# Impact of gender, urbanization, and food preference on university students' body composition post-COVID-19

*Impacto del género, la urbanización y la preferencia alimentaria en la composición corporal de los estudiantes universitarios después de la COVID-19*


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## Abstract

Introduction: The COVID-19 lockdown significantly altered university students' lifestyles, affecting their physical activity and dietary habits, which impacted their body composition.
Objective: This study examined the influence of gender, urbanization, and food preferences on body composition among university students, after the COVID-19 pandemic lockdown.
Methodology: A cross-sectional study was conducted with 410 students (235 males, 175 females) classified by urbanization (200 urban, 210 rural) and dietary habits (147 vegetarians, 263 non-vegetarians). Body composition parameters were measured using the MA601 Body Composition Analyzer.
Results: Males had higher intracellular water, extracellular water, protein, minerals, and lean mass, while females exhibited greater fat mass, body fat percentage, and subcutaneous fat. Rural students showed higher intracellular water, protein, lean mass, and basal metabolic rate, whereas urban students had higher fat mass and subcutaneous fat. Food preferences had minimal influence on most parameters. Muscle quality assessment revealed that males, rural students, and non-vegetarians had significantly higher grip strength.
Discussion: These findings align with previous research on gender and urbanization-related differences in body composition, though the limited effect of dietary preferences warrants further investigation. The study's cross-sectional nature and reliance on self-reported dietary data may have influenced results.
Conclusions: Post-COVID-19 lockdown, gender and urbanization significantly impacted students' body composition, whereas food preferences had a lesser effect. Future studies should explore long-term lifestyle influences on body composition in diverse populations.



## Keywords

Body composition; food preferences; gender differences; lifestyle factors; urbanization.



## Resumen

Introducción: El confinamiento por COVID-19 alteró significativamente el estilo de vida de los estudiantes universitarios, afectando su actividad física y hábitos alimentarios, lo que impactó su composición corporal.
Objetivo: Este estudio analizó la influencia del género, la urbanización y las preferencias alimentarias en la composición corporal de los estudiantes de la Universidad Central de Punyab, India, después del confinamiento.
Metodología: Se realizó un estudio transversal con 410 estudiantes (235 hombres, 175 mujeres) clasificados según su urbanización (200 urbanos, 210 rurales) y hábitos alimentarios (147 vegetarianos, 263 no vegetarianos). Los parámetros de composición corporal se midieron utilizando el analizador de composición corporal MA601.
Resultados: Los hombres presentaron mayor agua intracelular y extracelular, proteínas, minerales y masa magra, mientras que las mujeres mostraron mayor masa grasa, porcentaje de grasa corporal y grasa subcutánea. Los estudiantes rurales tuvieron mayor agua intracelular, proteínas, masa magra y tasa metabólica basal, mientras que los urbanos mostraron más masa grasa y grasa subcutánea. Las preferencias alimentarias tuvieron una influencia mínima en la mayoría de los parámetros. La evaluación de la calidad muscular indicó que los hombres, los estudiantes rurales y los no vegetarianos tenían una fuerza de agarre significativamente mayor.
Discusión: Estos hallazgos coinciden con investigaciones previas sobre diferencias de género y urbanización en la composición corporal, aunque el escaso impacto de la dieta requiere más estudios. La naturaleza transversal del estudio y el uso de datos autoinformados sobre la dieta pudieron influir en los resultados.
Conclusiones: Tras el confinamiento por COVID-19, el género y la urbanización influyeron significativamente en la composición corporal de los estudiantes, mientras que la dieta tuvo un efecto menor. Futuras investigaciones deberían explorar los efectos a largo plazo del estilo de vida en poblaciones diversas.



## Palabras clave

Composición corporal; preferencias alimentarias; diferencias de género; factores del estilo de vida; urbanización.

## Introduction

The COVID-19 pandemic brought unprecedented changes to people's lives worldwide, including implementing lockdowns and restrictive measures to control the spread of the virus (Shrestha et al., 2020; Singh et al., 2020; Thanalakshmi et al., 2024). While these measures were essential for public health, they had various effects on the well-being of normal individuals. The COVID-19 not only lead to adverse physical health conditions like respiratory problems, headaches, musculoskeletal problems, and somatic complaints, the associated lockdown significantly impact physical health and body composition of general population (Ashouri et al., 2023; Ballering et al., 2022; Colmenero, (2023); Govindasamy et al., 2023; Jagadeesan et al., 2024). University students, in particular, faced unique challenges due to sudden changes in their living and studying environments. Research indicates that the pandemic's lockdowns led to decreased physical activity and increased sedentary behaviors among students, contributing to weight gain and changes in body composition (Caciula et al., 2024; Torres et al., 2023). Impact of gender differences was also observed, with males exhibiting a greater increase in body mass index during the lockdowns, although post-lockdown, females experienced a higher rate of body mass index increase (H. Li et al., 2024). Urbanization also plays a role, as students in urban areas may have different access to physical activity opportunities and dietary options compared to those from rural areas, although specific studies on this aspect are limited. The pandemic exacerbated food insecurity among students, with over 30% experiencing food insecurity, which further influenced their dietary quality and body composition (Jehi et al., 2023). The quality of diet deteriorated, with a decrease in the intake of essential nutrients and an increase in unhealthy eating behaviors such as binge eating and snacking, contributing to weight gain and poor body composition (Jehi et al., 2023; Sharma et al., 2024). Mental health issues, including increased symptoms of depression and anxiety, were prevalent among students and were associated with higher body fat percentages and lower skeletal muscle mass, indicating a negative impact on body composition (Caciula et al., 2024; Sanchis-Soler et al., 2022; Torres et al., 2023). The shift to digital activities and remote learning during lockdowns also contributed to these changes, as students spent more time on screens and less on physical activities (Jadrna et al., 2024).

