Research Article

Body Mass Index and Waist-Hip Ratio Profile Of Adolescents in Kerala, India: Implications For Emerging Cardiometabolic Risk

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Abstract

Introduction: Cardiometabolic risk has emerged as a global health crisis, affecting individuals of all ages, particularly adolescents. The World Health Organization (WHO) identifies obesity as a major risk factor for chronic diseases such as cardiovascular disease, type 2 diabetes, and certain cancers. With the alarming rise in adolescent obesity rates, this study aims to assess the anthropometric profile of adolescents and determine the prevalence of underweight, normal weight, overweight, and obesity among adolescents in Kerala, India. **Methods:** A descriptive cross-sectional study was conducted, sampling 1,240 adolescents aged 17 to 19 years from six randomly selected educational institutions in the northern three districts of Kerala, India. Anthropometric data, including height, weight, Body Mass Index (BMI), waist circumference, and waist-hip ratio, were collected and analysed statistically. **Results:** Of the 1240 participants, 73.8% were 19 years old and 309 (24.9%) were 18 years. 47.8% were male, and 52.1% were female, with one transgender participant. The BMI analysis revealed that 44.8% were underweight, 53.2% had a healthy BMI, and only 1.9% were overweight, with no cases of obesity, whereas 366 (29.5%) of them substantially increased waist-hip ratio by ≥0.90 cm (Men) ≥0.85 cm (Women). **Conclusion:** This study highlights the relatively low prevalence of overweight adolescents in Kerala, contrasting with global trends, but points to the potential for future increases due to lifestyle changes. But, one third of the adolescent's population pose risk under central obesity, which is a major implication for cardiometabolic risk. These findings provide critical data to inform public health interventions and policies aimed at early prevention and management of central obesity among adolescents, promoting long-term health and well-being.

Keywords: Adolescent; Body Mass Index; obesity; Waist-Hip Ratio; Cardiometabolic Risk, Anthropometrics.

1. Introduction

Obesity has become a pressing global health issue, affecting individuals across all age groups, including adolescents. The World Health Organization (WHO) identifies obesity as one of the leading risk factors for chronic diseases, such as cardiovascular disease, type 2 diabetes, and certain cancers. In recent decades, obesity rates among adolescents have been rising alarmingly, contributing to the global epidemic of non-communicable diseases.

Heart disease and other cardiovascular diseases are a major global health concern. In India, there are regional differences in the prevalence of coronary heart disease: it is higher in urban areas and lower in rural ones. Several factors increase one's risk of cardiovascular disease. The most common cause now would be obesity among the adolescents. (Dheeraj et al., 2024). In India, cardiovascular disease accounted for 27% (1,61,865) of the total number of deaths of 599,500 due to non-communicable diseases. The mortality rates had a slight male preponderance and are expected to increase in the coming years (Sreeniwas Kumar & Sinha., 2020).

Sedentary lifestyles and work habits are to blame for the sharp rise in cardiac arrest rates among Indians, particularly in the youth demographic. The study found that there is a significant relationship between Bloor Pressure risk and Body Mass Index (BMI) scores and that the relationship increases with increasing BMI. It was estimated that 53% of Indians between the ages of 26 and 40 were at risk for cardiovascular disease (CVD) because of the dual problems of obesity and hypertension, which can lead to CVD (Goel, 2022).

According to the WHO (2021) report, cardiovascular diseases (CVDs) are the leading cause of death globally. An estimated 17.9 million people died from CVDs in 2019, representing 32% of all global deaths. Of these deaths, 85% were due to heart attack and stroke. Cardiovascular disease accounted for 27% (1,61,865) of the total number of deaths of 599,500 due to non-communicable diseases.

A Brazilian study found that the prevalence of abdominal obesity was 22.7%, overweight was 13.1%, and obesity generally was 3.8%. It is concluded that boys attending private schools were more likely to be obese and to have abdominal obesity, whereas girls from higher socioeconomic backgrounds were more likely to be overweight (Marcus et al., 2015).

The COVID-19 lockdown school closure may affect adolescent obesity and physical inactivity. based on the first-ever investigation in China of a large national sample from the COVID-19 Impact on Lifestyle Change Survey. The average body mass index of the youths grew significantly from 21.8 to 22.1 kg/m2, while the prevalence of obesity and overweight/obesity increased from 10.5% to 12.6% and from 21.4% to 24.6%, respectively. This study would provide crucial evidence for developing international initiatives to mitigate or reverse the lockdown's adverse effect on youth obesity that leads to cardiovascular disease (Jia et al., 2020).

