International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 5, 2025
https://theaspd.com/index.php

Assessing Musculoskeletal Strength And Balance In Relation To Body Composition In Adolescents.

Alla Leela Rani[1], Dr. A. Krishnamanjari Pawar[2], Dr. Pallekona Sushma[3], Kancharla Madhuri[4]
[1]A. Leela Rani, Director, Lee pharma Limited, Plot.V, Phase -II, VSEZ, Duvvada, Visakhapatnam, Andhra Pradesh, 530049, India, researchlhd@leepharma.com
[2]Dr. A. Krishnamanjari pawar, Professor, Department of Pharmaceutical Sciences, Andhra University, Visakhapatnam, Andhra Pradesh, 530003, India, akmpawar@andhrauniversity.edu.in
[3]Dr. P. Sushma, Associate Project Management, Lee Pharma Limited, Plot.V, Phase -II, VSEZ, Duvvada, Visakhapatnam, Andhra Pradesh, 530049, India, pmunit3@leepharma.com
[4]K. Madhuri, Nutritionist, Lee pharma Limited, Plot.V, Phase -II, VSEZ, Duvvada, Visakhapatnam, Andhra Pradesh, 530049, India, nutrition@leepharma.com

Abstract: *This cross-sectional study assessed bone and joint health in 13-16 years old adolescents in Visakhapatnam using anthropometric (BMI, WHR, MUAC, SF) and physical fitness (HGS, Flamingo, Tapping) measures. Significant interrelationships were found, revealing gender/age-based variations in body composition and strength. The study emphasizes integrated nutritional and physical activity interventions for optimal adolescent bone health and lifelong well-being.*

Methodology: *This cross-sectional study enrolled 13-16 years old adolescents from Visakhapatnam. Non-invasive Nutrition Focused Physical Examination (NFPE) and Fit India Protocol tests measured BMI, WHR, MUAC, SF, HGS, Flamingo balance and tapping test. Data analysis employed t-tests to determine statistical significance between parameters. Nutritional and physical activity consultations were provided to participants.*

Results: *Statistical analysis showed significant interrelationships ($p<0.001$) between BMI and other health parameters. While most adolescents were normal weight, girls showed higher rates of overweight/obesity and high WHR, and older boys had lower handgrip strength. MUAC was consistently normal, and most participants demonstrated good balance and coordination.*

Conclusion: *The study highlights significant gender and age-based differences in adolescent body composition and physical fitness, underscoring their impact on bone health. Targeted interventions addressing abdominal adiposity in girls and improving hand grip strength in older boys are crucial. Promoting integrated nutritional and physical activity education within schools is vital for long-term skeletal health in this demographic.*

Keywords: *"Body mass Index BMI, Fit India Protocol, Flamingo test, Mid Upper arm Circumference, Nutrition focused physical examination NFPE, Waist hip ratio WHR"*

INTRODUCTION

Bone health truly takes root even before we are born. A mother's good nutrition during pregnancy lays the groundwork for a baby developing skeleton [1]. Then, childhood and adolescence become crucial for building a strong skeletal foundation – this is when we reach our peak bone mass, the highest amount of bone tissue we will ever have [2].

Our bones are constantly being remodeled by specialized cells. Osteoblasts and osteocytes are the dedicated builders, working hard to form new bone tissue, while osteoclasts act as the remodelers, breaking down old or damaged bone. During our growing years, the bone-building activity of osteoblasts takes the lead over the bone-resorbing action of osteoclasts.

Even a small boost in peak bone mass during childhood and adolescence can have a huge impact later in life. Studies suggest that a mere 10% increase in peak bone mass can slash the risk of a debilitating osteoporotic fracture in adulthood by a remarkable 50%. That really underscores how important it is to prioritize bone health early on [3].

The adolescent years represent a dynamic and critical phase of human development, characterized by profound hormonal shifts and accelerated physical growth [4]. This period is not only marked by visible changes but also serves as a foundational window for establishing robust bone and joint health, a cornerstone of lifelong well-being [5]. Compounding this challenge is the rising prevalence of obesity, a well-recognized

contributing factor to a spectrum of musculoskeletal disorders [6]. Addressing this critical health landscape demands a proactive and multifaceted approach, with proper nutrition and physical activity serving as indispensable pillars in preventing and managing these conditions. To gain a comprehensive understanding of musculoskeletal status, appropriate non-invasive tests play a vital role in determining key bone and joint health indices. Complementing this, a nutritional focused physical examination (NFPE) offers a specialized and holistic assessment, going beyond standard evaluations to scrutinize the nutritional status of adolescents through a detailed physical lens [7]. This examination meticulously assesses body composition, evaluates micronutrient sufficiency, and examines muscle functional capacity. Recognizing the fundamental role of movement, regular physical activity is inherently essential for the optimal function and maintenance of bones and joints. The NFPE incorporates crucial anthropometric measurements, including height, weight, waist and hip circumference, alongside functional assessments like handgrip strength, and body composition indicators such as mid-upper arm circumference and skinfold thickness [8].

Further promoting a physically active lifestyle, the Fit India protocols advocate for a suite of tests specifically designed to enhance motor skills and cultivate habits conducive to long-term health. By strategically integrating comprehensive nutritional assessments and the promotion of regular physical activity, we can effectively fortify the musculoskeletal foundation of adolescents during these transformative years, paving the way for a healthier, more active and resilient future [9].

"The landscape of adolescent health research reveals a rich yet often fragmented exploration of individual parameters. Numerous studies have illuminated the relationship between Body Mass Index (BMI) and hand grip strength, with findings often differ by factors such as age, gender, and muscle mass [10,11]. Similarly, the significance of mid-upper arm circumference as a key indicator of nutritional status has been well-documented, underscoring its impact on adolescent growth and development [12-15].

