



Compatibility of Existing Physical Education Model with Enhancing Muscular Strength in School Children: A Public Health Perspective

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ABSTRACT

Background and Study Aim: The purpose of this study was to evaluate the effectiveness of the physical education (PE) curriculum on the muscular strength of school children in India, with a particular focus on how the number of PE teachers and the duration of physical activity influence grip strength, an indicator of overall muscular strength.

Material and Methods: The study involved a sample of 1000 students (500 boys and 500 girls) aged 12 to 16 years from various schools in India. Dominant hand grip strength was measured using a CAMRY Digital Hand Dynamometer, and reference values were established for different age groups. Data on the number of PE teachers, total number of teachers, and student enrolment in physical education were collected from school records. Statistical analyses, including Two-Way MANOVA, were conducted to determine the effects of age, sex, the number of PE teachers, and physical activity duration on grip strength. Additionally, an adjacency network plot was used to display correlations among the selected variables.

Results: Grip strength increased with age for both boys and girls, with boys consistently showing higher values. The data revealed that schools with more PE teachers had significantly higher grip strength, with those having five PE teachers reporting the highest average strength (28.86 kg) and those with no PE teachers the lowest (20.07 kg). The two-way MANOVA showed significant effects of age ($F = 61.509, p < .001$), sex ($F = 141.781, p < .001$), number of PE teachers ($F = 9.460, p < .001$), and physical activity duration ($F = 3.306, p = .020$) on grip strength. Interaction effects between age and sex were significant ($F = 17.139, p < .001$), indicating differential development patterns. The adjacency network plot further supported these findings by showing positive correlations among PE teacher numbers, physical activity duration, and grip strength.

Conclusions: The findings reveal that students who actively engaged in physical education classes exhibited greater muscular strength. However, the study also underscores that the curriculum's success depends on its proper implementation, highlighting the necessity of adequate staffing and sufficient time allocated for physical activities to maximize benefits for student health and fitness. Overall, the study advocates for prioritizing physical education in schools as a crucial measure for improving children's muscular strength and advancing public health.

KEYWORDS

Physical Education, Public Health, Grip Strength

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INTRODUCTION

It is widely accepted that muscular strength is an important aspect of physical fitness and a decrease in muscular strength may cause functional limitations (de Moura et al., 2024; Ma et al., 2024). Muscular strength is a biomarker for skeletal health during development period and associated with motor function ability in adolescents and adults (Torres-Costoso et al., 2020; Wijngaarde et al., 2020). Health-benefits of childhood muscular strength extend into adulthood, with higher levels associated with decreased mortality (B. J. Fraser et al., 2021a) and cardiometabolic disease (B. Fraser et al., 2016; B. J. Fraser et al., 2018). Furthermore, greater muscular strength in childhood, young- and mid-adulthood are equally associated with reduced odds of prediabetes in midlife (B. J. Fraser et al., 2021b). These findings highlight the importance of muscular strength across the life course, beginning in childhood. However, the grip strength is reported as a predictor of overall muscular strength (Kuldeep Nara et al., 2022; Nara et al., 2023).

Schools are considered an important setting to influence the physical fitness of children, given the amount of time spent at school and the potential for schools to reach large numbers of children. Physical education may be an effective mean of increase muscle strength (Nara et al., 2022; Nara & Kumar, 2023). A significant amount of research work has supported effectiveness of physical education in improving physical activity (Kliziene et al., 2021; Uddin et al., 2020). Furthermore, it is also evident that physical activity improves cardiac, metabolic, psychological, and metabolic health and enhances cardiorespiratory and muscular fitness of children and adolescents (Poitras et al., 2016; Rhodes et al., 2017; Rodriguez-Ayllon et al., 2019; Whooten et al., 2019).

Model of Physical Education in India

The model of Physical Education in India, as depicted in figure 1, the syllabus provided by the National Council of Educational Research and Training (NCERT) (National Council of Educational Research and Training, 2024), is a comprehensive framework aimed at the holistic development of students from classes I to XII. The curriculum is designed to address the physical, mental, social, and emotional aspects of students' growth, with an emphasis on health and physical fitness. The following is a comprehensive note on the model of physical education adopted in India, highlighting key points relevant to research on the effects of physical education on muscular strength and physical activity.