A study was conducted on 433 MBBS students from eastern India to determine the prevalence of CVD risk variables and their relationship to the CVD risk ratio. Among the individuals who were neither overweight nor obese, a significant positive correlation was seen between the CVD risk score and WHR ($R = 0.33$, $p < 0.001$). It is troubling that a high prevalence of many modifiable CVD risk factors was found among the study's participants. In the Indian population, WHR shows promise as a stand-alone early predictor of CVD risk (Mukhopadhay et al., 2021).

George et al. (2021) studied rural adolescent subjects in Kerala, obesity and overweight prevalence rates were 16.0 and 7.0%, respectively. However, another study from Kerala among rural schoolgirls found that 8.7% of participants were obese and roughly 42.66 % were overweight. Obesity is a classical sign of physical inactivity and poor dietary patterns, which is a major contributor to the development of cardiovascular disease among adolescents.

The table no.1 was projected the comparison of National Family Health Survey 4 & 5 between Kerala and National data regarding anthropometrics of the adolescents in Kerala. It shows that there was steady rise in the obesity cases among the sets of adolescents age group.

Table No 1: Report on National Family Health Survey (NFHS) 2019 -2020

Parameters	**NFHS – 5 (2019-2020)**		**NFHS – 4 (2015-2016)**	
	Kerala	**National**	**Kerala**	**National**
Women who are Obese or Overweight (BMI >25Kg/m^2)	38.1	24.0	32.4	20.6
Men who are Obese or Overweight (BMI >25Kg/m^2)	36.4	22.9	28.5	18.9
Women who have high-risk-waist-to-hip ratio (>0.85)	70.7	56.7	NA	NA
Men who have high-risk-waist-to-hip ratio (>0.90)	56.8	47.7	NA	NA

This study aims to investigate the prevalence of obesity and associated risk factors among adolescents in studying college of boys and girls.

2. Objectives of the Study

1. To determine the prevalence of underweight, normal weight, overweight and obesity among adolescents.
2. To assess central obesity risk among adolescents using waist circumference and waist-hip ratio.
3. To examine the association between anthropometric indicators and selected demographic variables.

3. Methods

The study employed a descriptive cross-sectional design to assess the prevalence of obesity and related anthropometric measurements among adolescents. Data were collected from six educational institutions, which were randomly selected from the northern three districts of Kerala. These institutions included both boys' and girls' colleges, providing a diverse representation of adolescents in the region. The study targeted adolescents aged 17 to 19 years, with a sample size of 1240 participants. The data collection instrument was as follows,

Anthropometric measurement of the adolescent

The latest evidence-based reviews report that increased BMI and waist-hip ratio have a significant role in the development of cardiovascular health risk among adolescents. In view of this, the investigator measured the anthropometric measurements including height, weight, hip circumference, and waist circumference. The anthropometric measurement of the adolescent was assessed based on the standard procedure of measurement of height, weight, waist, and hip circumference. BMI will be calculated based on the measurement of height and weight. BMI Formula is Weight (Kg) / Height $(M)^2$. WHO classification (2020) of BMI and WHR as follows,

- Underweight <18.5 (5)
- Healthy Range 18.5 to 25 (0)
- Overweight 25 to <30 (5)
- Obese >30 (10)
- Waist circumference increased >94 cm (Men) >80 cm (Women) (5)
- Waist circumference substantially increased >102 cm (Men) >88 cm (Women) (10)
- Substantially increased Waist–hip ratio ≥0.90 cm (Men) ≥0.85 cm (Women) (10).

The anthropometric measurement maximum score is 30 and the minimum score is 0. The more the score the more the risk for development of cardiovascular health risk among adolescents.

Ethical clearance was obtained from Institutional Review Board of Lourde College of Nursing, Kannur, Kerala, India. Confirmed that research was performed in accordance with relevant guidelines / regulations. The present study tried its best to follow the ethical code. The purpose of the study and the procedures were disclosed after establishing a good rapport with the participants. Informed consent was obtained before administering the materials. The participants have ensured the freedom to withdraw from the study at any time. Even though cluster random was executed, the investigator ensured those participants who were willing to participate only were enrolled in the study. In this study, human rights were protected at all times, and human dignity also was preserved.

