terms of limitations, the use of convenience sampling may introduce selection bias, which could potentially limit the generalizability of the findings to the broader population of young adult Saudi women and to other demographic groups. However, despite this limitation, our study provides valuable preliminary insights into the relationships between body composition indices (such as FMI, FFMI, and FM/FFM), BMI, and their associations with sleep patterns and physical activity habits within this specific population. Therefore, examining non-linear associations between body composition indices and the variables considered in the study may offer deeper insights into the complex underlying relationships. Another limitation is the cross-sectional design inherently that limits the ability to draw causal conclusions, highlighting the necessity for longitudinal or experimental research to more effectively clarify the nature of these relationships [37]. Moreover, the reliance on a simple two-question questionnaire to assess physical activity may not capture the full complexity and variability of physical activity patterns. A more detailed and validated tool, such as the Physical Activity Questionnaire for Adults (PAQL), however, referring to previous population studies exploring physical activity issues, these questions were designed to capture both the frequency and the daily duration of physical activity participants engaged in [38, 39]. Hence, would provide more accurate and comprehensive data on physical activity behaviors. Therefore, it is recommended that future research utilize more robust assessment tools to further explore the relationship between body composition and lifestyle factors in this population. Additionally, collecting a broader range of baseline data on potential confounding factors, such as socioeconomic status, health status, details sleep patterns, and stress levels, will help account for their potential impact on the studied outcomes. Indeed, incorporating these variables will enhance the validity and applicability of the findings, providing a more nuanced understanding of the factors influencing body composition.

Conclusion

This study reinforces the importance of body composition metrics beyond BMI and demonstrates the potential of indices like FMI and FM/FFM in providing a more accurate picture of an individual's health in terms of fat distribution and lean mass. These insights can lead to better-informed health strategies and targeted interventions for improving public health outcomes. This could help in addressing not just body weight, but also fat distribution and lean mass preservation. Further investigations are needed, including larger, more diverse populations across a broader age range, and incorporating additional parameters beyond physical activity and sleep patterns to gain a more comprehensive understanding of the factors influencing body composition of Saudi population.

Acknowledgements
The authors specially thank the Dean of Student Affairs Deanship Dr. Dunia A. Alfarraj for supporting the research. The authors also thank the Health Awareness Society (Hayatona) to provide the material to conduct measure the Body composition, with the participation of a team from the association, and training a volunteer team of students to use it. Finally, the authors would like to thank Mona Al-Othaim, Nouf Almosaiteer, Mnahel Almshan, Amal Almobark, Abeer Alnasser and the team of student volunteers for helping in data collection.

Author contributions
All authors contributed to the study conception and design. Data acquisition was performed by AAA, AAA, GEA, GMA, LAA, NIA, NAA, NAA, and NMA. Data curation was performed by SAA and SA. Funding acquisition was carried by SAA. The formal analysis was performed by SAA, SA, and NB. The first draft of the manuscript was written by all authors. All authors read and approved the final manuscript. The work reported in the paper has been performed by the authors, unless clearly specified in the text.

Funding
Princess Nourah bint Abdulrahman University Researchers Supporting Project number (PNURSP2024R714), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

Data availability
Data can be provided by contacting the corresponding author. Further details are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
Ethical approval for the study was granted by the Institutional Review Board (IRB) of PNU (IRB Log number 24–0024). Informed consent was obtained from participants by their indication of agreement to use their data for research purposes. All data collected was kept confidential and anonymous, ensuring that it was used solely for the purposes of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Tissue Biobank Section, Research Department, Natural and Health Science Research Center, Princess Nourah bint Abdulrahman University, P.O.Box 84428, Riyadh 11671, Saudi Arabia
[2]Lifestyle and Health Research, Natural and Health Sciences Research Center, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia
[3]Joint Research Unit in Nutrition and Food, RDC-Nutrition AFRA/IAEA, Ibn Tofaïl University- CNESTEN, Rabat-Kénitra 242, Morocco
[4]Nutrition Department-Deanship of Students Affairs, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia
[5]Clinical Nutrition Department, College of Applied Medical Sciences, King Faisal University, Al Ahsa 31982, Saudi Arabia

Received: 2 December 2024 / Accepted: 16 February 2025
Published online: 05 March 2025

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