The Physical Education syllabus in India emphasizes the development of fundamental movements and neuromuscular coordination, which are essential for fostering muscular strength and promoting physical activity in children. Activities at the primary level focus on basic movements and coordination exercises that lay the foundation for physical fitness. As students' progress, the curriculum includes specific activities aimed at improving strength and endurance, such as running, hopping, leaping, throwing, and catching. These activities are crucial for enhancing muscular strength and overall physical fitness.

Moreover, the curriculum stresses the integration of physical activities and exercises into the daily routine of students, promoting regular physical activity and contributing to improved muscular strength over time. Participation in various sports and games is also encouraged, providing dynamic and engaging ways to develop muscular strength and physical skills. The inclusion of yoga and flexibility exercises further supports muscular strength, flexibility, and overall physical well-being.

Curriculum Structure in Context of Physical Fitness and Muscular Strength

- **Primary Level (Classes I-V):** Focuses on basic body awareness, fundamental movements, and the importance of hygiene and cleanliness. Activities include simple exercises, games, and movements that enhance neuromuscular coordination and basic motor skills.

- Secondary Level (Classes VI-X): Emphasizes physical fitness, team games, individual sports, and yoga. The curriculum includes activities to develop strength, flexibility, and endurance.
- Senior Secondary Level (Classes XI-XII): Focuses on advanced physical activities, sports, and fitness training. The curriculum is designed to improve physical fitness, promote a healthy lifestyle, and develop skills for specific sports.

As the Physical Education has proven significant consequences on muscular strength and overall fitness. Therefore, the need for this research is further underscored by the increasing prevalence of childhood obesity, and lifestyle-related illnesses, among Indian students. Effective physical education programs have the potential to counteract these trends by promoting physical activity, healthy habits, and resilience from a young age. Understanding how current PE practices impact students' muscular strength and activity levels will provide evidence-based recommendations for enhancing PE curricula.

Material and Methods

Participants

A total of 1000 (N = 500 girls) students were selected from 25 schools, consisting of 15 government and 10 private schools, across the Haryana province using a multistage cluster sampling method. Initially, schools were chosen to ensure representation from both government and private sectors, spanning various districts to capture a broad demographic. Within each selected school, students aged 12 to 16 were randomly selected, ensuring a balanced representation of different grades and genders, while excluding those with medical conditions or disabilities that could affect participation in physical education activities. Ethical approval was obtained, and written informed consent was secured from parents or guardians, along with student assent, ensuring confidentiality and anonymity throughout the study.

In order to ensure the implementation of physical education in Indian schools some additional point of qualitative information was also extracted from the school administration i.e., total number of teachers in school, physical education teachers in schools, total students and the students opted Physical Education as a subject. The schools were further categorized as per the physical education teachers recruited in the schools to differentiate muscular strength of school students.

Measurement of Hand Grip Strength

To measure hand grip strength, the CAMRY Digital Hand Dynamometer was used. The device was calibrated, and settings were adjusted for the participant's age and gender. The grip size was modified to ensure a comfortable fit for the participant's hand. Each participant was instructed to stand upright, with their arm at a right angle and elbow close to the body, maintaining a neutral wrist position.

Participants were asked to squeeze the dynamometer with maximum effort for at least 5 seconds. The maximum grip strength value was automatically displayed on the LCD screen, along with an indication of "weak," "normal," or "strong" based on the preset age and gender values. The test was repeated three times, with a brief rest period between trials, and the highest value was recorded for analysis. This procedure ensured a consistent and accurate assessment of hand grip strength among participants.

Statistical Application

The arithmetic mean, standard deviation, minimum and maximum values were used to construct reference standards for each age categories of boys and girls. One way analysis of variance (ANOVA) was used to differentiate the mean score of grip strength among the different strata. Further two-way MANOVA (multivariate analysis of variance) was employed as a statistical

tool to examine the effects of multiple independent variables on dependent variables simultaneously. It helps in determining whether there are any statistically significant differences between groups on a combination of dependent variables and whether the effects of independent variables are consistent across these variables. The two-way MANOVA used in this study assessed the impact of multiple factors—such as age, sex, number of physical education (PE) teachers, and duration of physical activity (PA)—on dominant handgrip strength, a measure of muscular strength. The SPSS version 26.0 (IBM Corp, 2017) was used to compute the statistical calculations. An adjacency network plot was created using Origin lab software (OriginLab Corporation, 2024) as a statistical tool to visually represent the correlation matrix among multiple variables, such as age, sex, number of physical education teachers, and physical activity duration. The plot illustrates the strength and direction of correlations through nodes (representing variables) and edges (lines connecting the nodes), where the thickness of the edges indicates the magnitude of the correlation.