Even though, the previous studies collectively highlighted the complex interplay of factors like gender, urbanization, and food preferences on body composition on student population, gaps remain in understanding the long-term post-lockdown impact of these factors on body composition of university students. The rationale for further research lies in addressing these gaps to develop targeted interventions that consider gender-specific needs, urbanization influences, and food preferences to promote healthier lifestyles among university students in the post-pandemic era. Thus, the purpose of the study was to explore how gender differences, urbanization, and food preferences have influenced body composition among university students in the aftermath of the COVID-19 pandemic lockdowns. We hypothesized that gender, urbanization, and food preferences would significantly affect body composition of university students.

## Method

### *Participants*

The study involved regular residential students of Central University of Punjab, India who reported in university after the COVID-19 pandemic lockdown in first week of October 2021. A sample of 410 students was purposively selected, out of which 200 students belong to urban and 210 belong to rural regions. Further, 235 participants were male, and 175 were female. Among the participant, 147 participants were vegetarian and 263 were non-vegetarian. All the subjects who participated, had submitted negative SARS-CoV-2 in the RT-PCR test report.

### *Inclusion and Exclusion Criteria*

Inclusion criteria required that participants be university hostel resident aged between 21 and 26 years. Only students who had resumed on-campus education at least three months post-lockdown were included, as this allowed for a sufficient period of potential lifestyle stabilization after the lockdowns. Participants were required to provide informed consent to confirm their willingness to take part in the

study and comply with the data collection procedures. On the other hand, students with any pre-existing medical conditions known to affect body composition, such as metabolic or endocrine disorders, were excluded to prevent biases stemming from conditions that might independently influence weight, body fat, or muscle mass. Additionally, students who experienced significant lifestyle disruptions unrelated to the pandemic lockdowns including recent major surgeries, accidents, or other impactful personal events were also excluded.

### *Variables*

For the purpose of the study, we selected the factors gender (male and female), urbanization (urban and rural) and food preference (vegetarian and non-vegetarian) as independent variables while we categorised the dependent variables under body composition (intracellular water mass (IWM), extracellular water mass (EWM), protein mass (PM), mineral mass (MM), fat mass (FM), lean mass (LM), skeletal muscle mass (SMM)), obesity (percentage body fat (PBF), waist circumference (WC), hip circumference (HC), body mass index (BMI)), abdominal fat (visceral fat area (VFA), subcutaneous fat area (SFA)), muscle quality (right hand grip force (RHGF), and left hand grip force (LFGF)) and fitness parameter (basal metabolic rate (BMR), and total energy expenditure (TEE)) categories.

### *Instruments and Measurements*

We developed a questionnaire to collect demographic data including age, gender (male or female), urbanization (urban or rural), and food preference data of the participants. Height (SECA model 213, Hamburg, Germany) and weight (ECA model 813, Hamburg, Germany) were measured manually as part of demographic data and also used to calculate the BMI of the participants. Whereas, to measure the other body composition related dependent variables, a MA601 Body Composition Analyzer (MA601 Body Composition Analyzer, Guozhong, Taiwan) was used. This instrument applies neural network algorithms to Bioelectrical Impedance Analysis (BIA) for accurate and reliable body composition measurement. The MA601 Body Composition Analyzer uses three frequencies (5kHz, 50kHz, 250kHz) for five segments (Right Arm, Left Arm, Trunk, Right Leg, Left Leg) with an 8-point tactile electrode design.

### *Research Design and Data Collection Procedure*

We adopted a quantitative cross-sectional study design for the present study during the month of October and November of 2021. The participants already adapted to post-lockdown lifestyle by resuming their usual hostel campus life and in-person interactions. They were recruited through campus announcements using email. The participants' informed consent was obtained after explaining the purpose, procedure and confidentiality of data. Thereafter, the participants filled the questionnaire containing demographic data. Height and weight were measured in a designated laboratory in the department of physical education. The MA601 Body Composition Analyzer device was also placed inside that laboratory and the participants underwent the test immediately after measuring their height and weight. To maintain a controlled condition and to ensure accuracy and reliability, the data collection was conducted after two hours post lunch by the participants and withing the time 3.00 PM to 6.00 PM. Before collecting the data, each participant was asked to remove his/her shoes, socks or any metallic wear from their body. Each data collection session lasted approximately 05 minutes.

### *Ethical Considerations*

Before conducting the study, an approval was taken (CUPB/Acad./20-21/1037 dated 11th February, 2021) from the research seed money committee (RSM) of the Central University of Punjab, India. The participants provided written consent after going through in details about the study, including its purpose, procedure and potential outcomes. They were also briefed on their rights, including voluntary participation and the option to withdraw at any time. All participant's data were anonymized using unique code and stored securely. Only authorized researchers had access to the stored data. The whole procedure was as accordance to declaration of Helsinki (World Medical Association, 2013).

### *Data analysis*

The mean and standard deviation for demographic data, body composition indicators across different factors (gender, urbanization, and food preference) were calculated. Independent Samples t-Test was applied for assessing differences in body composition between levels of different factors. Cohen's d was

calculated to indicate the effect size. For all the statistical calculation, IBM SPSS 30.00 version was used and the level of significant was set at 0.05.

## Results

The demographic data of the participants of the study are detailed from Table 1 and Table 2. They provide insights into the distribution of participants based on gender, region, and food preferences, with further analysis of age, height, and weight within each factor.