Acknowledging the limitations of isolated anthropometric measures, researchers have increasingly incorporated Nutritional Focused Physical Exam (NFPE) techniques. Studies employing triceps skinfold thickness alongside BMI have provided deeper insights into body fat distribution [16-20], while the waist-hip ratio has emerged as a critical predictor of abdominal adiposity and associated health risks [21,22].

Recognizing the integral role of neurocognitive and motor development, investigations have explored the link between BMI and coordination, often utilizing tests similar to the tapping test promoted by the Fit India protocols [9]. These protocols, emphasizing activities that enhance neurocognitive function, underscore a growing awareness of the mind-body connection in adolescent health. Furthermore, the importance of static balance, frequently assessed through measures like the flamingo balancing test, has been highlighted in relation to physical activity and overall postural stability [23-27].

Several studies explained that weight-bearing exercises are the main players in the bone-building process. These are activities where bones and muscles work against gravity. When engaged in these exercises, it creates a healthy amount of stress on bones. This stress isn't harmful; in fact, it's the signal that tells the bone cells to get to work and build more bone tissue. Some of them are jumping rope, walking, jogging and dancing. Higher bone mineral density indicates stronger, denser bones that are less prone to fractures. Studies have consistently shown a positive correlation between regular participation in weight-bearing activities during adolescence and higher peak bone mass [28-32].

While existing literature provides valuable insights into these individual facets of adolescent health, a notable gap emerges in the comprehensive integration of these diverse assessments within a single study population, particularly within the Indian context. Till date, to our knowledge research in the Visakhapatnam region has not, adopted such a holistic approach, simultaneously employing a battery of NFPE examinations and Fit India protocol-aligned tests.

Our study seeks to bridge this gap. By concurrently examining BMI, hand grip strength, mid-upper arm circumference, triceps skinfold thickness, waist-hip ratio, coordination (tapping test), and static balance (flamingo test) in adolescents aged 13-16 years in Visakhapatnam, we aim to provide a more integrated and nuanced understanding of their bone and joint health. This new methodology, combining established NFPE techniques with contemporary fitness assessments, promises to yield unique insights into the interrelatedness of these health indicators within this specific demographic and geographical setting."

MATERIALS AND METHODS

The medical camp was organized in the premises of the respective schools with prior permission and consent of the school authorities. This camp has facilitated the procedure to examine and determine the various parameters through noninvasive methods and only with aid of physical examinations, which were nutrition centered.

Instruments Involved:

Height scale: (Prime Surgicals Height measuring scale - Stadiometer - Precision Model);
Weight scale: (Beurer GS10 180kg Black Digital Glass Bathroom Scale with Easy to Read Display Weighing scale); Hand grip strength: (CAMRY Digital Hand Dynamometer Grip Strength Measurement Meter Auto Capturing Electronic Hand Grip Power 198 Lbs / 90 Kgs) ; Skinfold Caliper: (Lightstuff. Precision Skinfold Caliper); Shakir tape: (IS Indosurgicals Muac Tape); Measuring Tape: (Trendmakerz 1.50 meter 150 CM Superior Quality Measuring Tape inch measure tape)
Dietary consultation was provided and necessary interventions were suggested. The mentioned examination was based on the NFPE Nutrition Focused Physical Examination, Which was designed to identify signs of malnutrition or nutritional risk that might not be evident through medical history or lab results alone. By a thorough physical exam, dietitians can detect subtle changes in body composition, skin integrity, and other physical markers that indicate nutritional imbalances. This particular research was designed to utilize the NFPE for estimation of parameters in Bone Joint health.
The determinant tools of NFPE for Bone Joint health were mentioned as below:

Body mass index (BMI)

BMI is a calculated measure of a person's body weight (in kilograms) divided by the square of their height (in meters). BMI categories for children and teens were based on sex-specific BMI percentiles. Using percentiles to define BMI categories in children is important because they are still growing [33].

Waist and Hip Ratio (WHR):

It's crucial to recognize that excess fat around the abdomen poses health risks beyond what total body fat alone can indicate. The waist-to-hip ratio (WHR) helps us specifically assess this distribution of abdominal fat [34].

Handgrip strength (HGS):

Hand grip strength (HGS) reflects the peak static force generated by hand and finger muscles, including those in the thenar and hypothenar eminences and the hand's intrinsic muscles. Beyond indicating muscle mass and activity levels, HGS serves as a predictor for chronic disease risk and nutritional status, with typical values varying by gender and age [35].

Mid upper arm circumference:

Mid-Upper Arm Circumference (MUAC) is a simple yet effective measurement of upper arm muscle and fat. Measured with a non-stretch tape at the midpoint between the shoulder blade (acromion) and elbow (olecranon) bones, it serves as a quick indicator of body composition in both adults and children. A MUAC below 12.5 cm can signal malnutrition, while above 13.5 cm is typically considered normal [36].

Skinfold thickness:

Measurement of skinfold thickness, obtained using calipers, is useful in assessing and monitoring nutritional status [37].

Static Balance - Flamingo Balance Test:

This test determines the ability to balance successfully on a single leg. This single leg balance test assesses the strength of the leg, pelvic, and trunk muscle as well as Static balance.

To perform this balance assessment, the individual stands on a non-slip surface, or for a greater challenge, on a beam or block. Balancing on their chosen leg, they hold the non-stance leg with the knee bent and foot

close to the buttocks. The tester records the total number of times balance is lost (falls) within a 60-second period. If balance is lost more than 15 times in the first half-minute, the test is discontinued [9].

