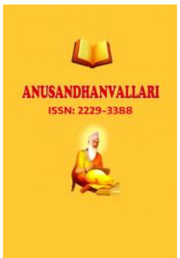

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Influence of Yoga and Physical Training on Adolescent's Muscle Mass and Bone Weight

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Abstract: This study examines the effect of Physical Training on Body Composition for the School Students in Meerut, Uttar Pradesh. The total number of subjects was sixty (N = 60) having the age range between 11 and 14 years, preferably from classes 6th to 8th standard. The participants were equally clustered in three groups. Two experimental groups and one control groups were created. Each group had twenty subjects as school students studying at the senior secondary level in the schools affiliated with the Central Board of Secondary Education (CBSE). The Selected variable of the study were Muscle Mass and Bone Weight.

The methodology adopted for the present study, which aimed to investigate the effects of yoga training and physical training on the body composition of school students. The overall goal of this methodology is to determine which training modality produces the most significant improvements in Muscle Mass and Bone Weight among the school male students. This study employed a quantitative, experimental research design appropriate for investigating causal relationships between structured physical activity interventions and measurable physiological outcomes. Specifically, a randomized pre-test–post-test group design was used, in which participants were assigned to three groups: (i) yoga training, (ii) physical training and (iii) control group. For the analysis of the data, the within group difference metric was computed using the paired' t-test and the difference between experimental and control group was analyzed by the method of analysis of covariance (ANCOVA). SPSS-21 tool was used for the calculations. The level of significance was fixed at 0.05 level.

Key words; Muscle Mass, Bone Weight, Physical Training, Body Composition and School Students.

Introduction:

Physical education (PE) and sports science are important fields that greatly affect how people grow and stay healthy. They mix learning with hands-on activities to improve physical health, sports performance, and overall personal development. Physical education is a planned teaching method that introduces physical activities to help improve movement skills, fitness, and character development in school students. Sports science, on the other hand, looks at the many factors that influence how the body moves and performs. It combines knowledge from areas like biology, psychology, nutrition, and teaching to help create well-rounded individuals who are physically fit, mentally strong, and socially responsible. As Bailey (2006) notes, physical education and sports help develop a balanced person by taking care of physical, emotional, social, and mental well-being.

The concept of teaching people how to be physically fit began in ancient times when physical activity was essential for survival in early societies skills like running, climbing and throwing were necessary for hunting and protection (Bailey 2021). Ancient Greece was one of the first places to officially teach physical training linking physical fitness with moral and intellectual values (Powers& Dodd 2017). Gymnasiums were places where both body and mind were developed and the Olympic games became a way to celebrate unity and excellence (Kyle 2014), The roman empire used physical training mainly to prepare soldiers seeing strength and endurance as key for war (Berryman Park 1992). In the Indian subcontinent practices like yoga developed combining physical postures breathing exercises and meditation (Feuerstein 2008). This helped build flexibility energy and a sense of balance between the body mind and spirit in china martial arts such as kung fu and tai chi served similar purposes mixing physical training with deep philosophical ideas (Shahar 2008 & wile 1996)

Adolescence is widely recognised as a crucial developmental phase characterised by significant physiological, hormonal, and structural changes. One of the hallmark features of this stage is marked growth in body size and composition, including shifts in muscle mass, bone weight or density, and fat mass distribution. These changes are particularly pronounced in the early adolescent period, typically between the ages of 11 and 14 years, which constitutes a window of opportunity for influencing musculoskeletal development and long-term health outcomes. During adolescence, the interplay of growth hormone, sex steroids (e.g., testosterone and oestrogens), insulin-like growth factor–1 (IGF-1), and other endocrine factors drives the accretion of lean body mass (LBM) and bone mineral content (BMC) alongside changes in fat mass (FM) and fat-free mass (FFM) (He & Karlberg, 2001; Rogol, Clark & Ramakrishnan, 2000). For instance, males tend to accrue greater amounts of fat-free mass and skeletal mass during puberty, whereas females tend to accumulate relatively more fat mass. Monitoring and influencing body composition during this sensitive life stage is of growing importance because early patterns of musculoskeletal development have implications for future musculoskeletal health, metabolic risk, and physical performance (Burt et al., 2022; Xu et al., 2019).