Table 1. Distribution of the participants by factors

| Factors | Level | Number | Percentage |
|---|---|---|---|
| Gender | Male | 235 | 57.3% |
| | Female | 175 | 42.7% |
| Urbanization | Urban | 200 | 48.8% |
| | Rural | 210 | 51.2% |
| Food Preference | Veg | 147 | 35.9% |
| | Non-Veg | 263 | 64.1% |

In table 1, the gender breakdown shows a slightly higher proportion of male participants (57.3%) compared to female participants (42.7%), while the regional distribution is nearly balanced between urban (48.8%) and rural (51.2%) backgrounds. Food preference distribution reveals a predominance of non-vegetarian participants, comprising 64.1% of the sample, with vegetarians making up the remaining 35.9%.

Table 2. Demographic distribution of the participants by factors

| Variables | Factors | Levels | Statistic | |
|---|---|---|---|---|
| Age | Gender | Male | Mean | 23.98 |
| | | | Std. Deviation | 2.73 |
| | | Female | Mean | 23.24 |
| | | | Std. Deviation | 1.79 |
| | Urbanization | Urban | Mean | 23.78 |
| | | | Std. Deviation | 2.68 |
| | | Rural | Mean | 23.56 |
| | | | Std. Deviation | 2.09 |
| | Food Preference | Veg | Mean | 23.61 |
| | | | Std. Deviation | 1.73 |
| | | Non-Veg | Mean | 23.70 |
| | | | Std. Deviation | 2.71 |
| Height | Gender | Male | Mean | 170.90 |
| | | | Std. Deviation | 6.57 |
| | | Female | Mean | 156.67 |
| | | | Std. Deviation | 6.40 |
| | Urbanization | Urban | Mean | 163.61 |
| | | | Std. Deviation | 9.80 |
| | | Rural | Mean | 165.99 |
| | | | Std. Deviation | 9.24 |
| | Food Preference | Veg | Mean | 164.16 |
| | | | Std. Deviation | 10.52 |
| | | Non-Veg | Mean | 165.20 |
| | | | Std. Deviation | 9.01 |
| Weight | Gender | Male | Mean | 67.23 |
| | | | Std. Deviation | 13.12 |
| | | Female | Mean | 53.83 |
| | | | Std. Deviation | 9.79 |
| | Urbanization | Urban | Mean | 61.36 |
| | | | Std. Deviation | 13.14 |
| | | Rural | Mean | 61.65 |
| | | | Std. Deviation | 13.95 |
| | Food Preference | Veg | Mean | 60.57 |
| | | | Std. Deviation | 13.56 |
| | | Non-Veg | Mean | 62.04 |
| | | | Std. Deviation | 13.53 |

Further examination of gender-specific demographic data in table 2 indicates that the average age of male participants is slightly higher (mean = 23.98 years) compared to females (mean = 23.24 years). Height and weight differences between genders are also visible, with males showing a higher mean height (170.9 cm) and weight (67.23 kg) compared to females (156.67 cm & 53.83 kg). However, demographic data by urbanization reveals that urban and rural participants have almost similar mean ages, with urban participants averaging 23.78 years and rural participants 23.56 years. However, there are slight differences in physical measurements, as rural participants tend to be taller (mean height = 165.99 cm) compared to urban participants (mean height = 163.61 cm). Average weight between urban and rural participants is nearly identical, with urban participants averaging 61.36 kg and rural participants 61.65 kg. Similarly, demographic data by food preference and the average age for vegetarians and non-vegetarians is almost identical, with vegetarians averaging 23.61 years and non-vegetarians 23.70 years. Physical differences by dietary preference show that non-vegetarians have a slightly higher mean height (165.20 cm) and mean weight (62.04 kg) than vegetarians (164.16 cm and 60.57 kg).

Table 3. Descriptive statistics and mean comparisons of body composition variables

| Variables | Factors | Levels | Mean | Std. Deviation | Mean Difference | Cohen's d |
|---|---|---|---|---|---|---|
| Intracellular Water Mass | Gender | Male | 23.65 | 3.34 | 7.57* | 2.78 |
| | | Female | 16.08 | 1.76 | | |
| | Region | Urban | 19.96 | 4.69 | -0.91* | 4.65 |
| | | Rural | 20.87 | 4.62 | | |
| | Food Habit | Veg | 19.89 | 4.92 | -0.86 | 4.62 |
| | | Non-Veg | 20.75 | 4.47 | | |
| Extracellular Water Mass | Gender | Male | 14.14 | 1.85 | 4.05* | 1.54 |
| | | Female | 10.08 | 0.98 | | |
| | Region | Urban | 12.16 | 2.57 | -0.49 | 2.52 |
| | | Rural | 12.65 | 2.48 | | |
| | Food Habit | Veg | 12.15 | 2.67 | -0.39 | 2.50 |
| | | Non-Veg | 12.54 | 2.40 | | |
| Protein Mass | Gender | Male | 10.41 | 1.52 | 3.51* | 1.26 |
| | | Female | 6.90 | 0.78 | | |
| | Region | Urban | 8.70 | 2.17 | -0.42* | 2.14 |
| | | Rural | 9.12 | 2.11 | | |
| | Food Habit | Veg | 8.68 | 2.26 | -0.38 | 2.12 |
| | | Non-Veg | 9.06 | 2.05 | | |
| Mineral Mass | Gender | Male | 3.45 | 0.38 | 0.77* | 0.32 |
| | | Female | 2.68 | 0.20 | | |
| | Region | Urban | 3.08 | 0.49 | -0.09 | 0.50 |
| | | Rural | 3.17 | 0.51 | | |
| | Food Habit | Veg | 3.06 | 0.53 | -0.10 | 0.49 |
| | | Non-Veg | 3.17 | 0.48 | | |
| Fat Mass | Gender | Male | 15.57 | 7.80 | -2.51* | 7.48 |
| | | Female | 18.08 | 7.03 | | |
| | Region | Urban | 17.52 | 7.37 | 1.68* | 7.54 |
| | | Rural | 15.84 | 7.69 | | |
| | Food Habit | Veg | 17.02 | 8.05 | 0.45 | 7.81 |
| | | Non-Veg | 16.58 | 7.70 | | |
| Lean Mass | Gender | Male | 48.65 | 6.70 | 15.13* | 5.56 |
| | | Female | 33.51 | 3.49 | | |
| | Region | Urban | 41.27 | 9.41 | -1.82* | 9.30 |
| | | Rural | 43.09 | 9.19 | | |
| | Food Habit | Veg | 41.17 | 9.84 | -1.63 | 9.23 |
| | | Non-Veg | 42.80 | 8.90 | | |
| Skeletal Muscle Mass | Gender | Male | 28.58 | 4.19 | 9.47* | 3.48 |
| | | Female | 19.11 | 2.16 | | |
| | Region | Urban | 23.97 | 5.89 | -1.13 | 5.82 |
| | | Rural | 25.10 | 5.75 | | |
| | Food Habit | Veg | 23.90 | 6.15 | -1.02 | 5.77 |
| | | Non-Veg | 24.92 | 5.57 | | |

