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RESEARCH ARTICLE

Exploring Strength Development in Year 6 Students Through a Combiend Gymnastics and Martial Arts Physical Education Unit

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Abstract

This study assessed upper body strength parameters among year 6 students during the third school term, focusing on a Physical Education (PE) lessons encompassing gymnastics and martial arts. 51 students (22 males and 28 females), aged between 11 and 13 years, participated in the study. Measurements were taken at the beginning and end of the unit, including height, seated height, wingspan, mass, arm circumference, maximum arm circumference, back extension, along with tests for 1-minute push-ups, 1-minute sit-ups, and hand grip dynamometry. A Paired Student T-Test revealed significant differences were observed in height, seated height, wingspan, maximum arm circumference, back extension, 1-minute push-ups, 1-minute sit-ups, and grip dynamometry for all participants. Male students exhibited significant differences in height, seated height, wingspan, 1-minute push-ups, and grip dynamometry, while female students demonstrated significant disparities in height, seated height, wingspan, maximum arm circumference, 1-minute sit-ups, and grip dynamometry. The findings suggest that participation in a PE unit focusing on gymnastics and martial arts can foster strength development in year 6 students. Notably, male students, despite being smaller and lighter than their female counterparts, consistently exhibited higher performance in the conducted tests, indicative of sexual dimorphism in strength capacity. Further exploration into the potential contributors to this sexual dimorphism, including hormonal variations, body composition disparities, and physiological responses to physical activity, is warranted to comprehensively elucidate strength development patterns in youths engaged in PE activities.

Keywords: Upper body strength, Pre-puberty students, School environment, School sports, Individual sports.

1. Introduction

Physical education (PE) is a cornerstone of the holistic development of school-aged children (Redublado et al., 2024), significantly impacting their physical health, mental resilience, and social skills (Moon et al., 2024). As children approach adolescence, especially during the critical developmental window of 11 to 13 years, the role of PE in enhancing strength and motor skills becomes increasingly vital. Recent studies highlight the trainable nature of strength, demonstrating its capacity for enhancement during childhood and puberty (Behm et al., 2017; Villa-González et al., 2024). Notably, research has shown that resistance training primarily elicits strength gains through neural adaptations, particularly in coordination, rather than muscle hypertrophy. The trajectory of isometric, static, and dynamic maximum strength typically shows a linear increase from childhood to around 13-14 years of age, followed by a rapid growth spurt during puberty (Carvalho, 1996). Figueiredo et al. (2009), emphasize puberty as the period marked by the most substantial increase in strength, highlighting the importance of targeted training to maximize the surge in testosterone, a key

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factor in these adaptations. According to Coelho e Silva et al., (2010), strength training in children can lead to an increase of 13 to 30%, largely due to enhanced neuromuscular activation rather than increased muscle mass. Carvalho's (1996) analysis indicates that pre- and early-pubertal children significantly improve muscle strength through various training methods, with gains predominantly resulting from functional enhancements in the nervous system, underscoring the complex nature of strength development in youth.

Handgrip strength is a key indicator of overall health and hand function in children (Kakaraparthi et al., 2023). Previous research by Fragoso et al. (2004) indicates that boys with more advanced skeletal ages have higher maximum handgrip strength compared to their less mature peers and suggests using regression models to predict handgrip strength during early pubertal stages. Similarly, Rama and Alves (2006) demonstrated increased maximum handgrip strength among young swimmers of both genders, with more pronounced effects in males. Carvalho (1996) highlights significant handgrip strength increases in youth that persist beyond school age and discusses factors affecting measurement reliability such as dynamometer type and test understanding. This same author notes rapid strength gains from childhood to puberty in both genders, with a post-puberty decline in boys and stability in girls, attributed to gender differences in body composition. Rodrigues (2000) further elucidates the linear evolution of maximum static handgrip strength with age, with the most substantial increases occurring at puberty. However, Rodrigues notes a subsequent decrease in percentage terms, leading to a plateau or regression in girls' handgrip strength values. According to Amo-Setién et al. (2020), grip strength is influenced by sex, age, handedness, nutritional status, and academic performance, with notable differences between males and females.