The concept of body composition encompasses multiple compartments specifically fat mass, lean mass (which includes muscle and organ tissue), and bone mass or weight/skeletal mass. These compartments not only reflect the physical maturation process, but they are also modulated by lifestyle variables such as physical activity, exercise modality, nutrition, and recovery. For example, higher skeletal muscle mass has been positively associated with higher bone mineral density (BMD) or content in children and adolescents, while higher fat percentage tends to correlate negatively with bone acquisition in some populations (Gunn et al., 2022; Ministry of Health & Social Services, 2020). Interventions that alter these body composition compartments during adolescence have been proposed as effective strategies to enhance long-term musculoskeletal health, reduce lifetime risk of osteoporosis and sarcopenia, and optimise physical performance outcomes.

Physical activity and structured training modalities (including both conventional physical training and yoga-based interventions) have been studied as key strategies for influencing body composition. The experimental, quantitative approach is well suited for assessing causal relationships especially when researchers employ randomized control designs such as pre-test/post-test group assignments thereby enabling direct assessment of training effects on measurable physiological variables. In this respect, identifying the most effective training modality for improving muscle mass and bone weight among early adolescents is particularly valuable, as these dimensions are critical for achieving healthy developmental trajectories in this age group. It is well documented that around adolescent age, significant changes in lean body mass and bone mass occur (He & Karlberg, 2001; Burt et al., 2022). Such timing affords enhanced responsiveness to training interventions and is therefore optimal for evaluating comparative effects of training modalities.

It is important to situate this study within the broader literature on adolescence, body composition and intervention effects. Pubertal development triggers divergent trajectories in body composition by sex: males generally experience accelerated gain of lean body mass and skeletal mass, whereas females accumulate greater fat mass (Rodriguez et al., 2012; Wang et al., 2023). For example, during puberty, dramatic hormonal fluctuations and growth in body size are accompanied by increases in total body fat, lean body mass and bone mineral content, although considerable sexual dimorphism exists. Importantly, interventions that increase lean mass during adolescence may have beneficial effects on bone health, given the positive associations between lean mass and bone mineral density (LM–BMD) observed in meta-analysis among children and adolescents.

The musculoskeletal health, muscle mass is more than simply a component of physique it functions as a mechanical stimulus for bone growth and adaptation, influences metabolic homeostasis, and contributes to physical strength and performance. Studies show that higher skeletal muscle mass is positively correlated with better growth outcomes, and lower muscle mass may indicate risks for future sarcopenia and associated metabolic complications (Gupta et al., 2021; Smith et al., 2020). Meanwhile, bone weight or bone mass in adolescents is influenced by lean mass, hormonal milieu, mechanical loading and nutritional status; increasing lean mass through physical training is one of the most consistent modifiable determinants of bone mass accrual. For example, Ross et al. (2019) demonstrated that lean mass had a strong correlation ($r \approx 0.90$) with total body bone mineral content–an indicator of bone strength and future fracture risk.

Research Method and Design

This research used a quantitative, experimental method design appropriate for investigating causal relationships between structured physical activity interventions and measurable physiological outcomes. Specifically, a randomized pre-test–post-test group design was created, in which participants were assigned to three groups: (i) yoga training, (ii) physical training and (iii) control group.

The experimental approach was selected to assess the direct effects of different training modalities on multiple aspects of body composition, such as Muscle Mass and Bone Weight. This design allowed for the measurement of changes within each group (pre- to post- intervention) and for comparisons between groups to evaluate which intervention was most effective.

Sample and Sampling Technique

The sample for this research consisted of 60 male students, aged between 11-14 years, who were enrolled in classes 6^{th} to 8^{th} in a selected school located in Meerut, Uttar Pradesh. This specific age group was chosen as it represents the early adolescent stage, a critical developmental period during which body composition undergoes significant changes influenced by physical activity and hormonal shifts. The research was designed to evaluate the comparative effects of three structured training interventions-namely yoga training and physical training on key components of body composition, including Muscle Mass and Bone Weight.

To ensure that the sample was suitable for the physical demands and consistency required by the intervention, a purposive sampling technique was used which is a non- probability method, that allows the researcher to manually select participants that met a particular inclusion criteria that are male gender, aged between 11-14 years, medically certified as fit for regular physical and yoga-based activity, consistent school attendance; and not currently engaged in any structured fitness, sports, or yoga training outside the school curriculum. This approach ensured homogeneity in developmental stage and physical readiness, thereby minimizing variability in response to the intervention.