*Significant at 0.05 level.

The results of the body composition analysis (table 3) reveal significant differences influenced by gender, urbanization, and food preferences among university students following the COVID-19 pandemic lockdowns. For intracellular water mass, males had a significantly higher mean (23.65 ± 3.34 kg) than females (16.08 ± 1.76 kg), with a large mean difference of 7.57 (Cohen's d = 2.78), indicating a substantial gender difference. In terms of urbanization, rural students (20.87 ± 4.62 kg) had a slightly higher

intracellular water mass compared to urban students (19.96 ± 4.69 kg), with a small but significant mean difference of -0.91 (Cohen's d = 4.65). However, food preference did not significantly impact intracellular water mass, as vegetarians (19.89 ± 4.92 kg) and non-vegetarians (20.75 ± 4.47 kg) showed a non-significant mean difference of -0.86. For extracellular water mass, males again had a higher mean (14.14 ± 1.85 kg) than females (10.08 ± 0.98 kg), with a significant mean difference of 4.05 (Cohen's d = 1.54), reflecting a notable gender disparity. The difference between rural (12.65 ± 2.48 kg) and urban students (12.16 ± 2.57 kg) was not statistically significant, with a mean difference of -0.49. Similarly, food habit showed no significant influence, with vegetarians (12.15 ± 2.67 kg) and non-vegetarians (12.54 ± 2.40 kg) differing by only -0.39. For protein mass (the amount of protein present in an individual's body), males (10.41 ± 1.52 kg) had significantly more protein than females (6.90 ± 0.78 kg), with a mean difference of 3.51 (Cohen's d = 1.26), underscoring a strong gender effect. Rural students (9.12 ± 2.11 kg) also had significantly higher protein mass than urban students (8.70 ± 2.17 kg), with a mean difference of -0.42 (Cohen's d = 2.14). However, the difference between vegetarians (8.68 ± 2.26 kg) and non-vegetarians (9.06 ± 2.05 kg) was minimal and not significant (-0.38). In terms of mineral mass, males (3.45 ± 0.38 kg) had significantly higher values than females (2.68 ± 0.20 kg), with a mean difference of 0.77 (Cohen's d = 0.32). However, no significant differences were found between urban (3.08 ± 0.49 kg) and rural students (3.17 ± 0.51 kg) or between vegetarians (3.06 ± 0.53 kg) and non-vegetarians (3.17 ± 0.48 kg), with very small differences of -0.09 and -0.10, respectively. For fat mass, females (18.08 ± 7.03 kg) had significantly higher fat mass than males (15.57 ± 7.80 kg), with a mean difference of -2.51 (Cohen's d = 7.48). Urban students (17.52 ± 7.37 kg) also had significantly higher fat mass compared to rural students (15.84 ± 7.69 kg), with a mean difference of 1.68 (Cohen's d = 7.54). No significant differences were observed between vegetarians (17.02 ± 8.05 kg) and non-vegetarians (16.58 ± 7.70 kg), with a mean difference of only 0.45. For lean mass, males (48.65 ± 6.70 kg) had significantly higher lean mass than females (33.51 ± 3.49 kg), with a large mean difference of 15.13 (Cohen's d = 5.56), highlighting a substantial gender difference. Rural students (43.09 ± 9.19 kg) had significantly more lean mass than urban students (41.27 ± 9.41 kg), with a mean difference of -1.82 (Cohen's d = 9.30). However, food preference did not significantly affect lean mass, as vegetarians (41.17 ± 9.84 kg) and non-vegetarians (42.80 ± 8.90 kg) showed a non-significant difference of -1.63. Lastly, for skeletal muscle mass, males (28.58 ± 4.19 kg) had significantly higher values than females (19.11 ± 2.16 kg), with a large mean difference of 9.47 (Cohen's d = 3.48). However, there were no significant differences in skeletal muscle mass between urban (23.97 ± 5.89 kg) and rural students (25.10 ± 5.75 kg), with a small mean difference of -1.13. Similarly, no significant difference was observed between vegetarians (23.90 ± 6.15 kg) and non-vegetarians (24.92 ± 5.57 kg), with a mean difference of -1.02.