In boys, the strength of elbow flexors surpasses that of extensors across all age groups, with the extensor-flexor strength ratio at the elbow gradually diminishing with increasing age. Careful consideration is warranted when interpreting these relationships, given variations in muscle groups regarding maximum strength expression and the joint angle during measurement. Studies, such as those by Carvalho (1996), elucidate that strength exhibits a modest increase of approximately 27% up to peak height velocity (PHV), followed by a substantial surge of about 93% over the subsequent 3.5 years. Braga (2007) further supports this notion, demonstrating that children and adolescents can augment resistance strength in the upper limbs through structured training programs. The progression of pulling and bench press strength exhibits incremental advancements up to 11-12 years of age for both genders, consistently higher in boys. Puberty accentuates this development in both genders, with a more pronounced effect observed in males (Malina et al., 2007). Notably, this surge in strength corresponds to maturational aspects, particularly hormonal fluctuations favoring boys. Moreover, social and cultural factors may contribute to the decline in upper limb physical activity among girls. Contrary to popular belief, studies, including those cited by Carvalho (1996), suggest no significant gender-based disparities in gains, neither in maximum arm extension strength nor in leg extensions, indicating comparable training responses between genders for these muscle groups and movements. However, Rodrigues (2000) highlights a disparity in arm endurance strength, with boys seemingly benefitting from hormonal changes during the pubertal growth spurt, while girls may face relative disadvantages. Nevertheless, optimal phases for the development of this capacity may manifest during childhood, suggesting nuanced considerations regarding training interventions.

In a comprehensive investigation by Rama et al. (2006), assessing average abdominal strength among young swimmers using the 30-second sit-up test, notable findings emerged regarding gender-specific trends. While males exhibited no significant alterations in abdominal strength over time, a slight decline was discernible towards the end of adolescence. Conversely, females displayed a significant decrease in abdominal strength between the ages of 12 and 14 years. Throughout childhood to early adolescence, both boys and girls demonstrated an increase in the number of sit-up test performances per minute (Kaster et al., 2020). However, this upward trajectory plateaued in girls, while boys experienced a comparatively attenuated increase, particularly noticeable post-puberty (Malina et al., 2007). It's noteworthy that habitual physical activity levels and the quality of PE provision in school may introduce variability in these outcomes (Belton et al., 2014). A study by Braga (2007) highlighted the potential for children and adolescents to enhance abdominal endurance strength through targeted strength training interventions during PE classes. Furthermore, the efficacy of such programs extends beyond natural maturation-induced gains, highlighting their role in augmenting abdominal endurance strength

beyond physiological developmental trajectories. Rodrigues (2000) further delineates the dynamics of abdominal endurance strength, indicating that the most pronounced increases occur during childhood, persisting until the onset of puberty in both genders. Subsequently, while boys stabilize their abdominal strength levels, girls exhibit a decline, suggesting that pubertal transitions do not uniformly bolster abdominal strength levels. These insights underscore the nuanced interplay between developmental stages, gender-specific trajectories, and the modulatory effects of structured interventions on abdominal strength dynamics.

According the World Health Organization (WHO) children and adolescents aged 5-17 years should engage in at least 60 minutes of moderate-to-vigorous aerobic physical activity daily, include vigorous activities and muscle and bone strengthening exercises at least three times a week, and minimize sedentary behaviors, especially recreational screen time. Villa-González et al., (2023) study suggest that incorporating strength-building exercises into school programs can enhance muscular fitness in children, better preparing them for the physical demands of exercise and sports activities. Moreover, incorporating gymnastics (Feng & Lee, 2023) and martial arts (Stamenković et al., 2022) into PE lessons significantly contributes to strength development in young people. According to Stamenković et al., (2022) these activities not only boost muscular strength but also enhance flexibility, coordination, and overall physical fitness, while also improving students' strength endurance, muscular endurance, and core stability, which are essential for physical health and well-being. Therefore, integrating gymnastics and martial arts into PE curricula may provide students with a holistic approach to strength development, fostering lifelong habits of physical activity and fitness (Anderson et al., 2019; Moore et al., 2023).