Results

Table 1 References values of dominant hand grip strength for boys and girls in reference to their age

Age (Years)	Boys					Girls				
	N	Mean	SD	Min.	Max.	N	Mean	SD	Min.	Max.
12	100	21.84	4.80	12.98	37.95	100	19.11	3.81	8.72	30.05
13	100	24.82	5.21	13.85	37.23	100	22.71	4.46	12.80	37.86
14	100	29.21	7.00	15.44	47.76	100	23.69	4.70	12.71	34.87
15	100	33.27	7.19	17.52	56.02	100	24.56	5.22	12.35	39.50
16	100	38.42	7.08	19.43	63.20	100	25.59	5.08	13.98	38.68
Total	500	29.53	8.65	12.98	63.20	500	23.13	5.16	8.72	39.50

N = Number of students (Boys = 500, Girls = 500), SD = Standard deviation, Min. = Minimum, Max. = Maximum

The table 1 presents reference values for dominant hand grip strength in boys and girls across different age groups. For boys aged 12 to 16 years, grip strength increases steadily from 21.84 kg (SD = 4.80) at age 12 to 38.42 kg (SD = 7.08) at age 16. Similarly, for girls, grip strength ranges from 19.11 kg (SD = 3.81) at age 12 to 25.59 kg (SD = 5.08) at age 16. Overall, boys consistently exhibit higher grip strength compared to girls across all age groups. The standard deviations indicate variability within each age group, suggesting differing levels of strength among individuals. These findings underscore the developmental differences in grip strength between boys and girls throughout adolescence, which can be valuable for assessing physical fitness and health in this population.

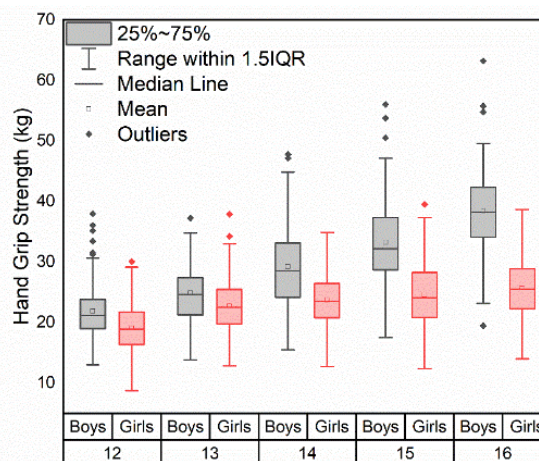


Figure 1 Box plot illustrating the mean, (bold horizontal midline), standard deviation, (upper and lower end of box) and 95% confidence interval (vertical lines attached to box) of different age groups in relation to their gender.

Table 2 Average, minimum and maximum teachers, and students' proportion in schools.

	Mean	Min	Max
Total Teachers in School	37	7	75
Physical Education Teacher in Schools	2	0	5
Total Students	597	157	1434
Student Selected Physical Education as a Subject	60	0	224

The data depicted in table 2 summarize the key information regarding the availability of the physical education teachers in proportion to the total number of teachers and students in the schools. On an average there are 37 teachers of different subjects were recruited in a school. Out of 37 most of the school have only 2 physical education teachers ranged from 0 to a maximum of 5 teachers in school settings. The percentage of students opted physical education as a subject is very low. Out of the school strength, 10% students have opted physical education. The mean value of student's strength was approximately 600 students in the school with two teachers of physical education. With this point, there is one teacher on every 300 students in context of physical education.

Table 3 Physical Education teacher and their Impact on Muscular Strength of Students

	Mean (kg)	SD	Minimum	Maximum
No Physical Education Teacher	20.07	4.76	10.99	28.97
One	25.29	7.19	8.72	48.85
Two	27.74	8.07	14.71	56.02
Three	27.00	7.71	12.98	55.75
Five Teachers	28.86	9.71	13.26	63.20
Total	26.32	7.80	8.72	63.20

The table 3 reveals an important insight into the availability of the number of physical education teacher and their impact on grip strength as an indicator of muscular strength of the students. It was observed that 3% schools had not been any physical education teacher and the value of grip strength of the students was also reported lowest in that schools. The muscular strength of the students is showing proportional relationship with the number of physical education teachers. The schools having maximum physical education teacher reported higher average grip strength. Another point of consideration was that, approximately 47% percent schools have only one physical education teacher. The cumulative percentage of one and two physical education teachers are 77% respectively.