Coordination (Plate Tapping Test):

Assessing speed and coordination of limb movement is the goal of this test, which utilizes a standardized setup. Two discs are positioned 60 cm apart on a table, with a rectangle placed exactly in the middle. The non-preferred hand remains on the rectangle, and the preferred hand rapidly taps each disc in an alternating fashion, passing over the central hand. The time taken to complete a consistent 25 cycles of this movement is the primary measure [9].

Based on all the above considerations, these parameters were measured for the subjects participated in the camp. Considering all results, nutritionist would diagnose their bone health condition and would suggest the good nutritional diet, physical exercise, and traditional games to improve the hand and eye coordination along with muscular health.

Participants:
Inclusion criteria
We included children (13-16 years) from Standard IX and X from three different schools in the urban area of Visakhapatnam who have accepted to participate in this camp and this consent was initiated in the form of registration with their basic details like name, age, sex who did not have medical comorbidities. We did not restrict inclusion based on body mass index.
The participants were initially registered with their basic details of Name, Sex, age, in a registration form with their consent. Later the height and weight were initially recorded and notified in the mentioned columns of the form. BMI is calculated based on these measurements. HGS, WHR, MUAC, SKIN fold were measured for each participant by the above metioned instruments and the readings were captured in their respective form.
Later all the participants were checked for the flamingo test and coordination plate test. Hence with all the completed tests and the respective reports in the form, the participants were given a nutritional consultation and explained their physical status of static balance and other bone and joint health condition. These mentioned above were concluded with a awareness talk on pros and cons of the bone jont health. The children were suggested to involve in the Physical activity, which will be already their part of curriculum. Along with these activities, they were introduced to the age-old traditional games, which are the foot print to have a good hand eye coordination, and other muscular coordination. Children were engaged in competitions like Jump rope which to develop a better hand and leg coordination's and the muscular strength.
All the obtained values for the various determinants by different tests mentioned above were subjected to statistical analysis comparing the important hypothesis of the study. Considering the T test and P value, the hypothesis was concluded and the results were reported.

RESULTS

The obtained data from various schools were consolidated and all the obtained values were categorized based on the sex and age to determine the comparative index of boy's vs girls and the age wise variation. All the results of the NFPE examination were consolidated and tabulated in the below Table: The comparative graphs for both the categories were consolidated in graphical representation which are represented in the Figures.

Parameters	**Normal ranges**	**% of population Gender**		**% population Age group**	
		Boys	**Girls**	**13-14**	**15-16**
Body Mass Index [33]	< 5 th - Underweight	12.8	7.3	8.9	16.4
	≥ 5 th and < 85 th -Normal weight	61	59.9	59.5	64.9
	≥85 th and <95 th - Overweight	13.5	17.9	17.5	7.2
	≥ 95 th - Obese-I	10.9	13.3	13.2	9.2

	≥ 99 th - Obese -II	1.46	1.38	0.76	2.06
Waist and Hip Ratio [34]	Male : ≤0.95 – low risk	95.6	-	94	40.4
	0.96-1.0 – moderate risk	3.29	-	3.8	18.6
	≥ 1.0 - high risk	1.09	-	0.9	40.9
	Females: ≤ 0.80 – low risk	-	40.5	95.5	44.8
	0.81- 0.85 – moderate risk	-	26.6	2.9	37.9
	≥ 0.85 – high risk	-	33.3	1.4	17.2

Table-1: Normal ranges of BMI, Waist hip ratio and % of population gender wise and age wise

Parameters	**Normal ranges**				**% of population Gender**		**% population Age group**		
					Boys	**Girls**	**13**	**14-15**	**16**
Hand Grip Strength [38]	**Category (Male)**	**12-13 Age group**	**14-15 Age group**	**16-17 Age group**	W-44.3		W-18.5	W-52.8	W-60
	Weak (W)	<19.4	<28.5	<32.6	N-53.8	-	N-75.7	N-46.6	N-40
	Normal(N)	19.4-31.2	28.5-44.3	32.6-52.4	S-1.83	-	S-5.7	S-0.5	S-0
	Strong (S)	>31.2	>44.3	>52.4					
	Category (Female)	**12-13 Age group**	**14-15 Age group**	**16-17 Age group**	-	W-15.6	W-11.6	W-18.2	W-0
	Weak (W)	<14.6	<15.5	<17.2	-	N-77.8	N-74.0	N-80.2	N-66.6
	Normal(N)	14.6-24.4	15.5-27.3	17.2-28.0	-	S- 6.4	S-14.2	S-1.45	S-33.3
	Strong (S)	>24.4	>27.3	>29.0					

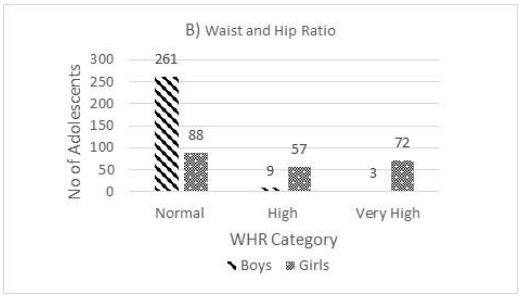
Table -2: Normal ranges of hand grip strength and % of population gender wise and age wise.