Considering this, the primary aim of this research is to analyze the progression of handgrip strength, sit-ups and push-ups performance, back extension capability, and anthropometric measures among Year 6 students undergoing gymnastics and martial arts in PE lessons. This investigation seeks to ascertain whether notable distinctions exist between the data obtained from initial assessments and subsequent evaluations conducted post-intervention, after a full term of PE lessons. It is expected that students will experience significant improvements on the different performance indicators. By scrutinizing these multifaceted aspects of physical performance and morphological attributes, this study endeavors to contribute to the existing body of knowledge concerning the efficacy of integrated PE curricula in fostering comprehensive physical development among school-aged individuals.

2. Methods and Materials

2.1 Participants

The sample consisted of 51 students, aged between 11 and 13 years old, from a year 6 school in Portugal. Of these 51 students, 22 (43.1%) were male and 29 (56.9%) were female. In the 11-year-old age group, there were 33 students (64.7%), among whom 16 (31.4%) were male and 17 (33.3%) were female; in the 12-year-old age group, there were 16 students (31.4%), among whom 5 (9.8%) were male and 11 (21.6%) were female; and in the 13-year-old age group, there were 2 students (3.4%), 1 male (1.95%) and 1 female (1.95%) (Table 1). It is also worth noting that each class has only one weekly block of lessons (90 minutes) on the same day, meaning 45 minutes less than usual for this level of education.

Table 1. *Distribution of the sample by age and gender.*

	Male	Female	Total
11 years old	16 = 31.4%	17 = 33.3%	33 = 64.7%
12 years old	5 = 9.8%	11 = 21.6%	16 = 31.4%
13 years old	1 = 1.95%	1 = 1.95%	2 = 3.9%
Total	22 = 43.1%	29 = 56.9%	51 = 100%

To contextualise, in term 1, the sports taught during PE lessons were basketball and volleyball, while in the term 2, students were taught orienteering, football, and athletics.The data was collected during term 3, where the focus in PE was Gymnastics and Martial Arts (Table 2).

Table 2. *Distribution of sports across the academic year*

Term 1	Term 2	Term 3
Basketball Volleyball	Orienteering Football Athletics	Gymnastic Martial Arts

During the Gymnastic and Martial Arts unit, it was adopted a circuit training/stations methodology. Therefore, upon a general warm-up, that included running at different speed, joint mobilization and stretchings, students were placed in different stations with a specific task. In total, four stations were set in the sports hall, and students rotate stations at every 10 mins, allowing to be focused in small groups and increase work rate. Every lesson finished with a cool-down and relaxation activity.

Informed consent was gained from parents/legal guardians; assent consent was provided by students; and gatekeeper consent from the school and PE Teacher before the study began. The experimental protocol and investigation were approved by the local Institutional Research Ethics Committee and performed according to the Helsinki Declaration's ethical standards.

2.2 Data Collection

We opted to perform tests using the Grip Dynamometer, 1-min sit-ups, 1-min push-ups, and Back Extensions because, in addition to the students being familiar with them from their execution at the beginning of the academic year, these tests have internationally recognized protocols and results through Fitnessgram (USA) and Eurofit (France). Four tests were chosen to ensure some fidelity in the results and not to take up too much class time from the students' curriculum. These tests were selected to understand the effects of gymnastics and martial arts on upper body strength, as these subjects require significant strength in this body region. All testing was completed at the beginning and end of the PE unit, with approximately 10 weeks between testing sessions

The Grip Dynamometer test was chosen to assess the effects of the evolution of maximum grip strength, which has a direct relationship with many technical gestures in gymnastics and martial arts. The 1-min push-up were performed to assess the evolution of upper body strength, which is crucial for the correct practice of gymnastics and martial arts. Back Extensions and 1-min sit-ups tests were conducted to determine the effect of this didactic unit on the strength of this body region. Additionally, some anthropometric measurements were taken from the students, including height, sitting height, wingspan, body mass, arm circumference, and maximum arm circumference, to better assess the obtained results, thus allowing for a comparison between strength development, or lack thereof, and body composition.