4. Results

Demographic distribution of the adolescents

Table No.2 shows classification of the adolescent as per age, out of 1240 participants, most of them 915 (73.8%) belonged to the age of 19 years and 309 (24.9%) were 18 years. Regarding the gender of 1240 adolescents, 593 (47.8%) were male and 646 (52.1%) were female. Also noted 1 (0.1%) of transgender from the Kannur districts.

Table 2: Distribution of adolescents according to age and gender

Bio-socio-demographic Variables	Sub-variables	Frequency (N=1240)	entage
Age	a. 17 Years	16	01.3
	b. 18 Years	309	24.9
	c. 19 Years	915	73.8
Gender	a. Male	593	47.8
	b. Female	646	52.1
	c. Transgender	01	00.1

Figure 1: Distribution of the respondents in the sample based on education

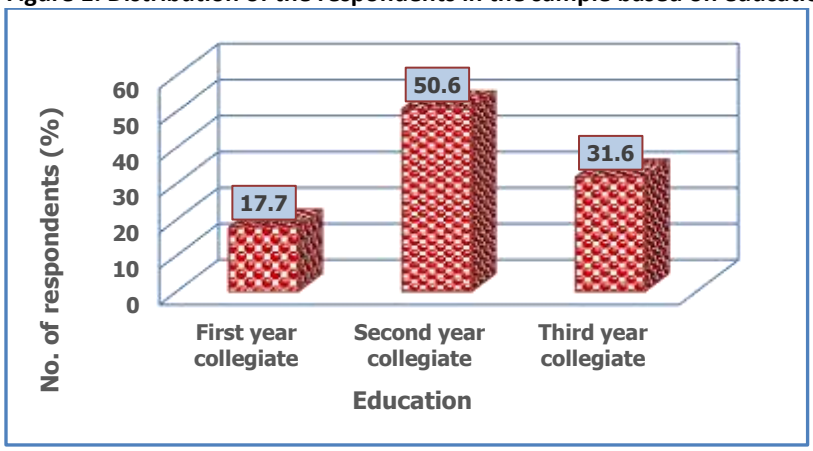

Figure No.1 Compares the education year of the adolescents in the college, out of 1240 participants most of the adolescents 628 (50.6%) were second-year collegiate students and 392 (31.6%) were third-year collegiate students. Around 220 (17.7%) adolescents were undergoing the first-year collegiate studies.

Figure 2. Distribution of the respondents in the sample based on Place of residence

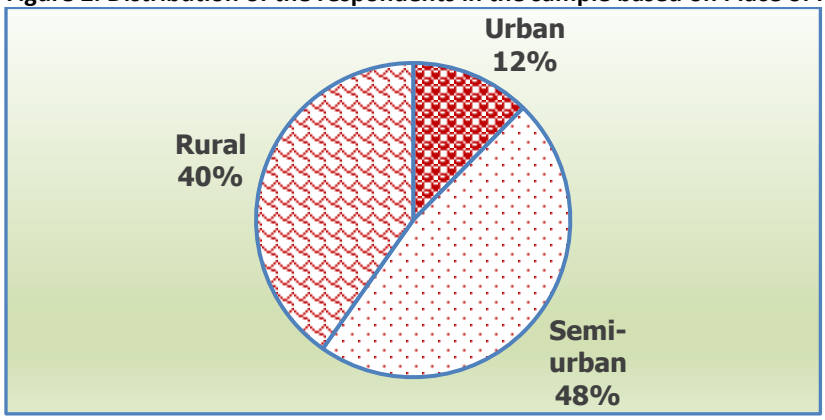

Figure 2. Comparing the place of residence of the adolescents, out of 1240 participants 588 (47.4%) were living in semiurban, 499 (40.2%) belonged to rural living, and 153 only (12.3%) were in urban residence. Figure 3. reveals the residential status, most of the adolescents 940 (75.8%) were attending college from home and 226 (18.2%) were residing in the college hostel. Only 13 (1%) of the students were staying in relatives' homes and 61 (4.9%) of the students opted paying guest accommodation.