Table 4 comparison of muscular strength among the schools have different number of physical education teachers

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2692.969	4	673.242	11.513	.000
Within Groups	58007.515	992	58.475		
Total	60700.485	996			

The analysis revealed significant differences in muscular strength among students from schools with varying numbers of physical education teachers, as indicated by the F-value of 11.513 and a significance level (Sig.) of .000. This suggests that the number of physical education teachers in a school may have a meaningful impact on the muscular strength of students, warranting further investigation into the role of teacher availability in physical education outcomes.

Table 5 Two-Way MANOVA of Dominant Handgrip Strength by Age, Sex, Number of PE Teachers, and Physical Activity Duration

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	ES
Corrected Model	35394.022 ^a	99	357.515	12.672	.000	.583
Intercept	244347.580	1	244347.580	8661.020	.000	.906
Age (Years)	6941.204	4	1735.301	61.509	.000	.215
Sex	3999.983	1	3999.983	141.781	.000	.136
PE Teacher	1067.576	4	266.894	9.460	.000	.040
PA Duration	279.772	3	93.257	3.306	.020	.011
Age × Sex	1934.092	4	483.523	17.139	.000	.071
Age × PE Teacher	821.541	16	51.346	1.820	.025	.031
Age × PA	334.893	12	27.908	.989	.457	.013
Sex × PE Teacher	91.153	3	30.384	1.077	.358	.004
Sex × PA	6.592	2	3.296	.117	.890	.000
PE Teacher × PA	113.040	3	37.680	1.336	.261	.004
Age × Sex × PE Teacher	783.462	12	65.288	2.314	.007	.030
Age × Sex × PA	252.951	8	31.619	1.121	.346	.010
Age × PE Teacher × PA	869.294	12	72.441	2.568	.002	.033
Sex × PE Teacher × PA	331.261	3	110.420	3.914	.009	.013
Age × Sex × PE Teacher × PA Duration	531.893	12	44.324	1.571	.094	.021
Error	25306.463	897	28.212			
Total	751815.277	997				
Corrected Total	60700.485	996				

a. R Squared = .583 (Adjusted R Squared = .537)

Factor: (Age: 12 to 16 Years; PE (Physical Education) Teacher: No Teacher, 1 teacher, 2 teachers, 3 teachers, 5 teachers; PA (Physical Activity) duration: 0-10 minutes, 10-20 minutes, 20-30 minutes, 30-40 minutes, 40-50 minutes)

In Table 5, the Two-Way MANOVA results for dominant handgrip strength reveal several significant effects with notable effect sizes. The overall model is highly significant ($F = 12.672$, $Sig. = .000$), with a substantial proportion of the variance explained ($R^2 = .583$, Adjusted $R^2 = .537$). Age has a strong effect on handgrip strength ($F = 61.509$, $Sig. = .000$), with a partial eta squared of .215, indicating a large effect size. Sex also significantly impacts handgrip strength ($F = 141.781$, $Sig. = .000$), with a partial eta squared of .136, reflecting a moderate effect size. The number of physical education (PE) teachers has a significant but smaller effect ($F = 9.460$, $Sig. = .000$), with a partial eta squared of .040, suggesting a small effect size. Physical activity duration also has a minor significant effect ($F = 3.306$, $Sig. = .020$), with a partial eta squared of .011, indicating a small effect size.

Interactions between factors provide further insights. The interaction between age and sex is significant ($F = 17.139$, $Sig. = .000$), with a partial eta squared of .071, suggesting a moderate effect size. The interaction between age and the number of PE teachers is also significant ($F = 1.820$, $Sig. = .025$), with a partial eta squared of .031, indicating a small effect size. The interaction of age, sex, and PE teachers is significant ($F = 2.314$, $Sig. = .007$), with a partial eta squared of .030, reflecting a small to moderate effect size. In contrast, the interaction between age, sex, and physical activity duration is not significant ($F = 1.121$, $Sig. = .346$). Interactions involving age, PE teachers, and physical activity duration ($F = 2.568$, $Sig. = .002$) and sex, PE teachers, and physical activity duration ($F = 3.914$, $Sig. = .009$) are significant, with partial eta squared values of .033 and .013, respectively.

.013 respectively, indicating small to moderate effect sizes. These findings highlight the complex interplay of factors influencing handgrip strength and emphasize the importance of considering both statistical significance and effect size in the analysis.