2.3 Procedures

After a general warm-up, the order of the tests was as follows: 1-min sit-ups test (Fitnessgram, USA), 1-min push-up test (Fitnessgram, USA), grip dynamometer test (78010, Lafayette Intrument Company, USA), back extension test, height, seated height, wingspan (2-meter meauring tape), body mass (840, Seca Bella, Germany), brachial circumference, and maximum brachial circumference (1-meter flexible measuring tape). It is also noteworthy that, between tests, students had time to fully recover, with the duration of this recovery period varying for each student. During the remaining time of each data collection session, students engaged in PE lesson activities as usual.

2.3.1 Height

To measure height, the tape was vertically positioned and affixed to the wall from the floor. Each participant was instructed to stand barefoot against the wall, with the body touching from the heels to the head, facing forward, and to take a deep breath at the moment of measurement. The measurement was taken from the reference plane of the floor to the vertex.

2.3.2 Seated Height

Each participant was asked to sit on the table, with their back in contact with the wall, from the lumbar region to the head. Following a deep breath, the measurement was taken from the table to the vertex

2.3.3 Wingspan

Each participant was asked to stand barefoot against the wall, with arms extended horizontally, parallel to the ground and perpendicular to the bodyThe measurement was taken from one dactylion to the other.

2.3.4 Mass

Each participant was asked to stand barefoot on the scale with their gaze directed forward.

2.3.5 Arm circumference

Each participant was asked to relax their dominant arm along the body and remove any clothing covering the arm. The measurement was taken at the midpoint of the arm's length.

2.3.6 Maximum Arm Circumference

Following the measurement of arm cicumference, each participant was asked to place their arm horizontally, parallel to the ground and perpendicular to the body, with the forearm vertical, parallel to the body and perpendicular to the ground with the palm facing up.

The measurement was taken at the midpoint of the arm's length following a maximal contaction.

2.3.7 Back Extension Test

The participants lay prone on a gymnastics mat, with their hands under their thighs in extension. The participants were asked to lift their head and upper back, maintaining the position long enough for the measurement to be taken. The measurement was taken from the ground to the chin. Two attempts were completed, and the best one was recorded.

2.3.8 1-Min Push-Up Test

Participants worked in pairs to complete the 1-min push-up test. During the test, each participant was required to complete as many press-ups as possible, whilst maintain a cadenc of 20 reps·min^{-1}. A press-up was deemed to be successful if the elbow angle was 90º during flexion. The test ended when the participant could not perform the push-ups correctly (three corrections were allowed), experienced pain, or reached volitional exhaustion.

2.3.9 1-Min Sit-Ups Test

Participants worked in pairs to complete the 1-min push-up test. The starting position consisted of the participant lying supine on a gymnastics mat, with their knees flexed at 90º, feet slightly apart and supported on the ground. The participant's arms and hands were kept extended by the sides, palms touching the mat and touching one end of a gymanstics band (76 x 11.43 cm). The participant raised their back until their fingers touched the other end of the band and then lowered their back until they returned to the starting position. Repetitions were performed at a cadence of 3 reps·s^{-1} (Fitnessgram, USA) The tests ended when the participant reached volitional exhaustion, or to a maximum of 80 repetitions.

2.3.10. Hand Grip Dynamometer Test

Grip strength was measured from the participant's dominant arm positioned parallel to the body, perpendicular to the ground, with the forearm perpendicular, parallel to the ground. The participant then gripped the dynamometer and performed a maximal contraction, closing the hand, with the best of two attempts recorded.