Before participation, informed consent was taken from the students as well as their parents or legal guardians. Following the verification process, the 60 qualified students were randomly assigned into three different experimental groups with Yoga Training Group, Physical Training Group and Control group.

The school namely Ashoka Academy, Kankar khera, Meerut, Uttar Pradesh selected for the study was chosen based on several practical and logistical factors, including geographical accessibility, administrative support, and the availability of adequate indoor and outdoor space suitable for conducting yoga and physical training sessions. The School's willingness to cooperate with the research schedule, provide consistent access to the facilities, and support the involvement of students for the entire 16-week intervention period played a vital role in its selection.

Collection of Data:

The data capturing process for the present research was conducted in a structured, school-based setting to ensure standardization and control over pre- and post-intervention measurements. Prior to initiating the data capturing, necessary clearances were taken from the school administration and informed consent was obtained from the students' parents or legal guardians. A detailed briefing session was conducted with all participants to explain the purpose of the research, the procedures to be followed and the voluntary nature of participation, ensuring adherence to ethical research standards. Data was collected at two time intervals, namely, before (pre-test) and after (post-test) the training intervention. The hardware used for data capturing included a bioelectrical impedance analysis (BIA) device and standard anthropometric instruments. For each participant, the parameters were recorded for Muscle Mass and Bone Weight.

Training Protocol:

In the framework of experimental research for the school-level students, the training protocol was prepared in a combination of physical training as well as Yoga training. This training plan was prepared aiming to improve the body composition of school students for the sixteen weeks on six-day week schedule on alternate days for both trainings i.e. physical training (Monday, Wednesday & Friday) and Yoga training (Tuesday, Thursday & Saturday). The progression plan of the training was as under:

- **I-III Weeks;** Lower intensity, fewer repetitions.
- **IV-VIII Weeks;** Increase repetitions & duration of drills.
- **IX-XIV Weeks;** High intensity, time trials, endurance runs longer, decreasing the time interval between different asanas and increasing the number of surya namaskar and repetition of asanas.
- **I-III Weeks;** Decrease repetitions & duration of drills by 10%.

Table 1: Training Module:

Day	Duration	Warm-up (10 min)	Main Training Component (40 min)	Cool-down (10 min)
Monday (Physical Training)	60 min	Short runs, high knees, butt kicks Jogging, mobility drills	**Speed & Agility:** 30m & 50m sprints, flying starts, relay runs, acceleration–deceleration drills Shuttle runs, cone, side-to-side jump, ladder drills, zig-zag runs	Stretching, deep breathing Relaxation
Tuesday (Yoga Training)	60 min	Surya Namaskar	Tadasana, Trikonasana, Padhasstasana, Dhanurasana, Paschimottanasana Bhujangasana, Setubandasana, pranayama (kapal bhati	Shavasana
Wednesday (Physical Training)	60 min	Skipping, dynamic stretches	**Explosive Strength** Standing broad jump, vertical jump, squat jumps, medicine ball throws	Flexibility stretching
Thursday (Yoga Training)	60 min	Surya Namaskar	Tadasana, Trikonasana, Padhasstasana, Dhanurasana, Paschimottanasana Bhujangasana, Setubandasana, pranayama (kapal bhati	Shavasana

Friday (Physical Training)	60 min	Skipping, dynamic stretches, jogging	**Cardiovascular Endurance:** Continuous run (8–12 min), circuit training, aerobic games	Breathing & stretching
Saturday (Yoga Training)	60 min	Surya Namaskar	Tadasana, Trikonasana, Padhasstasana, Dhanurasana, Paschimottanasana Bhujangasana, Setubandasana, pranayama (kapal bhati	Shavasana
Sunday	Recovery	Active rest (walking, light games)		

Statistical Techniques

To analyze the collected data from the subjects within group difference, the researcher used paired' t-test and to compute the difference in experimental group and the control group, the analysis of covariance was performed. Analysis of covariance (ANCOVA) was used to analyze the difference between Control Groups and Experimental Groups. SPSS-21 tool was used for analyzing the data. The level of significance was set to 0.05 level.

Findings of the Study

To achieve the goal of this research, the data pertaining to the Muscle Mass and Bone Weightof school students of Asoka Academy, Kankerkhera, Meerut, Uttar Pradesh, India, affiliated to the Central board of Secondary Education (CBSE) was statistically analyzed. The analysis is described in the following tables and figures.