Figure 3. Distribution of the respondents in the sample based on residential status

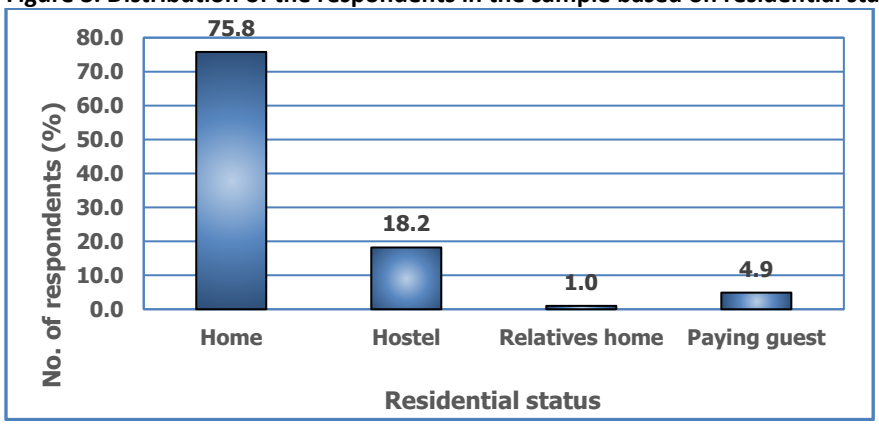

Table 3. Distribution of adolescents based on their Extracurricular and Relaxation activities.

Bio-socio-demographic Variables	variables	uency 240)	entage
Extracurricular activities	No Extracurricular activities	388	31.3
	Arts	268	21.6
	Sports	439	35.4
	Dance	215	17.3
Relaxation activities	No Relaxation	366	29.5
	Meditation	66	05.3
	Prayer	229	18.5
	Yoga	57	04.6
	Play with pets	259	20.9
	Others	322	26.0

Table No. 3 shows no extracurricular activities reported among 388 (31.3%) of the adolescents. One-third of them i.e. 35.4% are engaged in sports. Arts and dance were engaged by 268 (21.6%) and 215 (17.3%) respectively.
While analysing the relaxation activities of the adolescents with multiple responses, 366 (29.5%) reported no relaxation activities. Meditation and yoga are practiced by 66 (5.3%) and 57 (4.6%) respectively. Prayer and play with pets were followed by a nearly similar percentage of 18.5% and 20.9% of the adolescents.

Analysis of Prevalence of abnormal Anthropometric Measurements.

Table 4. Classification of adolescents based on anthropometric measurement

No	Cardiometabolic Risk	assification of Variables	Frequency (N=1240)	Percentage %
1	Body Mass Index (BMI)	nderweight	556	44.8
		ealthy	660	53.2
		verweight	24	1.9
2	Waist circumference	ormal	1177	94.9
		creased	63	5.1
3	Waist Hip Ratio	ormal	874	70.5
		ubstantially increased	366	29.5

Table No 4. explains Body Mass Index (BMI), calculated based on the measurement of height and weight. BMI Formula is Weight (Kg) / Height $(M)^2$. WHO classification (2020) of BMI as follows, Underweight <18.5, Healthy Range 18.5 to 25, Overweight 25 to <30, and Obese >30. While discussing the level of Body Mass Index of 1240 adolescents, 556 (44.8%) belonged to the category of underweight. Half of the adolescents 660 (53.2%) were under the category of healthy. On the other hand, only 24 (1.9%) adolescents were found to be as overweight. Interesting to note that none of them found as overweight.
The Waist circumference of the adolescent was assessed based on the standard procedure. WHO classification (2020) of waist circumference as follows, Waist circumference increased by >94 cm (Men) >80 cm (Women), and Waist circumference substantially increased by >102 cm (Men) >88 cm (Women). From the above table, most of the adolescents' 1177 (94.9%) had normal waist circumferences and only 63 (5.1%) had increased waist circumferences.
The waist-hip ratio (WHR) of the adolescent was assessed based on the standard procedure. WHO classification (2020) of WHR as follows, substantially increased Waist–hip ratio ≥0.90 cm (Men) ≥0.85 cm (Women). While analyzing the above table, the majority of 874 (70.5%) adolescents fell under the normal Waist Hip Ratio, whereas 366 (29.5%) of them substantially increased waist-hip ratio by ≥0.90 cm (Men) ≥0.85 cm (Women).

Descriptive statistics of adolescent anthropometric measurements

The anthropometric measurement of the adolescent includes height, weight, waist, and hip circumference. BMI was calculated based on the measurement of height and weight. BMI Formula is Weight (Kg) / Height $(M)^2$. WHO classification (2020) of BMI and WHR as follows, Underweight <18.5 (5), Healthy Range 18.5 to 25 (0), Overweight 25 to <30 (5), Obese >30 (10).

Waist circumference increased >94 cm (Men) >80 cm (Women) (5)

Waist circumference substantially increased >102 cm (Men) >88 cm (Women) (10)

Substantially increased Waist–hip ratio ≥0.90 cm (Men) ≥0.85 cm (Women) (10).