Table 4. Descriptive statistics and mean comparisons of obesity variables

| Variables | Factors | Levels | Mean | Std. Deviation | Mean Difference | Cohen's d |
|---|---|---|---|---|---|---|
| Percentage Body Fat | Gender | Male | 22.13 | 7.56 | -10.43 | 7.33 |
| | | Female | 32.56 | 7.00 | | |
| | Region | Urban | 28.17 | 8.83 | 3.08* | 8.85 |
| | | Rural | 25.09 | 8.86 | | |
| | Food Habit | Veg | 27.57 | 10.38 | 1.47 | 9.20 |
| | | Non-Veg | 26.10 | 8.57 | | |
| Waist Circumference | Gender | Male | 81.19 | 10.07 | 3.35* | 9.29 |
| | | Female | 77.84 | 8.13 | | |
| | Region | Urban | 80.36 | 8.97 | 1.16 | 9.43 |
| | | Rural | 79.21 | 9.84 | | |
| | Food Habit | Veg | 79.72 | 9.06 | -0.28 | 9.63 |
| | | Non-Veg | 80.00 | 9.89 | | |
| Hip Circumference | Gender | Male | 93.94 | 7.09 | 2.10* | 6.54 |
| | | Female | 91.84 | 5.72 | | |
| | Region | Urban | 93.45 | 6.27 | 0.76 | 6.62 |
| | | Rural | 92.69 | 6.93 | | |
| | Food Habit | Veg | 93.03 | 6.59 | -0.18 | 6.76 |
| | | Non-Veg | 93.21 | 6.84 | | |
| Body Mass Index | Gender | Male | 22.94 | 3.80 | 1.01* | 3.79 |
| | | Female | 21.93 | 3.77 | | |
| | Region | Urban | 22.81 | 3.78 | 0.58 | 3.81 |
| | | Rural | 22.24 | 3.85 | | |
| | Food Habit | Veg | 22.55 | 3.67 | -0.06 | 3.93 |
| | | Non-Veg | 22.62 | 4.05 | | |

*Significant at 0.05 level.

The obesity analysis results (table 4) demonstrate notable differences in body fat percentage, waist circumference, hip circumference, and body mass index (BMI) across gender, urbanization, and food preferences in university students following the COVID-19 pandemic lockdowns. For percentage body fat, females (32.56 ± 6.99%) had significantly higher values than males (22.13 ± 7.56%), with a substantial mean difference of -10.43 (Cohen's d = 7.33). This highlights a significant gender disparity in body fat. Urban students (28.17 ± 8.83%) had significantly higher body fat compared to rural students (25.09 ± 8.86%), with a mean difference of 3.08 (Cohen's d = 8.85). In contrast, food preference showed no significant effect, as vegetarians (27.57 ± 10.38%) and non-vegetarians (26.10 ± 8.57%) had a small and non-significant difference of 1.47. For waist circumference, males (81.19 ± 10.07 cm) had a significantly higher mean waist circumference than females (77.84 ± 8.13 cm), with a mean difference of 3.35 (Cohen's d = 9.29). However, there was no significant difference between urban (80.36 ± 8.97 cm) and rural students (79.21 ± 9.84 cm), with a small mean difference of 1.16. Similarly, food preference did not have a significant impact, with vegetarians (79.72 ± 9.06 cm) and non-vegetarians (80.00 ± 9.89 cm) showing a minimal difference of -0.28. For hip circumference, males (93.94 ± 7.09 cm) had a significantly larger hip circumference than females (91.84 ± 5.72 cm), with a mean difference of 2.10 (Cohen's d = 6.54). The differences between urban (93.45 ± 6.27 cm) and rural students (92.69 ± 6.93 cm) were small and non-significant, with a mean difference of 0.76. Similarly, vegetarians (93.03 ± 6.59 cm) and non-vegetarians (93.21 ± 6.84 cm) showed no significant difference, with a mean difference of -0.18. For body mass index (BMI), males (22.94 ± 3.80 kg/m$^2$) had significantly higher BMI values than females (21.93 ± 3.77 kg/m$^2$), with a mean difference of 1.01 (Cohen's d = 3.79). Urban students (22.81 ± 3.78 kg/m$^2$) had slightly higher BMI than rural students (22.24 ± 3.85 kg/m$^2$), with a mean difference of 0.58, though this was not significant. Similarly, food preferences showed no significant impact, as vegetarians (22.55 ± 3.67 kg/m$^2$) and non-vegetarians (22.62 ± 4.05 kg/m$^2$) had a negligible difference of -0.06.

Table 5. Descriptive statistics and mean comparisons of abdominal fat variables

| Variables | Factors | Levels | Mean | Std. Deviation | Mean Difference | Cohen's d |
|---|---|---|---|---|---|---|
| Visceral Fat Area | Gender | Male | 70.36 | 39.81 | -3.65 | 34.48 |
| | | Female | 74.01 | 25.63 | | |
| | Region | Urban | 75.08 | 31.34 | 6.07 | 34.43 |
| | | Rural | 69.01 | 37.11 | | |
| | Food Habit | Veg | 71.76 | 33.70 | -0.64 | 35.56 |
| | | Non-Veg | 72.41 | 36.44 | | |
| Subcutaneous Fat Area | Gender | Male | 128.51 | 80.94 | -51.18* | 77.61 |
| | | Female | 179.69 | 72.88 | | |
| | Region | Urban | 161.39 | 79.87 | 21.34* | 81.04 |
| | | Rural | 140.05 | 82.12 | | |
| | Food Habit | Veg | 156.78 | 88.24 | 8.60 | 84.19 |
| | | Non-Veg | 148.18 | 82.12 | | |

*Significant at 0.05 level.