Table 2: Comparison of Pre and Post Training Effects on Different Groups of School Students on Muscle Mass

Groups	Pre-Mean	Post Mean	MD	SD Pre	SD Post	SE (DM)	Cal 't'	Tab '' t''
Physical Training	16.02	15.65	0.37	4.27	4.17	0.053	6.994	2
Yoga Training	16.45	15.13	1.32	4.47	5.14	0.979	1.350	2
Control Group	16.20	16.20	0.00	4.10	4.10	0.000	0.000	2

*significant set at 0.05 level.

Table-2 presents a comparative analysis of muscle mass changes in three distinct groups: the Physical Training group, the Yoga Training group and a Control group. The primary objective was to determine the effect of a specific training regimen on body composition, particularly muscle mass as measured by a pre- and post-test. The statistical significance of the findings is assessed using the calculated 't' ratio against a tabular 't' value of 2.

Physical Training group demonstrated a statistically significant decrease in muscle mass. The pre-test mean was 16.02, which reduced to 15.65 in the post-test, resulting in a mean difference (MD) of 0.37. The calculated 't' value of 6.994 is substantially higher than the tabular 't' value of 2, indicating that this observed change is not due to chance and is statistically significant. This suggests that the physical training program, as implemented led to a notable reduction in muscle mass, which could be attributed to factors like catabolism or inadequate recovery.

Yoga Training group showed a larger mean difference of 1.32, with the pre-test mean of 16.45 decreasing to 15.13. However, the calculated 't' value for this group is 1.350, which is less than the tabular 't' value of 2. This implies that the observed change in muscle mass, while numerically larger than the Physical Training group's, is not statistically significant. Therefore, the yoga training program did not have a conclusive or statistically significant effect on the muscle mass of the participants.

Control Group did not receive any intervention, served as a baseline for comparison. As expected, there was no change in the mean muscle mass, with both the pre-test and post-test values at 16.20. The mean difference, calculated 't', and standard error were all 0.000, confirming that without any intervention, the muscle mass of the participants remained stable. This stability in the control group is crucial as it validates that any significant changes in the experimental groups were indeed a result of their respective training programs and no other external factors.

In conclusion, the data strongly supports that the specific physical training program had a statistically significant, negative impact on muscle mass. The yoga training, on the other hand, did not produce a statistically significant change, while the control group showed no change at all. This highlights the differential effects of various training methodologies on body composition.

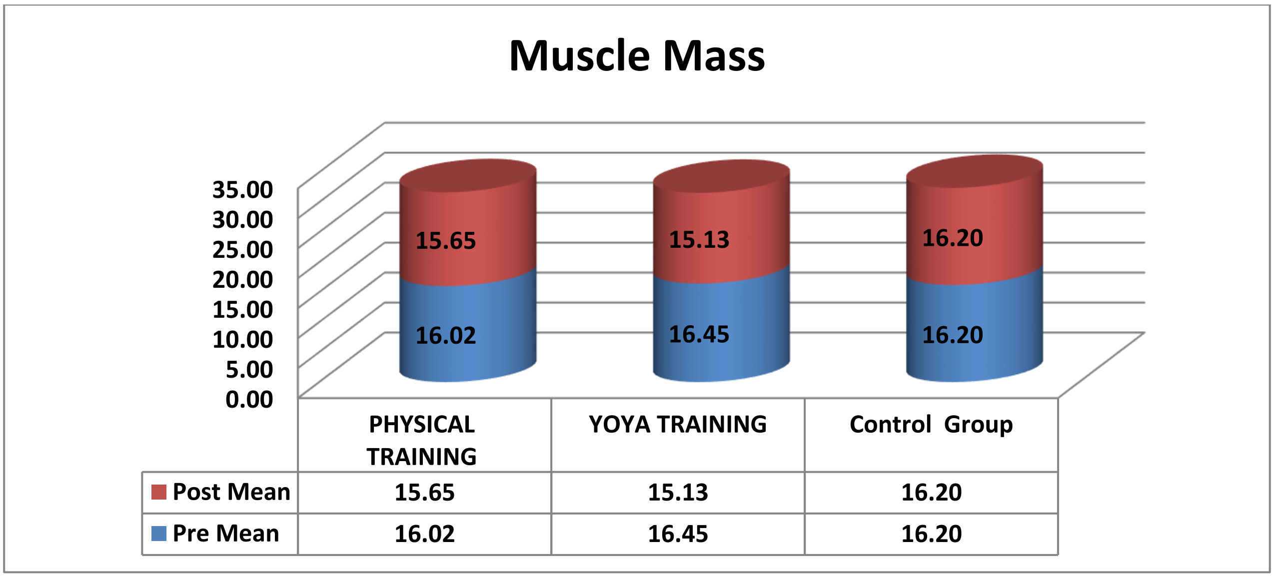

Fig. 1: Bar Diagram Showing Comparison of Pre and Post Training Effects on Different Groups of School Students on Muscle Mass