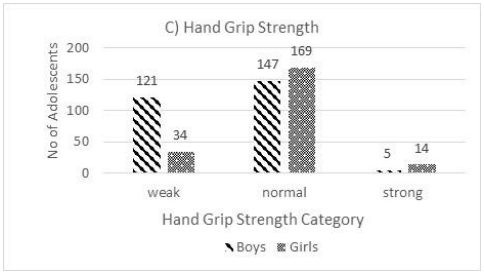
Parameters	**Normal ranges**	**% of population Gender**		**% population Age group**	
		Boys	**Girls**	**13-14**	**15-16**
Mid upper arm circumference [39]	**Red colour: 0 - 11.5 cm (Wasted)**	-	-	-	-
	Yellow colour :11.5 – 12.5 cm (Borderline)	-	-	-	-
	Green colour: from 12.5 cm (Normal)	100	100	100	100
Skinfold Thickness [40]	**Males (0-20 years)**				
	Lean: 2-8 mm	9.15	-	27.2	
	Healthy: 8.5 – 14mm	36.6	-	38.6	
	Average :14.3- 20.2mm	50.9	-	31.2	
	Fat: 21.3 – 24.9mm	3.29	-	2.7	
	Females (0-20 years)				
	Lean: 11.3 – 17mm	-	52.9	34	
	Healthy: 17.7 – 23mm	-	41.47	39	
	Average: 23.2 – 29mm	-	3.22	23.7	
	Fat: 30.2 - 34.6mm	-	2.30	3.09	

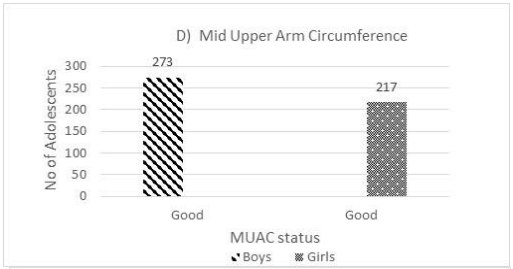
Table -3: Normal ranges of mid upper arm circumference, Skin fold thickness and % of population gender wise and age wise.

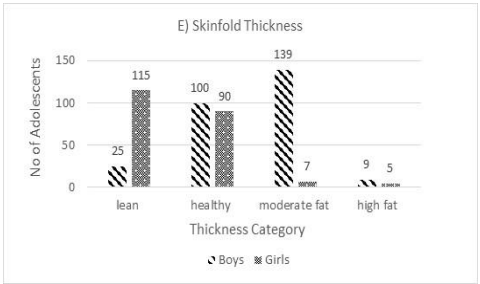
Parameters	Normal ranges	% of population Gender		% population Age group	
		Boys	Girls	13-14	15-16
Tapping Test [9]	Measures the time taken for 25 full cycles (50 taps)	Good-57.5	Good-51.6	Good-54	Good – 57.7
		Need to Improve 42.4	Need to Improve 48.3	Need to Improve 45.8	Need to Improve 10.4
Flamingo Balance Test [9]	No. of falls or loss of balance is recorded in 60 seconds	Good-66.6	Good 66.3	Good-66.9	Good- 64.4
		Need to Improve 33.3	Need to Improve 33.6	Need to Improve 33.1	Need to Improve 35.05

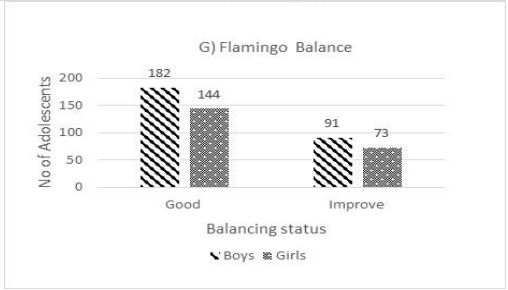
Table-4: Normal ranges of tapping test, flamingo balance test and % of population gender wise and age wise.











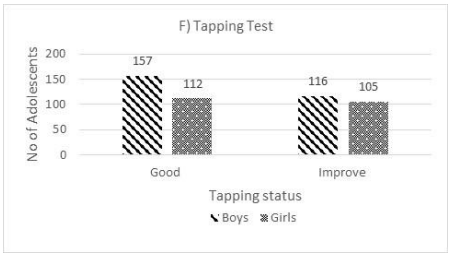


Figure 1: Graphical represenation of all the anthropometric measurements which were derived as based on sex of the study population.