The anthropometric measurement maximum score is 30 and the minimum score is 0. The more the score the more the risk for the development of cardiovascular health risk among adolescents.

Table 5. Descriptive statistics regarding anthropometric measurements

S.No	Variables	Minimum	Maximum	Mean	Std. Deviation
1	Height	136.0	190.0	164.99	9.53
2	Weight	29.6	142.3	55.15	12.58
3	BMI	10.3	52.6	20.16	3.78
4	Waist circumference	48.0	195.0	70.07	10.03
5	Hip circumference	33.0	126.0	82.55	9.00

Table No 5 depicts the mean score and standard deviation of the anthropometric measurements including height, weight, Body Mass Index, Waist circumferences, and Hip circumferences. The mean score of 1240 adolescents for height were 164.99 with a standard deviation of 9.53, whereas the weight mean was 55.15 with a standard deviation of 12.58. BMI's mean score was 20.16 with a standard deviation of 3.78. The mean score for waist and hip circumferences was 70.07 and 82.55 with a standard deviation of 10.03 and 9.00 respectively.

Table 6. Descriptive statistics of anthropometric scores of adolescents

S.No	Descriptive measures	Statistic
1	Minimum	.00
2	Maximum	25.00
3	Mean	5.64
4	Std. Deviation	5.66
5	Median	5.00
6	Interquartile Range	10.00
7	Skewness	0.955
8	Kurtosis	0.522
9	Kolmogorov Smirnov Statistic	0.239**
10	P-value	<0.001

** Significant at 0.01 level

The anthropometric measurement maximum score as per WHO is 30 and the minimum score is 0. The more the score the more the risk for the development of cardiovascular health risk among adolescents.

Table No 6 depicts descriptive statistics of scores regarding anthropometric measurements of the adolescent. The scores range between 0 and 25 with mean a score was 5.64 and a standard deviation was 5.66. Kolmogorov Smirnov test was done to test the normality of the scores regarding anthropometric measurements of adolescents and it was found to be 0.239, which is highly significant at 0.01 level. Here, the P-value is less than 0.001 which is an indication of the fact that the score regarding the anthropometrics of adolescents is not following a normal distribution. Hence, further analysis was done by using non-parametric tests.

Classification of central obesity risk among adolescents using waist circumference and waist-hip ratio.

Table 7. Classification of respondents based on having risk related to waist circumference

Level of Risk	**Waist Circumference**		**waist hip ratio**	
	Samples	Percentage	Samples	Percentage
Normal	1177	94.9	874	70.5
Increased / Substantially Increased	63	5.1	366	29.5
Total	1240	100	1240	100

Table 8. Classification of Central Obesity Risk based on Anthropometrics of adolescents.

Level	Frequency	Percentage
No risk	874	70.5
Have risk	366	29.5
Total	1240	100

Based on the table No. 7 & 8, the waist-hip ratio (WHR) of the adolescent was assessed in par with standard procedure. WHO classification (2020) of WHR as follows, substantially increased Waist–hip ratio ≥0.90 cm (Men) ≥0.85 cm (Women). While analyzing the above table, the majority of 874 (70.5%) adolescents fell under the normal Waist Hip Ratio, whereas 366 (29.5%) of them substantially increased waist-hip ratio by ≥0.90 cm (Men) ≥0.85 cm (Women). It is concluded that one third of the adolescent's population pose risk under central obesity, which is a major implication for cardiometabolic risk.

a. Association of anthropometric measurements with selected demographic variables

Table 8. Association of anthropometric scores among different subgroups with selected demographic profiles.

Demographic variables	**Gender**	**Mean**	**SD**	**Z-value**	**P-value**
Gender	Male	5.60	5.96	1.094^{ns}	0.274
	Female	5.68	5.37		
Residential status	Home	5.75	5.70	2.467^{ns}	0.481
	Hostel	5.35	5.28		
	Relative's house	5.77	6.07		
	Paying guest	5.00	6.26		

Place of residence	Urban	5.69	5.99	0.060^{ns}	0.970
	Semi-Urban	5.60	5.49		
	Rural	5.67	5.76		
Extracurricular activity	Nil	5.64	5.68	0.017^{ns}	0.987
	Yes	5.64	5.65		
Relaxation activity	Nil	5.20	5.55	1.907^{ns}	0.057^{ns}
	Yes	5.82	5.69		

ns non-significant

Table No 8 depicts the comparison of scores related to anthropometrics of adolescents and selected demography variables including gender, Residential status, Place of residence, extracurricular activity, and relaxation activity. The calculated Z – value for the above-selected variables with anthropometric scores was not statistically significant. It is concluded that there is no association found between anthropometric scores and selected demographic variables of the adolescents.