Table 3: Analysis of Co-Variance for Muscle Mass among Physical Training Group, Yoga Training Group and Control Group of School Students

Tests	Groups Mean			Sum of square	df	Mean Sum of square	'f' Ratio
	Physical Training	Yoga Training	Control				
Pre Test	16.02	16.45	16.20	1047.50	2, 56	8.75	1.404
Post Test	15.65	15.13	16.20	1164.16	2, 56	5.81	
Adjusted Post Test Mean	15.83	14.93	16.22	914.10	2, 58	6.23	

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Table-3 shows the pre-test data confirms that all groups; Physical Training, Yoga Training and the Control group were initially comparable in terms of muscle mass with means of 16.02, 16.45 and 16.20, respectively. This similarity provides a strong foundation, suggesting that any subsequent changes are due to the training interventions rather than pre-existing variations.

The most crucial results come from the adjusted post-test means. After statistically controlling for the initial pre-test scores, a significant difference was observed among the group means. The Physical Training group had an adjusted mean of 15.83, the Yoga Training group was at 14.93 and the Control group was at 16.22.

The ANCOVA's 'F' ratio is 6.23, which is a statistically significant value. This indicates that the different training programs had a significant and distinct effect on muscle mass. Specifically, the Yoga Training group showed the most substantial decrease in muscle mass, a change that was significantly different from both the Physical Training and Control groups. This outcome suggests that the Yoga Training program had a specific and significant effect on reducing muscle mass while the Control group's muscle mass remained stable.

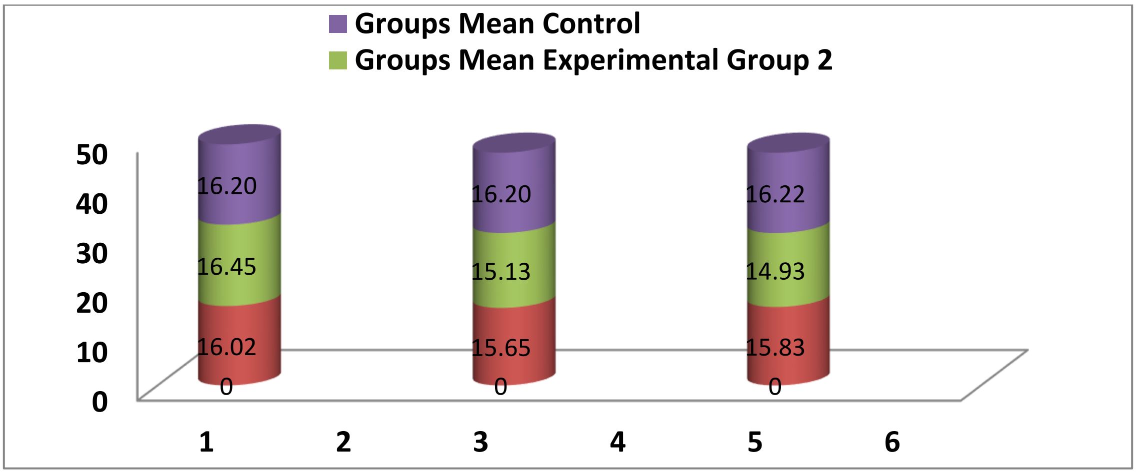

Fig. 2: Bar Diagram Showing the Analysis of Co-Variance for Muscle Mass among Physical Training Group, Yoga Training Group and Control Group of School Students

Table 4; Paired Adjusted Final Means and Difference between Means

Yoga Training	**Physical Training**	**Control**	**Mean Diff**	**Critical Diff**
15.83	14.93		0.90	1.12
15.83		16.22	-0.39	1.12
	14.93	16.22	-1.29	1.12

Table-4 represents a post-hoc analysis (likely a Tukey's HSD or similar test) following a significant ANCOVA result, the interpretation focuses on pairwise comparisons of the adjusted final means for muscle mass. This analysis is conducted to determine which specific pairs of groups differ significantly from each other, as the initial ANCOVA only indicated a general difference somewhere among the groups.