The analysis of abdominal fat (table 5) in university students following the COVID-19 pandemic lockdowns revealed interesting patterns in both visceral fat area and subcutaneous fat area across gender, region, and food preferences. For visceral fat area, males (70.36 ± 39.81 cm$^2$) had a slightly lower mean value compared to females (74.01 ± 25.63 cm$^2$), with a mean difference of -3.65, though this difference was not statistically significant. In terms of urbanization, urban students (75.08 ± 31.34 cm$^2$) had a higher visceral fat area than rural students (69.01 ± 37.11 cm$^2$), with a mean difference of 6.07. However, this difference was not significant either. Food preference did not show a significant impact on visceral fat area, with vegetarians (71.76 ± 33.70 cm$^2$) and non-vegetarians (72.41 ± 36.44 cm$^2$) showing a minimal difference of -0.64. In the case of subcutaneous fat area, significant gender differences were observed. Females (179.69 ± 72.88 cm$^2$) had a significantly higher subcutaneous fat area than males (128.51 ± 80.94 cm$^2$), with a mean difference of -51.18 (Cohen's d = 77.61), highlighting a notable disparity between the sexes. Urban students (161.39 ± 79.87 cm$^2$) had significantly higher subcutaneous fat area compared to rural students (140.05 ± 82.12 cm$^2$), with a mean difference of 21.34 (Cohen's d = 81.04). However, food preferences did not show a significant effect on subcutaneous fat area, with vegetarians (156.78 ± 88.24 cm$^2$) and non-vegetarians (148.18 ± 82.12 cm$^2$) exhibiting a small, non-significant difference of 8.60.

Table 6. Descriptive statistics and mean comparisons of muscle quality variables

| Variables | Factors | Levels | Mean | Std. Deviation | Mean Difference | Cohen's d |
|---|---|---|---|---|---|---|
| Right Hand Grip Force | Gender | Male | 403.93 | 37.26 | 164.52* | 33.80 |
| | | Female | 239.41 | 28.49 | | |
| | Region | Urban | 322.47 | 89.62 | -22.43* | 87.51 |
| | | Rural | 344.90 | 85.46 | | |
| | Food Habit | Veg | 320.38 | 88.99 | -21.74* | 86.77 |
| | | Non-Veg | 342.12 | 85.66 | | |
| Left Hand Grip Force | Gender | Male | 377.57 | 33.12 | 160.23* | 30.01 |
| | | Female | 217.34 | 25.21 | | |
| | Region | Urban | 298.13 | 86.17 | -22.06* | 84.13 |
| | | Rural | 320.19 | 82.15 | | |
| | Food Habit | Veg | 296.10 | 85.27 | -21.40* | 83.46 |
| | | Non-Veg | 317.51 | 82.56 | | |

*Significant at 0.05 level.

The analysis of muscle quality (table 6), particularly hand grip force, revealed notable differences across gender, region, and food preferences among university students. For right hand grip force, males demonstrated significantly higher strength (403.93 ± 37.26 N) compared to females (239.41 ± 28.49 N), with a large mean difference of 164.52 (Cohen's d = 33.80), indicating substantial gender disparity in grip strength. Regionally, rural students (344.90 ± 85.46 N) exhibited significantly greater right hand grip force than urban students (322.47 ± 89.62 N), with a mean difference of -22.43 (Cohen's d = 87.51). Similarly, non-vegetarians (342.12 ± 85.66 N) showed significantly stronger right hand grip force compared to vegetarians (320.38 ± 88.99 N), with a mean difference of -21.74 (Cohen's d = 86.77). For left hand grip force, the pattern was consistent, with males again displaying significantly higher strength (377.57 ± 33.12 N) compared to females (217.34 ± 25.21 N), with a mean difference of 160.23 (Cohen's d = 30.01). Rural students (320.19 ± 82.15 N) had significantly greater left hand grip force compared to urban students (298.13 ± 86.17 N), with a mean difference of -22.06 (Cohen's d = 84.13). As with the right hand, non-vegetarians (317.51 ± 82.56 N) had significantly stronger left hand grip force than vegetarians (296.10 ± 85.27 N), with a mean difference of -21.40 (Cohen's d = 83.46).

Table 7. Descriptive statistics and mean comparisons of fitness parameters

| Variable | Factor | Levels | Mean | Std. Deviation | Mean Difference | Cohen's d |
|---|---|---|---|---|---|---|
| Basal Metabolic Rate | Gender | Male | 1485.07 | 152.60 | 343.59* | 126.71 |
| | | Female | 1141.49 | 79.58 | | |
| | Region | Urban | 1317.52 | 213.72 | -41.44* | 211.42 |
| | | Rural | 1358.96 | 209.22 | | |
| | Food Habit | Veg | 1315.20 | 223.79 | -37.36 | 209.66 |
| | | Non-Veg | 1352.56 | 202.35 | | |
| Total Energy Expenditure | Gender | Male | 2109.72 | 216.77 | 488.06* | 179.98 |
| | | Female | 1621.66 | 112.96 | | |
| | Region | Urban | 1871.69 | 303.57 | -58.90* | 211.42 |
| | | Rural | 1930.59 | 297.19 | | |
| | Food Habit | Veg | 1868.42 | 317.90 | -53.08 | 297.84 |
| | | Non-Veg | 1921.50 | 287.47 | | |

*Significant at 0.05 level.

The analysis of fitness parameters (table 7), focusing on basal metabolic rate and total energy expenditure, revealed significant variations based on gender, region, and food habits. For basal metabolic rate, males had a significantly higher Basal Metabolic Rate (1485.07 ± 152.60 kcal/day) compared to females (1141.49 ± 79.58 kcal/day), with a substantial mean difference of 343.58 (Cohen's d = 126.71). Regionally, rural students (1358.96 ± 209.22 kcal/day) exhibited significantly higher Basal Metabolic Rate compared to urban students (1317.52 ± 213.72 kcal/day), with a mean difference of -41.44 (Cohen's d = 211.42). In terms of food habits, non-vegetarians (1352.56 ± 202.35 kcal/day) had a slightly higher Basal Metabolic Rate compared to vegetarians (1315.20 ± 223.79 kcal/day), though the mean difference of -37.36 was not statistically significant. For total energy expenditure, males also demonstrated significantly higher Total Energy Expenditure (2109.72 ± 216.77 kcal/day) compared to females (1621.66 ± 112.96 kcal/day), with a large mean difference of 488.06 (Cohen's d = 179.98). Rural students (1930.59 ± 297.19 kcal/day) had significantly greater Total Energy Expenditure than urban students (1871.69 ± 303.57 kcal/day), with a mean difference of -58.90 (Cohen's d = 211.42). Similarly, non-vegetarians (1921.50 ± 287.47 kcal/day) exhibited slightly higher Total Energy Expenditure compared to vegetarians (1868.42 ± 317.90 kcal/day), but the mean difference of -53.08 was not statistically significant.