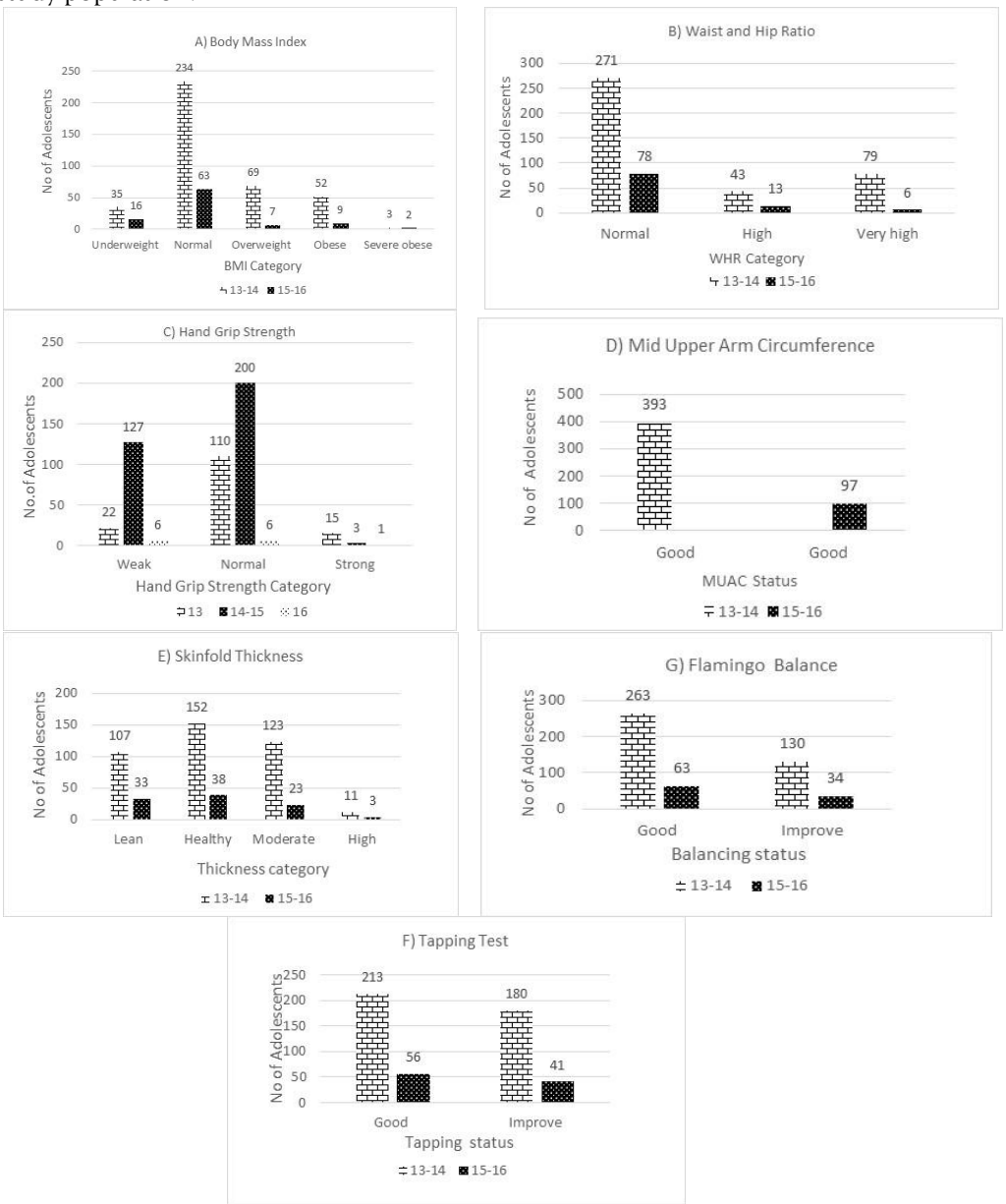


Figure 2: Graphical represenation of all the anthropometric measurements which were derived as based on Age Group of the study population.

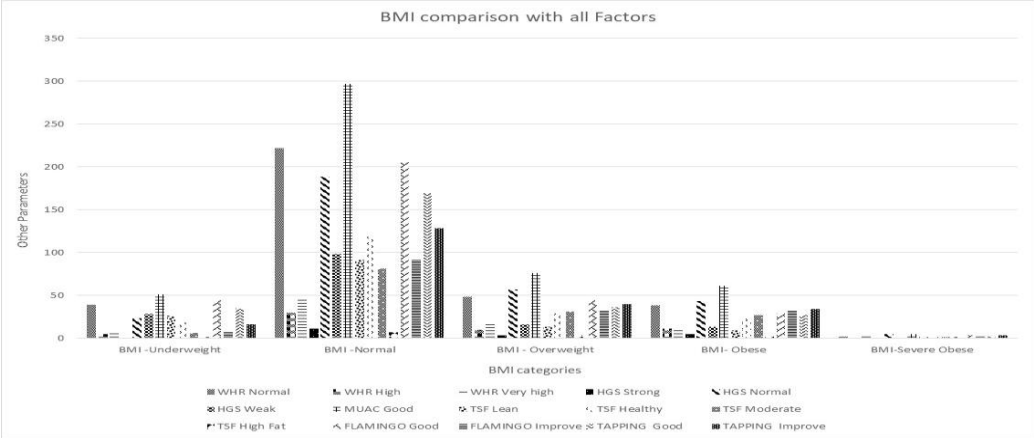


Figure 3: Comprehensive Graphical represenation of all the anthropometric measurements considering the BMI categories.

Statistical Analysis:

Parameters	**P-value**	**t- stat**
Age and BMI	<0.001	6.296058
BMI and WHR	<0.001	55.40265
BMI and HGS	<0.001	14.7961
BMI and MUAC	<0.001	21.13737
BMI and SF	<0.001	6.450239

Table -5: Statistical Determination of p-value and t-value of BMI with other parameters.

DISCUSSION

The BMI data reveals that the majority of both boys (61%) and girls (59.9%) fall within the normal weight range. This trend is consistent across both age groups, with a slightly higher percentage in the 15-16 age group (64.9%) compared to the 13-14 age group (59.5%).

The prevalence of underweight increases significantly in the 15-16 age group (16.4%) compared to the 13-14 age group (8.9%). A higher percentage of boys (12.8%) are underweight compared to girls (7.3%).

The 13-14 age group has a higher percentage of overweight individuals (17.5%) compared to the 15-16 age group (7.2%). More girls (17.9%) are overweight compared to boys (13.5%).

The 13-14 age group has a higher prevalence (13.2%) compared to the 15-16 age group (9.2%) in category Obese-I. A higher percentage of girls (13.3%) are classified as Obese-I compared to boys (10.9%).

However, the 15-16 age group shows a higher prevalence (2.06%) compared to the 13-14 age group (0.76%). The percentages are relatively low for both boys (1.46%) and girls (1.38%) in the Obese –II category.

The WHR results obtained shows that, in the age 13-14, most individuals (95.5%) are at low risk. Very few are at moderate (2.9%) and high risk (1.4%). In the age group 15-16, the distribution is more varied, with 44.8% at low risk, 37.9% at moderate risk, and 17.2% at high risk. In consideration to gender, vast majority of boys (95.6%) are at low risk (WHR ≤ 0.95). A small percentage are at moderate (3.29%) and high risk (1.09%). A significant portion of girls (40.5%) is at low risk (WHR ≤ 0.80). However, a notable percentage are at moderate (26.6%) and high risk (33.3%).