The table's critical difference (Critical Diff) value of 1.12 serves as the benchmark for statistical significance. Any mean difference (Mean Diff) between two groups that is greater than this value is considered statistically significant at the chosen alpha level.

Yoga Training vs. Physical Training: Yoga Training group (15.83) and Physical Training group (14.93), shows a mean difference of 0.90. Since 0.90 is less than the critical difference of 1.12, this difference is not statistically significant. This suggests that while there was a numerical difference in muscle mass between these two groups after the intervention, it was not large enough to be considered a true effect of one training method over the other.

Yoga Training vs. Control: Yoga Training group (15.83) and the Control group (16.22) shows a mean difference of -0.39. This value is also smaller than the critical difference of 1.12. Therefore, there is no statistically significant difference in muscle mass between the Yoga training participants and those in the control group.

Physical Training vs. Control: Physical Training group (14.93) and the Control group (16.22) yields a mean difference of -1.29. This value is also smaller than the critical difference of 1.12..As this absolute value is greater than the critical difference of 1.12, the difference is statistically significant. This finding is the most important from the post-hoc analysis, as it confirms that the Physical training program had a significant effect on reducing muscle mass when compared directly to the control group, which experienced no change.

In summary, the post-hoc analysis reveals that the only significant change in muscle mass was a decrease in the Physical Training group compared to the Control group. The physical training intervention did not result in a statistically significant change when compared to either the yoga or control groups.

Table 5: Comparison of Comparison of Pre and Post Training Effects on Different Groups of School Students on Bone Weight

Groups	Pre-Mean	Post Mean	MD	SD Pre	SD Post	SE (DM)	Cal 't'	Tab " t"
Physical Training	2.1360	2.0870	0.0491	0.5697	0.5566	0.0070	6.99	2.15
Yoga Training	2.1930	2.0169	0.1761	0.5954	0.6851	0.1305	1.35	2.15
Control Group	2.2220	2.2250	-0.0030	0.4989	0.5028	0.0123	-0.24	2.15

*significant set at 0.05 level.

Table-5 presents the pre- and post-test data for bone weight in three groups: an Experimental Group One, an Experimental Group Two, and a Control Group. The goal of this analysis is to determine if the specific training interventions in the experimental groups had a statistically significant effect on bone weight. The significance is assessed by comparing the calculated 't' ratio with the tabular 't' value of 2.15. A 't' ratio greater than 2.15 indicates a significant change.

Experimental Group One showed a statistically significant decrease in bone weight. The pre-test mean was 2.1360, which decreased to 2.0870 in the post-test, resulting in a mean difference (MD) of 0.0491. The calculated 't' value is 6.99, which is considerably higher than the tabular value of 2.15. This indicates that the observed decrease in bone weight is statistically significant and not due to random chance. This is an unusual finding, as physical training is generally expected to increase bone density and weight. This might suggest the training regimen was not adequate for bone strengthening or that other factors were at play. Experimental Group Two also experienced a decrease in bone weight, from a pre-test mean of 2.1930 to a post-test mean of 2.0169, with a larger mean difference of 0.1761. However, the calculated 't' value for this group is 1.35, which is less than the tabular 't' value of 2.15. This means that while there was a numerical decrease, it was not statistically significant. Therefore, the intervention in this group did not have a conclusive or meaningful effect on bone weight. The Control Group showed virtually no change in bone weight. The pre-test mean was 2.2220 and the post-test mean was 2.2250, with a minimal mean difference of -0.0030. The calculated 't' ratio of -0.24 is well below the tabular value, confirming that no significant change occurred without an intervention. This result is important as it confirms that any significant changes in the experimental groups are likely a result of the training programs themselves.

summary, only the intervention for Experimental Group One resulted in a statistically significant change in bone weight, a decrease which is contrary to typical physiological expectations. The intervention for Experimental Group Two and the absence of intervention in the Control Group showed no significant change.