## Discussion

The study results reveal gender as a significant determinant of body composition, with males showing higher intracellular water mass, extracellular water mass, protein mass, mineral mass, lean mass, and skeletal muscle mass, while females have higher fat mass. Urban and rural differences are significant for certain components like lean mass and fat mass, with rural students tending to have slightly better lean mass and lower fat mass. Food habits, however, show minimal influence on body composition parameters.

Gender differences in body composition are well-documented, with males typically exhibiting higher lean mass and skeletal muscle mass, while females tend to have higher fat mass. This is consistent with findings from multiple studies, which reveal that males generally have higher skeletal muscle mass and protein content, while females have a predisposition for higher body fat storage due to genetic and hormonal factors (Bray, 1998; Janssen et al., 2000; Loomba-Albrecht, 2018; Lundsgaard & Kiens, 2014; Schleinitz et al., 2014; Schorr et al., 2018). The influence of urbanization on body composition, where rural students show slightly better lean mass and lower fat mass, can be attributed to lifestyle differences (de Lanerolle-Dias et al., 2015). Rural environments often encourage more physical activity and access to fresh, less processed foods, which can contribute to better body composition metrics. This is supported by findings that physical activity levels significantly impact body composition, with higher activity levels correlating with better muscle mass and lower fat percentages (Białkowski et al., 2024; Jaremków et al., 2024; Minu et al., 2021; Nishikori & Fujita, 2024; Thanalakshmi et al., 2024). The minimal influence of food habits on body composition parameters, as observed in the study, might be due to the complex interplay between diet, physical activity, and genetic predispositions. While diet is a crucial factor, its impact can be overshadowed by physical activity levels and genetic factors, which play a more direct role in determining body composition (Xu et al., 2022, pp. 2011–2018; Zadro et al., 2017). Studies have shown that despite changes in dietary intake during the pandemic, physical activity levels had a more pronounced effect on body composition changes, such as the decrease in physical activity leading to increased body mass and BMI (Bell et al., 2023; Dobrowolski & Włodarek, 2021; Kriaucioniene et al., 2023; Raine et al., 2023). Additionally, the pandemic-induced stress and lifestyle changes, including increased sedentary behavior, have been significant contributors to changes in body composition, often independent of dietary habits (Caroppo et al., 2021; Cervera-Martínez et al., 2021; Zhao et al., 2023). Furthermore, the relationship between mental health and body composition, where increased stress and anxiety correlate with higher body fat and lower muscle mass, suggests that psychological factors may also mediate the impact of diet on body composition (Fulton et al., 2022; Rog et al., 2024; Torres et al., 2023). Therefore, while food preferences and dietary habits are important, their influence on body composition is often mediated by other factors such as physical activity, urbanization, and mental health, which can have more immediate and significant effects.

Furthermore, in aligned with our study, it is well documented that females often exhibit higher body fat percentages, which can be attributed to hormonal and physiological differences (Ciardullo et al., 2023; Ethun, 2016). The COVID-19 pandemic exacerbated these differences, as seen in studies where males showed a greater increase in BMI during lockdowns, possibly due to reduced physical activity and increased caloric intake (Bolesławska et al., 2023; J. Lee & Yoo, 2024; Maltoni et al., 2021; Piesch et al., 2024, 2024). Females, on the other hand, were more prone to emotional eating and eating disorders, which could contribute to higher body fat percentages (Dakanalis et al., 2023). Urbanization's slight effect on body fat can be linked to lifestyle differences between urban and rural students. Urban population often have more sedentary lifestyles and greater access to high-calorie foods, leading to increased body fat (Ghosh et al., 2023; Nurwanti et al., 2019). This is supported by findings that urban students tend to consume more meals and have higher carbohydrate intake, contributing to obesity (Huo et al., 2024; Ruiz et al., 2020; Zou et al., 2023). However, the impact of food preferences on obesity indicators appears minimal, possibly because the pandemic led to changes in dietary habits across the board, with increased consumption of both healthy and unhealthy foods, as seen in the increased intake of fruits, vegetables, and snacks among adolescents during the pandemic (Samanta et al., 2022; Woods et al., 2024). Additionally, the stress and mental health challenges during the pandemic may have overshadowed the influence of food preferences, as students turned to comfort foods regardless of their usual preferences (Olfert et al., 2022; Sadler et al., 2021). The pandemic's impact on physical activity also played a crucial role, with significant reductions in physical activity levels observed among university

students, further contributing to changes in body composition (Park et al., 2022; Podstawski, 2022). The interplay of these factors highlights the complex nature of body composition changes post-pandemic, where gender and urbanization have more pronounced effects compared to food preferences, which were likely moderated by the broader lifestyle disruptions caused by the pandemic.