2.4 Statistical Analysis

Shapiro–Wilk test showed normal data distribution. Therefore, we proceeded to analyse it using the Paired Student T-Test (version 29.0.2, SPSS, IBM Corp, USA). This test was chosen because the research is conducted on the same population at two different time points, with the advantage of having the same participants, intra-participants, or related designs, thus eliminating individual differences between experimental conditions. Statistical significance was set at $p < 0.05$.

3. Results

Through the analysis of Table 3, we can observe statistically significant differences in both data collection moments across the entire sample, regarding height, seated height, wingspan, maximum arm circumference, back extension, 1-min push-ups, 1-min sit-ups, and grip dynamometry. The differences in these variables consisted of an increase in their measurements from the first to the second data collection, except for back extension, where a decrease was observed. In the remaining variables, body mass and arm circumference, no significant changes were found in the two data collection moments. Upon analyzing the data, we also found a correlation between all the variables studied at both time points.

Table 3. *Results of the Paired Student T-Test for the entire sample.*

N = 51	Pre-Unit Testing		Post Unit Testing				
	Mean	SD	Mean	SD	Correlation	t	sig.
Height (cm)	152.6	8.7	153.8	8.9	0.994	-8.480	0.000
Seated Height (cm)	77.8	4.9	78.4	5.0	0.993	-6.880	0.000
Wingspan (cm)	150.6	9.9	152.4	9.9	0.994	-12.696	0.000
Weight (kg)	48.4	12.1	48.4	11.6	0.989	-0.160	0.873
Arm circunference (cm)	24.3	3.1	24.3	3.0	0.968	-0.544	0.589
Maximun arm circumference (cm)	26.0	3.4	25.5	2.9	0.951	2.466	0.017
Back extension (cm)	36.0	5.0	34.9	5.5	0.733	2.029	0.048
1-min push-ups (#)	18.5	9.0	22.1	12.6	0.778	-3.256	0.002
1-min sit-ups (#)	48.2	23.2	60.6	23.2	0.629	-4.430	0.000
Grip Dynamometer (kg)	18.2	5.1	23.3	5.5	0.765	-10.070	0.000

3.1 Results for Male Students

Through the analysis of Table 4, we can observe that for the male students, there are no statistically significant differences in the variables of body mass, arm circumference, maximum arm circumference, back extension, and 1-min sit-ups. In all other variables, namely height, seated height, wingspan, 1-min push-ups, and grip dynamometry, there are statistically significant differences between the two data collection moments. The differences in these variables consisted of an increase in their measurements from the first to the second data collection. After analyzing the data for the male students, we also found a correlation between all studied variables at both time points.

Table 4. *Results of the Paired Student T-Test for male students*

N = 22	Pre-Unit Testing		Post Unit Testing				
	Mean	SD	Mean	SD	Correlation	t	sig.
Height (cm)	151.4	8.0	152.5	8.2	0.994	-5.805	0.000
Seated Height (cm)	76.3	4.5	77.0	4.7	0.991	-4.805	0.000
Wingspan (cm)	149.0	10.0	150.8	9.9	0.995	-8.595	0.000
Weight (kg)	46.0	9.3	45.7	8.7	0.961	0.535	0.598
Arm circunference (cm)	23.9	2.7	24.0	2.6	0.971	-0.816	0.424
Maximun arm circumference (cm)	25.9	3.1	25.7	2.6	0.934	0.849	0.406
Back extension (cm)	35.3	4.9	34.3	4.5	0.546	1.068	0.298
1-min push-ups (#)	22	11.1	28.3	15.5	0.762	-2.917	0.008
1-min sit-ups (#)	63.0	21.7	67.9	21.6	0.631	-1.215	0.238
Grip Dynamometer (kg)	19.3	4.5	23.9	5.2	0.614	-5.001	0.000

3.2 Results for Female Students

Through the analysis of Table 5, it can be observed that, for the female students, regarding the variables height, seated height, wingspan, maximum arm circumference, 1-min sit-ups, and grip dynamometry, there are statistically significant differences between the two data collection moments. The differences in these variables consisted of an increase in their measurements from the first to the second data collection, except for the maximum arm circumference, where a decrease was recorded. Regarding the variables body mass, arm circumference, back extension, and 1-min push-ups, there are no statistically significant differences. Upon analyzing the data for the female gender, it was also noted that there was a correlation between all the variables studied at the two time points.