Considering the HGS results of the data, A significant portion of boys in the 12-13 age group fall into the weak category (44.3%), but this percentage decreases in the 14-15 age group (18.5%) and then increases again in the 16-17 age group (52.8%). The majority of boys in the 14-15 age group are in the normal category (75.7%), but this percentage decreases in the 16-17 age group (46.6%).

The majority of girls across all age groups fall into the normal category, with the highest percentage in the 16-17 age group (80.2%). The percentage of girls in the weak category is relatively low across all age groups, with the highest being in the 16-17 age group (18.2%). The percentage of girls in the strong category is highest in the 14-15 age group (14.2%).

The data of Mid Upper Arm Circumference reveals that all boys and girls across the specified age groups fall within the normal range, indicating good nutritional status and muscle mass development.

With respect to Skinfold Thickness, the majority of boys fall within the average (50.9%) and healthy (36.6%) categories, indicating a balanced body fat percentage. A smaller percentage falls within the lean (9.15%) and fat (3.29%) categories. The distribution across age groups shows variability, with some age groups having higher percentages in the lean category.

A significant portion of girls fall within the lean (52.9%) and healthy (41.47%) categories, indicating a generally lower body fat percentage compared to boys. The percentages in the average (3.22%) and fat (2.30%) categories are relatively low, suggesting that most girls maintain a healthy body fat level.

Statistical Significance Based on P value, t-stat:

The very low p-value ($p < 0.001$) indicates a statistically significant relationship between BMI in relation to age, WHR, HGS, MUAC, and SF. The t-stat value is well above the critical value, further confirming the significance. The confidence interval does not include zero, reinforcing the significance of the relationship.

CONCLUSION

To conclude on all the above results, boys are more likely to be underweight, while girls have higher percentages in the overweight and obese categories. This suggests potential differences in dietary habits, physical activity, or metabolic factors between genders. The majority of boys are at low risk based on WHR, while girls have a more balanced distribution across risk categories. The majority of girls has the normal range across all age groups, indicating generally good sign for handgrip strength. However, there is a small percentage of girls in the strong category, suggesting room for improvement. The data indicates that both boys and girls generally have a normal mid upper arm circumference, reflecting good nutritional status.

The 15-16 age group shows a higher prevalence of underweight and Obese-II categories, indicating a possible shift in body composition as children grow older. The 15-16 age group shows a higher percentage of individuals at moderate and high risk, suggesting increased health risks as they approach late adolescence.

There is a noticeable fluctuation in handgrip strength across different age groups, with a significant portion of boys in the weak category in the 16-17 age group. This suggests a need for targeted interventions to improve handgrip strength in this age group.

Boys tend to have a higher percentage in the average and healthy categories, while girls predominantly fall within the lean and healthy categories. This suggests gender differences in body fat distribution, with girls generally having lower body fat percentages.

Boys generally perform better in the tapping test, and performance improves with age. Performance in the Flamingo Balance Test is consistent across genders and age groups, with a majority performing well.

Overall, the data indicates good nutritional status and physical fitness among the population, with some areas for improvement, particularly in hand grip strength for boys and balance for both genders. Targeted interventions and continuous monitoring can help address these areas and promote overall health and well-being.

The statistical analysis shows significant relationships between various parameters such as BMI, WHR, HGS, MUAC, and SF. The low p-values and high t-statistics across these relationships indicate strong statistical significance, suggesting that these parameters are interrelated and can provide valuable insights into the health and fitness of the population studied.

The study reveals that Bone joint development in the adolescent age has a consequence role in their future bone development and its overall health. The prominent features of examination as per NFPE have shown the significance impact in the determination of Bone health.

In essence, to address the final determinants and let them understand, we have shared an awareness to the participants, which had insights on the importance of bone development in the adolescent age. Bone health during adolescence is pivotal for ensuring long-term skeletal integrity and overall well-being. This study

disseminates critical insights into the importance of bone development and encourages regular engagement in weight-bearing exercises. These activities are not solely for immediate physical fitness but represent a vital investment in the participants future health.

This study aims to address the critical determinants of bone health in adolescents by promoting awareness and implementing structured interventions. The study advocates for the inclusion of free playtime in school curricula to foster physical activity, which is essential for developing a robust skeletal system. Additionally, the importance of good nutritional habits and their impact on bone and joint health was emphasized. Future research will incorporate indigenous games and exercises designed to enhance compression forces, improve bone density, and optimize axial posture.

The findings underscore the necessity of integrating physical activity and nutritional education into adolescent routines. By fostering an environment that supports these practices, schools can significantly contribute to the development of strong and resilient bodies in their students. Promoting bone health in adolescents through structured physical activity and nutritional education is crucial for long-term skeletal health. The study highlights the importance of early intervention and the role of schools in facilitating these practices. Future initiatives will continue to explore effective methods for enhancing bone density and overall physical well-being in adolescents.

Acknowledgement

We acknowledge the support of the respective school management and our project team (A.Ratna Kumari, T.Suresh, G.Jayalakshmi, K.Sarojini, Ch. Bhagyalatha and paramedical team) for their extended cooperation in organizing the camps.

Funding Sources

This project is funded by Lee Pharma Limited as a CSR Initiative and executed by Lee Health Domain as an area of interest for public health & research initiative.

Conflict of Interest

"The author(s) do not have any conflict of interest."