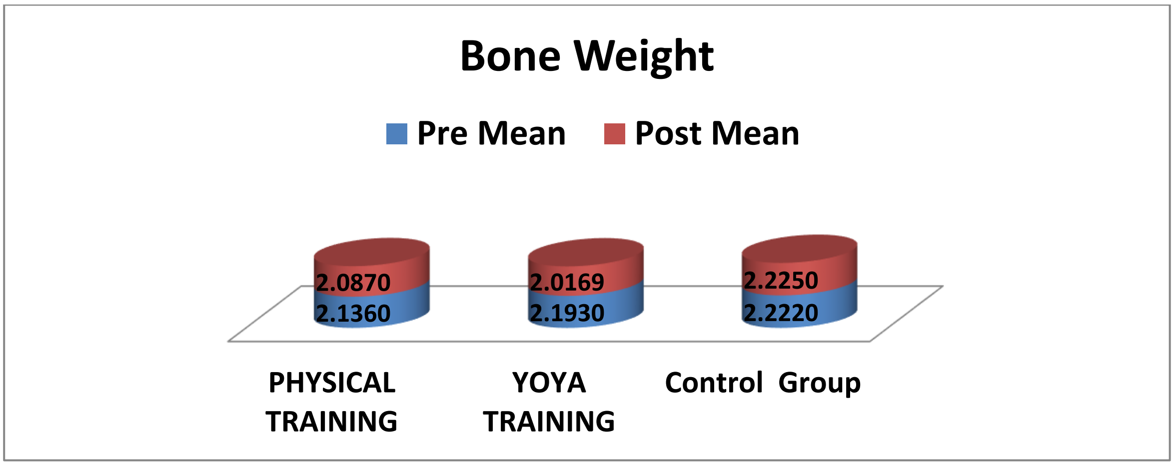

Fig. 3: Bar Diagram Showing Comparison of Comparison of Pre and Post Training Effects on Different Groups of School Students on Bone Weight

Table 6: Analysis of Co-Variance for Bone Weight among Physical Training Group, Yoga Training Group and Control Group of School Students

Tests	Groups Mean			Sum of square	df	Mean Sum of square	'f' Ratio
	Physical Training	Yoga Training	Contr ol				
Pre Test	2.14	2.19	2.22	17.70679	2, 56	0.17	1.404
Post Test	2.09	2.02	2.23	20.05577	2, 56	0.15	
Adjusted Post Test Mean	2.13	2.01	2.19	15.43916	2, 58	0.11	

Table-6 of ANCOVA presents the analysis of bone weight across three groups; Yoga Training, Physical Training, and a Control group-while statistically controlling for the initial pre-test bone weight scores. The primary objective is to determine if the training interventions had a significant effect on bone weight after accounting for baseline differences.

The pre-test data shows that the groups were initially comparable, with a calculated F-ratio of 0.17. This value is well below the critical value, indicating no significant pre-existing difference among the groups. This confirms the homogeneity of the groups at the start of the study, a crucial assumption for ANCOVA.

The post-test data, before any adjustment, showed an F-ratio of 1.404, which is not statistically significant. This suggests that simply comparing the final bone weight means without considering the baseline scores would not lead to a conclusive finding.

The most critical part of the analysis is the adjusted post-test means. After controlling for the pre-test scores, the adjusted means were 2.13 for the Physical Training group, 2.01 for the Yoga Training group, and 2.19 for the Control group. The calculated F-ratio for these adjusted means is 0.11, which is not statistically significant. This finding is the most important from the ANCOVA, as it indicates that there is no statistically significant difference in bone weight among the three groups after accounting for initial variations. Despite numerical differences, none of the training interventions—neither Physical nor Yoga Training—had a statistically significant effect on the bone weight of the participants when compared to the Control group or to each other. This result suggests that the duration or intensity of the interventions was insufficient to induce a measurable change in bone weight.