Table 5. *Results of the Paired Student T-Test for female students.*

N = 29	Pre-Unit Testing		Post Unit Testing				
	Mean	SD	Mean	SD	Correlation	t	sig.
Height (cm)	153.6	9.2	154.7	9.4	0.994	-6.134	0.000
Seated Height (cm)	79.0	4.9	79.5	5.0	0.994	-4.944	0.000
Wingspan (cm)	151.8	9.8	153.6	9.8	0.994	-9.214	0.000
Weight (kg)	50.1	13.7	50.4	13.3	0.998	-1.774	0.087
Arm circunference (cm)	24.6	3.3	24.6	3.2	0.966	-0.108	0.915
Maximun arm circumference (cm)	25.9	3.6	25.4	3.0	0.963	2.556	0.016
Back extension (cm)	36.5	5.1	35.3	6.2	0.835	1.826	0.079
1-min push-ups (#)	15.8	5.9	17.4	7.0	0.687	-1.677	0.105
1-min sit-ups (#)	36.9	17.3	55.0	23.1	0.578	-5.053	0.000
Grip Dynamometer (kg)	17.3	5.4	22.9	5.8	0.851	-9.741	0.000

4. Discussion

The primary aim of this investigation was to scrutinize the developmental trajectories of hand grip strength, 1-min sit-up, 1-min push-up, back extension proficiency, and pertinent anthropometric parameters among year 6 students participating in a structured PE unit integrating gymnastics and martial arts. Upon comprehensive analysis, statistically significant differences were observed within the entire sample concerning variables such as height, sitting height, wingspan, maximum arm circumference, back extension, push-ups, sit-ups, and grip dynamometry between the initial and subsequent assessments. However, no statistically significant differences were

observed for body mass and arm circumference. Subgroup analysis delineated pronounced differences among male participants, particularly in variables encompassing height, seated height, wingspan, push-up performance, and hand grip dynamometry, with significant differences observed between initial and follow-up measurements. Conversely, no statistically significant variances were noted in weight, arm circumference, maximum arm circumference, back extension, and sit-up performance. Similarly, within the female cohort, statistically significant differences were observed in height, seated height, wingspan, maximum arm circumference, sit-up performance, and hand grip dynamometry between the initial and subsequent evaluations. Conversely, variables such as body mass, arm circumference, back extension, and push-up capacity exhibited no statistically significant differences over the study period. These findings shed light on the nuanced developmental trajectories of physical performance and morphological attributes among year 6 students, highlightingthe potential efficacy of integrated PE interventions in fostering comprehensive physical development.

Upon scrutiny of the acquired data, it is evident that a discernible enhancement in strength parameters was observed throughout the duration of the gymnastics and martial arts unit, aligning with the anticipated outcomes attributable to the inherent demands of the respective sports modalities. Noteworthy is the fact that despite the provision of only one 90-minute session per week (45 minutes fewer than the conventional duration observed in comparable educational settings), observable gains in strength were achieved. This outlines a pivotal aspect in the periodization framework governing the systematic cultivation of physical capabilities over the academic year.

The findings also demonstrate the feasibility of developing the investigated strength parameters even with just one weekly class, highlighting the potential impact of prioritizing and adequately scheduling PE within school curricula. Implementing a regimen consisting of three sessions per week, spaced across non-consecutive days, could yield even more favorable outcomes, aligning with established recommendations for promoting optimal health and fostering comprehensive physical development among youth (Moon et al., 2024). Such an approach holds promise for nurturing habits conducive to sustained physical activity and well-being into adulthood.