REFERENCES

1.International Osteoporosis Foundation. (n.d.). Maternal nutrition. Retrieved May 21, 2025, from https://www.osteoporosis.foundation/healthprofessionals/prevention/maternal-nutrition

2. International Osteoporosis Foundation. (n.d.). Prevention. Retrieved May 21, 2025, from https://www.osteoporosis.foundation/health-professionals/prevention

3. International Osteoporosis Foundation. (n.d.). Bone biology. Retrieved May 21, 2025, from https://www.osteoporosis.foundation/healthprofessionals/aboutosteoporosis/bone-biology

4.Kumar, A. K., & Reshmi, R. S. (2014, October 5). Adolescent health in India and development implications. International Journal of Development Research, 4(10), 2078–2083. https://www.journalijdr.com/adolescent-health-india-and-development-implications

5. Levine, M. A. (2012). Assessing bone health in children and adolescents. Indian Journal of Endocrinology and Metabolism, 16(Suppl 2), S205–S212. https://doi.org/10.4103/2230-8210.104040

6. Merder-Coşkun, D., Uzuner, A., Keniş-Coşkun, Ö., Çelenlioğlu, A. E., Akman, M., & Karadağ-Saygı, E. (2017). Relationship between obesity and musculoskeletal system findings among children and adolescents. Turkish Journal of Physical Medicine and Rehabilitation, 63(3), 207–214. https://doi.org/10.5606/tftrd.2017.422

7. Hummell, A. C., & Cumming, M. (2022). Role of nutrition-focused physical examination in identifying malnutrition and its effectiveness. Nutrition in Clinical Practice, 32(41-49). https://doi.org/10.1002/ncp.10797

8. Ferozi, S., Taneja, A. G., & Bakshi, N. (2024). Assessment of nutritional status, physical fitness and physical activity of school going adolescents (12–15 years) in Delhi. BMC Pediatrics, 24(331), 1–11. https://doi.org/10.1186/s12887-024-04733-y

9. Ministry of Youth Affairs and Sports. (2019). Fitness protocols and guidelines for 18+ to 65 years. https://yas.nic.in/sites/default/files/Fitness%20Protocols%20for%20Age%2018-65%20Years%20v1%20(English).pdf

10. Lad, U. P., Satyanarayana, P., Shisode-Lad, S., Chaitanya siri, C., & Ratna kumara, N. (2013). A study on the correlation between the body mass index (BMI), the body fat percentage, the hand grip strength and the handgrip endurance in underweight, normal weight and overweight adolescents. Journal of Clinical and Diagnostic Research, 7(1), 51–54. http://dx.doi.org/10.7860/JCDR/2012/5026.2668

11. Kotecha, M. M., & Desai, M. (2022). Correlation of BMI with Hand Grip and Pinch Grip Strength in Children of 6-12 Years. International Journal of Health Sciences and Research, 12(11), 33–42. https://doi.org/10.52403/ijhsr.20221106

12. Musa, I. R., Omar, S. M., AlEed, A., Al-Nafeesah, A., & Adam, I. (2023). Mid-upper arm circumference as a screening tool for identifying underweight adolescents. Frontiers in Nutrition, 10, 1200077:01–06. https://doi.org/10.3389/fnut.2023.1200077

13. Craig, E., Bland, R., Ndirangu, J., & Reilly, J. J. (2014). Use of mid-upper arm circumference for determining overweight and overfatness in children and adolescents. Archives of Disease in Childhood, 99(763-766). https://doi.org/10.1136/archdischild-2013-305137