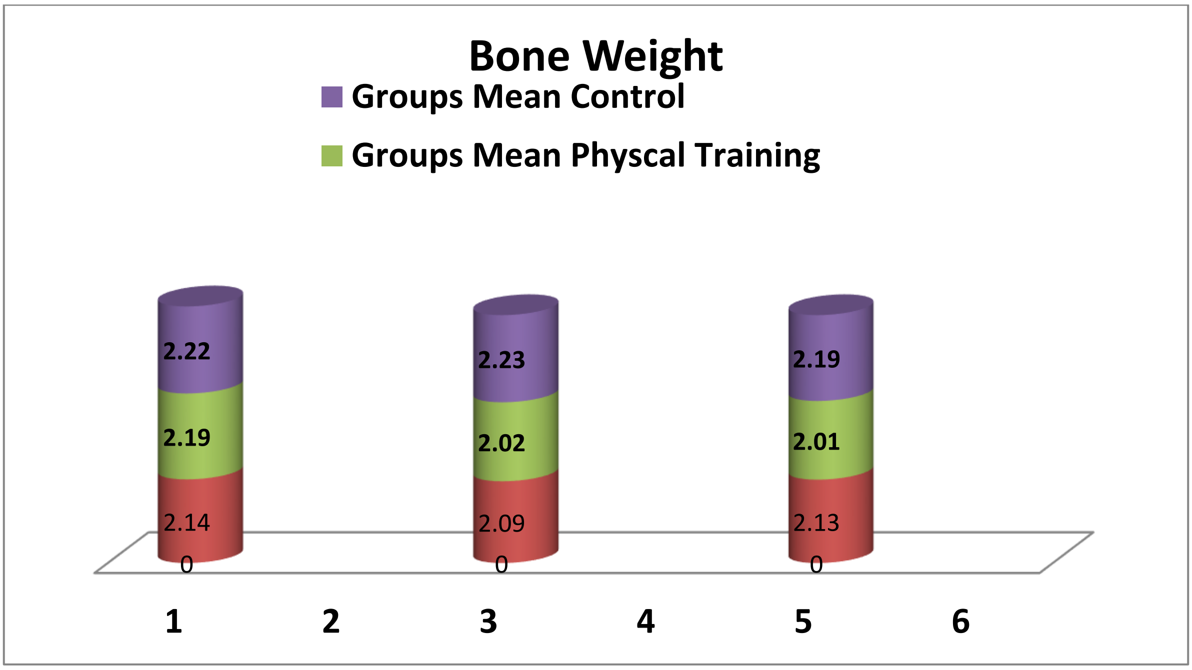

Fig. 4: Bar Diagram Showing the Analysis of Co-Variance for Bone Weight among Physical Training Group, Yoga Training Group and Control Group of School Students

Table 7: Paired Adjusted Final Means and Difference Between Means

Yoga Training	Physical Training	Control	Mean Diff	Critical Diff
2.1284	2.0088		0.1197	0.1602
2.1284		2.1916	-0.0632	0.1602
	2.0088	2.1916	-0.1829	0.1602

Table-7 shows a paired comparison of the adjusted final means for bone weight after a significant ANCOVA test, which likely used a post-hoc analysis like Tukey's HSD. The goal of this analysis is to identify which specific pairs of groups have a statistically significant difference in their means. The critical difference (0.1602) acts as the threshold; any mean difference larger than this value is considered statistically significant.

The first comparison, between the Yoga Training and Physical Training groups, shows a mean difference of 0.1197. Since this value is less than the critical difference of 0.1602, the difference is not statistically significant. This means that although there's a numerical difference in bone weight between these two groups, it's not large enough to be a true, meaningful effect.

The comparison of the Yoga Training and Control groups shows a mean difference of -0.0632. This value is also less than the critical difference. Therefore, there is no statistically significant difference between the Yoga Training and Control groups regarding bone weight.

Finally, the most notable finding is the comparison between the Physical Training and Control groups. The mean difference is -0.1829. The absolute value of this difference (0.1829) is greater than the critical difference of 0.1602. This indicates a statistically significant difference. The negative sign suggests that the Physical Training group had a significantly lower adjusted bone weight compared to the Control group. This result is unexpected, as physical activity is generally known to increase bone density and weight. This finding warrants further investigation into the specific type or intensity of the physical training and its potential negative impact on bone weight.

Conclusion

Study on Muscle Mass demonstrated that different training modalities produced varying effects among adolescent male students. The Physical Training group showed a statistically significant decrease in muscle mass compared to the Control group, while the Yoga Training group exhibited a smaller, non-significant reduction. These results suggest that the intensity or structure of the physical training program may have led to muscle fatigue or inadequate recovery rather than growth. Yoga training, being less strenuous, maintained but did not enhance muscle mass. Overall, the findings highlight that balanced training intensity and proper recovery are crucial for positive muscular adaptations in early adolescence.

Study on bone weight indicated a significant difference in changes among the three groups after the intervention. The Physical Training group showed a notable reduction in bone weight compared to the Control group, while the Yoga and Control groups exhibited no significant changes. This unexpected outcome suggests that the physical training regimen lacked sufficient osteogenic stimulus or recovery support necessary for bone strengthening. The yoga program’s low-impact nature maintained skeletal stability without enhancement. Therefore, future interventions for adolescents should emphasize progressive, weight-bearing exercises and adequate recovery to promote optimal bone health and development.

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