5. Discussion

Projections of anthropometrics of 1240 adolescents, 556 (44.8%) belonged to the category of underweight. On the other hand, only 24 (1.9%) adolescents were found to be as overweight. Interesting to note that none of them found as overweight. only 63 (5.1%) had increased waist circumferences. whereas 366 (29.5%) of them substantially increased waist-hip ratio by ≥0.90 cm (Men) ≥0.85 cm (Women). It is concluded that one third of the adolescent's population pose risk under central obesity, which is a major implication for cardiometabolic risk. It was also found that there is no association found between anthropometric scores and selected demographic variables of the adolescents.

A similar study report regarding the distribution of the level of body mass index among early adolescents. Among 60 early adolescents, 42 (70%) of them were underweight and 5 (8%) of them were normal 10 (17%) of them were overweight and 3 (5%) of them were obese (Anitha & Blanshie, 2020).

Turkish children aged 15 to 17 were studied by Abrignani et al. in 2019 for trends in body mass index (BMI) over 15 years. When compared to 0.7% obese and 4.2% overweight in 1990, 3.4% of youngsters were obese and 15.8% were overweight in 2005, per the international standards (P 0.001). Regarding the percentage of overweight adolescents, the results of this international study do not bear out the results of the current study.

The results of this study are consistent with the anthropometric data of 432 adolescents from a study by De Oliveira et al. (2022), which showed that the prevalence of excess body weight and abdominal obesity were 16.7% and 27.5%, respectively. It was found that adolescents in the adult period (post-puberty) who had an insufficient waist-to-height ratio and a high body fat percentage were 2.5, 7.44, 2.79, and 1.43 times more likely to have abdominal obesity, respectively.

The results of a different study differed from those of a study by James et al. (2023), which likewise found that 223 students (25%) and 53 children (6.03%) were fat. The study by Ekta & Tulika (2016) indicated that the rates of overweight and hypertension were greater in girls (11.7% and 24.1%) than in boys (6.8% and 18.1%). Additionally, the NFHS 2019-2020 report discovered that a higher percentage of Keralites—more than 70% of men and 56% of women—had potbellies. The percentage of overweight or obese women in the 15–49 age group is 38%; this is an increase from 32% in the NFHS-4. For men between the ages of 15 and 54, the percentage went from 28% to 36%.

Results oppose a study among rural adolescent subjects in Kerala, obesity and overweight prevalence rates were 16.0 and 7.0%, respectively. (Jeffy & Rajendra, 2014). However, another study from Kerala among rural schoolgirls found that 8.7% of participants were obese and roughly 42.66 % were overweight. (Abraham & Pillai, 2019).

Turkish children aged 15 to 17 were studied by Abrignani et al. in 2019 for trends in body mass index (BMI) over 15 years. When compared to 0.7% obese and 4.2% overweight in 1990, 3.4% of youngsters were obese and 15.8% were overweight in 2005, per the international standards (P 0.001). This international study's findings are also not like the present study's findings regarding the percentage of overweight adolescents.

6. Conclusion

This study particularly relevant because it aims to provide data on Body Mass Index and Waist-Hip Ratio Profile of Adolescents aged 17 to 19 years in higher educational institutions of Kerala, India, a state that is experiencing rapid changes in socioeconomic, lifestyle and dietary patterns. The findings of the present study, especially on one third of adolescents with central obesity will provide foundation for policy making and development of school, college and community-based programs to combat cardiometabolic risk among adolescents. Early identifications and management of cardiometabolic risk can reduce the risk of developing CVD among young productive populations, and thereby improve the overall well-being of the population.

Data Availability Statement

The data supporting the inferences of this research findings will be made available in open access by the authors without any reservations.

Author Contributions

Senthilkumar Thavasiappan and Tamilselvi Arumugam: Conceptualization, methodology, investigation. Writing - original draft preparation and formal analysis. Tamilselvi Arumugam and Hariprasath Pandurangan: review, editing and supervision. Nandini Mannadath: Data curation and review of literature. Joseph Jeganathan, Johnson L.K & Majid Alotni: Final reviewer and editing. All authors contributed to the article and approved the submitted version.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be constructed as a potential conflict of interest.

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