14. Jeyakumar, A., Ghugre, P., & Gadhave, S. (2013). Mid-Upper-Arm Circumference (MUAC) as a simple measure to assess the nutritional status of adolescent girls as compared with BMI. ICAN: Infant, Child, & Adolescent Nutrition, 5(1), 22–25. http://dx.doi.org/10.1177/1941406412471848
15. Normayanti, Suparyatmo, J. B., & Prayitno, A. (2020). The effect of nutrition education on body mass index, waist circumference, mid-upper arm circumference and blood pressure in obese adolescents. Electronic Journal of General Medicine, 17(5), em221. https://doi.org/10.29333/ejgm/7884
16. Sardinha, L. B., Going, S. B., Teixeira, P. J., & Lohman, T. G. (1999). Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. American Journal of Clinical Nutrition, 70(6), 1090–1095. https://doi.org/10.1093/ajcn/70.6.1090
17. Freedman, D. S., Katzmarzyk, P. T., Dietz, W. H., Srinivasan, S. R., & Berenson, G. S. (2009). Relation of body mass index and skinfold thicknesses to cardiovascular disease risk factors in children: The Bogalusa Heart Study. American Journal of Clinical Nutrition, 90(1), 210–216. https://doi.org/10.3945/ajcn.2009.27525
18. Sivrikaya, K., Ziyagil, M. A., & Çebi, M. (2019). Relationship between body mass index and skinfold thickness in exercised and sedentary boys and girls. Universal Journal of Educational Research, 7(1), 48–54. http://dx.doi.org/10.13189/ujer.2019.070107
19. Nooyens, A. C. J., Koppes, L. L. J., Visscher, T. L. S., Bouter, L. M., & van Mechelen, W. (2007). Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: The Amsterdam Growth and Health Longitudinal Study. American Journal of Clinical Nutrition, 85(6), 1533–1539. https://doi.org/10.1093/ajcn/85.6.1533
20. Ashtekar, S. V., Padhyegurjar, M. S., Padhyegurjar, S. B., & Powar, J. D. (2022). Nutritional assessment with skinfold thickness and body-fat proportion in tribal and urban schoolchildren in Nashik district: A cross sectional study. Journal of Family Medicine and Primary Care, 11(6), 3148–3155. http://dx.doi.org/10.4103/jfmpc.jfmpc_712_21
21. Bacopoulou, F., Efthymiou, V., Landis, G., Rentoumis, A., & Chrousos, G. P. (2015). Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. BMC Pediatrics, 15(50), 1–9. https://doi.org/10.1186/s12887-015-0366-z
22. Mukhopadhyay, S., Bhattacharjee, P., & Joshi, P. (2017). School based screening tools for childhood obesity: A comparison of TSFT, WHR and BMI. International Journal of Contemporary Pediatrics, 4(2), 370–373. http://dx.doi.org/10.18203/2349-3291.ijcp20170525
23. Burdacka, K., Chwała, W., Walaszek, R., & Burdacki, M. (2021). Evaluation of postural stability in girls and boys during the adolescence period. Physiotherapy Quarterly, 29(2), 73–78. https://doi.org/10.18502/ijph.v52i5.12713
24. Wilcox, G., & Nordstokke, D. (2021). Pediatric Co-Norms for Finger Tapping, Grip Strength, and Grooved Pegboard in a Community Sample. Journal of the International Neuropsychological Society, 1–9. http://dx.doi.org/10.1017/S13556s17721000175
25. Latino, F., Cataldi, S., & Fischetti, F. (2021). Effects of a coordinative ability training program on adolescents' cognitive functioning. Frontiers in Psychology, 12, 620440:01–09. https://doi.org/10.3389/fpsyg.2021.620440
26. Haverkamp, B. F., Oosterlaan, J., Königs, M., & Hartman, E. (2021). Physical fitness, cognitive functioning and academic achievement in healthy adolescents. Psychology of Sport and Exercise, 57, 102060:01–09. http://dx.doi.org/10.1016/j.psychsport.2021.102060
27. June, R. A. (1977). Delinquents and the tapping test. Journal of Clinical Psychology, 33(3), 786–791. https://doi.org/10.1002/1097-4679(197707)33:3%3C786::aijclp2270330340%3E3.0.co;2-x
28. Zulfarina, M. S., Sharkawi, A. M., Aqilah-S, N. Z. S., Mokhtar, S. A., Nazrun, S. A., & Naina-Mohamed, I. (2016). Influence of adolescents' physical activity on bone mineral acquisition: A systematic review article. Iranian Journal of Public Health, 45(12), 1545–1557. https://pmc.ncbi.nlm.nih.gov/articles/PMC5207095/pdf/IJPH-45-1545.pdf
29. Nguyen, V. H. (2018). School-based exercise interventions effectively increase bone mineralization in children and adolescents. Osteoporosis and Sarcopenia, 4(2), 39–46. https://doi.org/10.1016/j.afos.2018.05.002
30. Min, S. K., Oh, T., Kim, S. H., Park, J. H., Kim, M. H., Kim, K. C., & Lee, J. (2019). Position statement: Exercise guidelines to increase peak bone mass in adolescents. Journal of Bone Metabolism, 26(4), 225–239. http://doi.org/10.11005/jbm.2019.26.4.225
31. Ondrak, K. S., & Morgan, D. W. (2007). Physical activity, calcium intake and bone health in children and adolescents. Sports Medicine, 37(7), 587–600. https://doi.org/10.2165/00007256-200737070-00003
32. McKay, H., Liu, D., Egeli, D., Boyd, S., & Burrows, M. (2011). Physical activity positively predicts bone architecture and bone strength in adolescent males and females. Acta Paediatrica, 100(1), 97–101. https://doi.org/10.1111/j.1651-2227.2010.01995.x
33. Centers for Disease Control and Prevention. (n.d.). Child and Teen BMI Categories. BMI | CDC. Retrieved April 29, 2025, from https://www.cdc.gov/healthyweight/bmi/childrens_bmi/tool_for_children.html
34. Mahan, L. K., & Raymond, J. L. (2018). The essential pocket guide for clinical nutrition (2nd ed.). Wolters Kluwer Health.
35. Zárate-Osuna, F., Zapico, A. G., & González-Gross, M. (2025). Handgrip strength in children and adolescents aged 3 to 16 years and residing in Spain: New reference values. Children, 12(4), 471. https://doi.org/10.3390/children12040471
36. Caballero, B., Allen, L., & Prentice, A. (Eds.). (2005). Encyclopedia of human nutrition (2nd ed., Vol. 3, pp. 311–318). Academic Press. https://books.google.co.in/books?hl=en&lr=&id=N588_47K3iEC&oi=fnd&pg=PA311&dq=Body%20composition%20measurements%20for%20nutritional%20assessment&ots=g4P5I-N79v&sig=5kCg2_gV_1h914XfG0-K77D-xQ4&redir_esc=y#v=onepage&q=Body%20composition%20measurements%20for%20nutritional%20assessment&f=false
37. Hume, P. A., & Ackland, T. (2017). Physical and clinical assessment of nutritional status. In A. M. Coulston, C. J. Boushey, M. G. Ferruzzi, & L. M. Delahanty (Eds.), Nutrition in the prevention and treatment of disease (4th ed., pp. 71–84). Academic Press. https://doi.org/10.1016/B978-0-12-802928-2.00003-5
38. Gaikwad, N. R., Gupta, S. J., Samarth, A. R., & Sankalecha, T. H. (2016). Handgrip dynamometry: A surrogate marker of

malnutrition to predict the prognosis in alcoholic liver disease. Annals of Gastroenterology, 29(4), 509–514. http://dx.doi.org/10.20524/aog.2016.0049
39. Rana, R., Barthorp, H., McGrath, M., Kerac, M., & Myatt, M. (2021). Mid-upper arm circumference tapes and measurement discrepancies: Time to standardize product specifications and reporting. Global Health: Science and Practice, 9(4), 1011–1014. https://www.ghspjournal.org/content/9/4/1011
40. Lightstuff. (2017, December 17). Precision Skinfold Caliper – Quick Start Guide for Beginners, Detailed Booklet for Advanced Users. Amazon.in. https://www.amazon.in/Lightstuff-Precision-Skinfold-Caliper-Monitoring/dp/B072ZR2TZN