The significant increase in subcutaneous fat area among females compared to males aligns with findings that females experienced more severe eating disorders and weight fluctuations during the pandemic, possibly due to heightened stress and emotional eating patterns (Dakanalis et al., 2023; Mentzelou et al., 2024; Piątkowska-Chmiel et al., 2024). This gender disparity in fat distribution is further supported by the observation that males generally had higher dietary energy and macronutrient intake, yet females reported more weight fluctuation, indicating a complex interplay between dietary habits and body composition (Blaak, 2001; Chiriboga et al., 2008; Ethun, 2016). Urban students' higher subcutaneous fat levels compared to their rural counterparts can be attributed to lifestyle changes during the pandemic, such as reduced physical activity and increased sedentary behavior, which were more pronounced in urban settings due to stricter lockdown measures and limited outdoor spaces (Gülü et al., 2022; Nurwanti et al., 2019; Tripathy et al., 2016). The urban environment may also have facilitated greater access to calorie-dense foods, contributing to increased fat accumulation (Cao et al., 2021; A. Lee et al., 2000; Shams et al., 2024). Despite these differences, food preferences did not significantly affect abdominal fat measures, which could be due to the overall increase in intuitive eating practices that helped mitigate weight gain, as students adapted to eating more in line with their bodily needs rather than external cues (Souto et al., 2024). Additionally, the pandemic-induced sensory changes in taste and smell did not significantly alter dietary patterns enough to impact abdominal fat, as the primary changes were in protein and sodium intake rather than overall caloric consumption (McCormack & Peng, 2024). The overall trend towards unhealthy eating behaviors, such as increased junk food consumption and reduced physical activity, was more prevalent among lower-income groups, indicating that socioeconomic factors might have a more substantial impact on dietary outcomes than food preferences alone (Parker et al., 2023). Therefore, the study's findings are consistent with the broader literature, which suggests that gender and urbanization have a more pronounced effect on fat distribution due to behavioral and environmental factors, while food preferences alone do not significantly alter abdominal fat measures in the context of the COVID-19 pandemic (de Lanerolle-Dias et al., 2015; Drywien et al., 2020; Feraco et al., 2024; Sruthi et al., 2023; Verma et al., 2023).

In the current study, we observed higher muscle quality in males compared to females, which can be attributed to differences in dietary intake and physical activity levels. Males generally have higher dietary energy and macronutrient intake, which supports muscle development and maintenance (Bennett et al., 2018; Carbone & Pasiakos, 2019; Y. Y. Lee & Wan Muda, 2019). Additionally, males tend to engage in higher levels of physical activity, which is crucial for muscle quality, as indicated by the higher METs in men compared to women during the pandemic (Craft et al., 2014; del-Cuerpo et al., 2023; Miles, 2007). The rural students outperforming urban counterparts in muscle quality could be linked to lifestyle differences, where rural students might have more opportunities for physical labor and outdoor activities, contributing to better muscle development. This is supported by findings that suggest physical activity levels were significantly impacted during the lockdown, with reduced opportunities for exercise in urban settings (X. Li et al., 2024; Panisset & Galea, 2023; Park et al., 2022). Furthermore, the impact of food preferences, with non-vegetarians exhibiting stronger grip strength than vegetarians, can be explained by the nutritional differences between these diets. Non-vegetarian diets typically provide higher levels of protein and essential amino acids, which are vital for muscle synthesis and repair, as highlighted in the context of dietary intake among university students (Carbone & Pasiakos, 2019; Hegde & Roberts, 2023; Mariotti & Gardner, 2019). The pandemic-induced changes in eating habits, such as increased consumption of low-nutritional-quality foods, were noted to have adverse effects on body composition and physical condition, particularly among those with less balanced diets (Alomari et al., 2022; González-Monroy et al., 2021; Woods et al., 2024). Additionally, the stress and mental health challenges faced during the pandemic, which were more pronounced in certain demographics, could have indirectly influenced physical health and muscle quality by affecting lifestyle choices and physical activity levels (Zhao et al., 2023).

The results regarding the gender differences in basal metabolic rate and total energy expenditure are consistent with previous findings that males generally have higher dietary energy and macronutrient

intake compared to females, which contributes to higher basal metabolic rate and total energy expenditure values (del-Cuerpo et al., 2023). This is further supported by the observation that males exhibited a greater increase in BMI during the lockdown, indicating a higher adverse metabolic rate and energy expenditure (McLaren et al., 2024). The impact of urbanization is reflected in the fitness parameters, where rural students showed higher fitness levels than their urban counterparts. This can be attributed to lifestyle differences, as urban students often experience more sedentary behavior due to limited space and opportunities for physical activity during lockdowns, as seen in the reduced physical activity levels and increased sedentary behavior among university students during the pandemic (Eubank et al., 2024; Ferreira Silva et al., 2023). Additionally, rural environments may offer more opportunities for physical activity, contributing to better fitness outcomes (Marcen et al., 2022). The influence of food preferences, particularly the non-significant differences between vegetarians and non-vegetarians in basal metabolic rate and total energy expenditure, aligns with findings that dietary intake and physical activity levels were altered during the pandemic, but the overall energy intake was sufficient for most students, regardless of dietary preference (Bertrand et al., 2021; Ferrara et al., 2022; Hori et al., 2021; Kosendiak et al., 2024). Moreover, the pandemic led to changes in eating habits and stress levels, which could have affected metabolic parameters, but these changes were not necessarily linked to specific dietary preferences (Alomari et al., 2022; Ferrara et al., 2022).

## Conclusions

The current study reveals valuable insights into the impact of gender, urbanization, and food preferences on body composition. However, we noted certain limitations in the study. The sample size and the cross-sectional nature of the study may limit the generalizability of the findings, and the reliance on self-reported food habits could introduce bias. Additionally, while physical activity levels were discussed as influential, they were not quantitatively measured, which might impact the study's comprehensiveness. In conclusion, gender and urbanization significantly affect body composition, with males generally having higher lean mass and skeletal muscle mass, and rural students showing better lean mass and lower fat mass compared to their urban counterparts. However, food preferences alone showed minimal effect on body composition, likely due to the complex interplay of lifestyle and environmental factors. For future research, a longitudinal design with larger, diverse samples is recommended to better capture the variations in body composition across populations. Including direct measures of physical activity, stress, and mental health could also enhance understanding of their influence on body composition, particularly in the context of rapid lifestyle changes such as those seen during the COVID-19 pandemic.

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