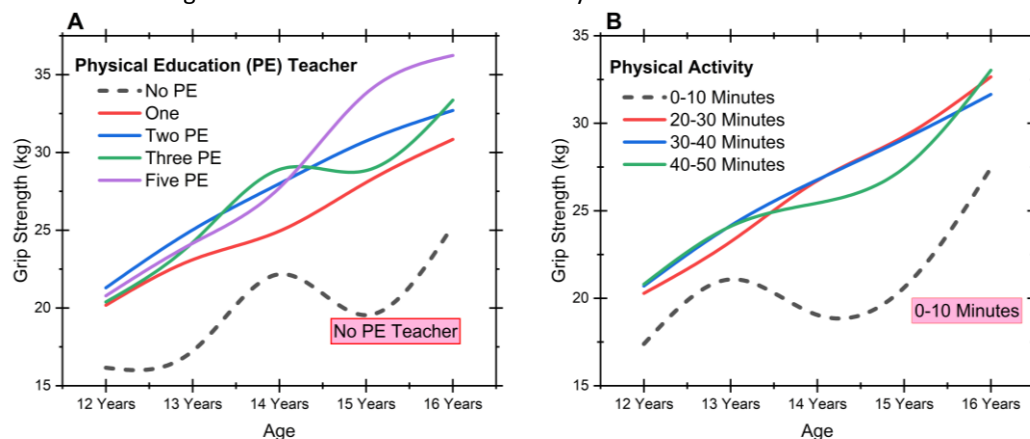


Figure 2 Line graph representing the mean score of student's hand grip strength between the schools having different number of PE teachers (A) and duration of physical activity (B). Dotted line indicating lowest muscular strength in relation to PE teacher and physical activity.

Discussion

The present study aimed to explore the effectiveness of physical education curriculum on students' muscular strength in Indian school settings. In order to accomplish the study, the existing curriculum of physical education implemented in schools has been thoroughly examined in terms of curriculum framework designed by NCERT (National Council of Educational Research and Training) and its implementation in the schools in terms of duration of physical activity during physical education classes, ratio of physical education teacher, number of physical education students and so on.

NCERT is the organization responsible to frame the curriculum of all subjects including physical education in Indian school settings. The curriculum developed by NCERT approach the different dimensions of student's development including awareness towards their environment, physical fitness and health, food and nutrition, social health, safety and security and vocational and leadership aspect, respectively. It was evident from the literature that successful implementation of physical education curriculum improves the muscular strength. A study conducted in Jammu and Kashmir in India reported significant improvement in grip strength in physical education students in comparison to their counterparts (Dar & Vijay, 2018). The curriculum ensures the physical activity (PA) levels of students. If the curriculum focusses more on theoretical or academic aspects rather than practical, it limits the physical activity of the students during schools' hours. The active participation in physical education classes is significantly associated with physical activity and sedentary behavior of the students (Silva et al., 2018). Another study investigates the impact of a healthy physical education curriculum model on the sports ability of Chinese senior high school students. Results from a 12-week quasi-experimental trial showed that students in the experimental group significantly improved their sports ability compared to those receiving traditional instruction, demonstrating the effectiveness of the healthy PE curriculum in promoting physical literacy (Shengting Dai et al., 2024). Similarly, the study conducted in Korea identified the importance of physical education curriculum. To design the framework of physical education curriculum a prior study was designed to explore the relationship between fundamental movement skills (FMSs) and health-related fitness (HRF) among first and second graders in South Korea, aiming to inform physical education program development. The findings indicated that higher scores in jumping and static balance were linked to improved muscular strength, cardiorespiratory endurance, and flexibility, highlighting the need to prioritize these skills in early

childhood physical education (Hailing Li & Jadeera Phaik Geok Cheong, 2023; Se-Won Park & Seung-Man Lee, 2024). It is sufficiently reported in the literature that physical education is an effective mean to increase the physical activity and muscular strength of the students. Another important aspect of the study was to explore the implementation of the physical education curriculum in the schools.

A healthy model of curriculum may be less effective until its proper implementation. The objectives of the model should be met after ensuring the sufficient implementation on the population. The effectiveness of the curriculum model of physical education developed by NCERT is approached after ensuring its implementation in the school settings. The present study extracts the various factors associated with the implementation of the curriculum. Grip strength was used as an indicator of muscular strength as well as a marker of implementation of physical education curriculum in school students. Various factors affecting muscular strength were assessed and reported thoroughly.

First, the reference values of grip strength were prepared in reference to the age ranged (Table1) i.e., 12 to 16 years for both sex. In a school setting, reference values for grip strength help assess the muscular strength of students in a standardized way. These values allow teachers and physical education instructors to identify students whose strength levels fall below the expected range for their age and gender, signaling potential developmental concerns or physical weaknesses that may need attention. Second, the total number of students, and physical education teacher have been extracted from the school database (Table 2). Various key points have been highlighted in the obtained data. For instance, the ratio of physical education teachers was one teacher per 300 students. 46.6% schools have only one physical education teacher. The implementation of physical education model is directly associated with the number of physical education teacher recruited in the schools. The schools are classified as per the number of physical education teachers and duration of physical activity, then muscular strength was compared among the strata. Both, number of physical education teacher and duration of physical activity significantly effects the muscular strength of the students. The schools who have no physical education teacher reported low grip strength among the students. Similarly, the students who involved less than 10 minutes in physical activity have significantly less grip strength compared to their counterparts (figure 4).

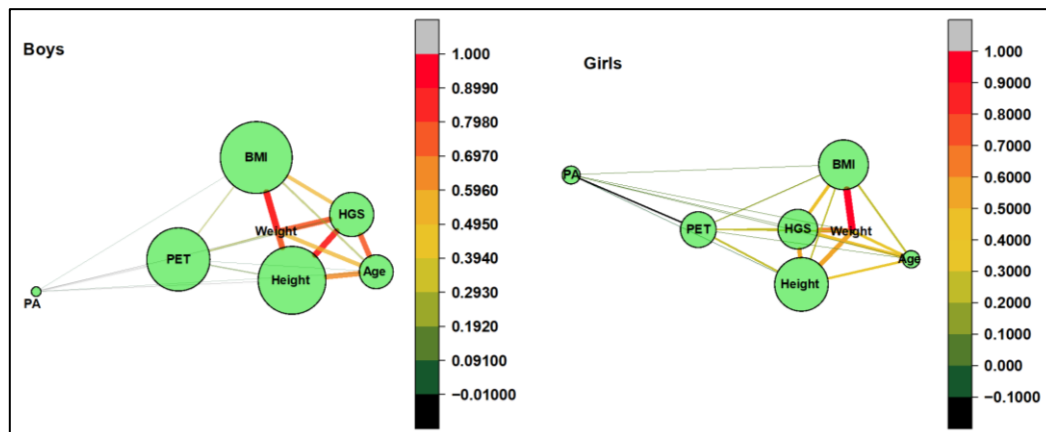


Figure 3 Square adjacency matrix illustrating network plot with direction and weight of correlation. Size of Edge and Nodes are fixed according to the degree (weight) of correlation among selected variables i.e., BMI = body mass index, HGS = hand grip strength, PET = number of physical education teacher in schools, PA = duration of physical activity

Limitations of the Study

The present study used hand grip strength as an indicator of muscular strength among school children. There are several factors which associated with the hand grip strength (HGS)

(Figure 5). Therefore, the nature of hand grip strength is necessary to write the final outcomes. A limitation of the study is that grip strength is influenced by various factors such as age, height, weight, and body mass index (BMI) (Taojin Xu et al., 2023). During the growth years, grip strength is predominantly associated with age, reflecting natural development and maturation (Michał Górecki et al., 2024). However, after reaching maturity, grip strength tends to be more closely linked to height, weight, and BMI (Zheng-Yang Xu et al., 2021). Therefore, when interpreting the reference values for grip strength, it is essential to consider these factors, as they can significantly impact the results. The lack of adjustment for these variables may limit the accuracy and generalizability of the findings, as they do not account for individual differences in physical characteristics that could influence grip strength.

Conclusion

The study concludes that the physical education curriculum implemented in schools is effective in enhancing the muscular strength of students. The curriculum, developed by NCERT, promotes physical fitness and health by integrating diverse physical activities into the school schedule. The findings demonstrate that students who actively participated in physical education classes shown higher muscular strength. However, the study also highlights that the curriculum's effectiveness relies on its proper implementation, emphasizing the need for adequate staffing and sufficient activity time to maximize the benefits for student health and fitness. Overall, the study supports the prioritization of physical education in schools as a valuable tool for enhancing children's muscular strength and promoting public health.

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