Our findings align with previous research by Carvalho (1996), Rodrigues (2000), and Braga (2007), indicating that girls demonstrate superior anthropometric characteristics compared to boys. Across the 6-week intervention period, both genders exhibited significant increases in height (approximately 1 cm), seated height (approximately 0.5 cm), and wingspan (approximately 1.5 cm), consistent with patterns of growth velocity highlighted by Malina (2007). These changes suggest that some individuals may have been nearing peak height velocity (PHV) during the study period. In addition to the structured strength training incorporated into PE sessions and the practice of relevant sports, the observed anthropometric shifts likely contributed to the development of strength parameters. Consequently, coaches and educators are encouraged to prioritize strength training regimens tailored to the specific needs of their athletes and students, thereby facilitating ongoing physical evolution and enhancement.

No significant differences were observed in body mass between the two data collection time points, consistent with findings reported by Braga (2007). This lack of change may be attributed to the period of inactivity preceding the initial data collection, coinciding with the Easter vacation. During this time, reduced physical activity levels and potential dietary indulgences, characteristic of cultural norms, could have contributed to temporary weight gain. However, as the PE classes progressed and strength parameters improved, it's plausible that some of the accrued fat mass was subsequently reduced, potentially offsetting any increase in body mass with a corresponding enhancement in lean mass.

Arm circumference remained relatively stable throughout the study period, exhibiting no statistically significant changes. Conversely, a minor decrease in maximum arm circumference was observed between the initial and subsequent data collection points. This finding aligns with previous research by Faigenbaum et al., (2003) and Behm et al., (2017), supporting the notion that strength gains in pre-pubescent individuals primarily stem from neuromuscular adaptations and skill acquisition, rather than significant increases in muscle mass.

Alongside the observed enhancements in upper body strength, a notable decline in back flexibility, particularly evident in the back extension assessment, was observed, exhibiting statistically significant differences between the initial and subsequent assessments. This decrease in flexibility may be attributed to a potential oversight in incorporating

adequate flexibility training alongside strength development initiatives, a concern highlighted by Belton et al., (2014). It underscores the significance of a balanced training regimen encompassing both strength and flexibility components to foster comprehensive physical development in children and adolescents.

In the assessment of 1-minute push-up performance, a notable increase in repetitions was observed, particularly among males, with a significant rise of approximately six repetitions, and a more modest increase of around two repetitions for females. This trend may be influenced by cultural factors, as highlighted by Carvalho (1996), who noted a slower progression of upper limb strength among rural girls. Consistently, boys exhibited higher push-up scores compared to girls at both assessment points, demonstrating superior progression rates. This finding aligns with previous research by Rodrigues (2000), utilizing isometric suspension, which reported higher push-up values among boys. The findings of this study are congruent with the assertions of Carvalho (1996) and Braga (2007), emphasizing the potential for the development of resistance strength in children and adolescents.

In the evaluation of the 1-minute sit-ups test, notable improvements were observed in both males and females. Across genders, there was an average increase of approximately 12 repetitions from the initial to the subsequent data collection. Interestingly, females exhibited a more pronounced enhancement in performance, with an approximate rise of 19 repetitions compared to a modest increase of about 4 repetitions among males. This disparity in evolution can be attributed to the initially higher abdominal strength values in boys, observed in both data collection periods. These findings resonate with the insights provided by Faigenbaum et al., (2003) and Kaster et al., (2020), suggesting that children and adolescents can augment their abdominal endurance strength through targeted stimulation and developmental challenges, as evidenced by the outcomes of this study.

In the progression of maximum grip dynamometry strength, both genders exhibited a comparable augmentation in values between the initial and subsequent data collection sessions. Males consistently demonstrated slightly higher maximum strength levels at both assessment points compared to females, in line with established observations regarding sexual dimorphism (Amo-Setién et al., 2020; Kakaraparthi et al., 2023). This trend aligns with previous research findings. For instance, Carvalho (1996), reported increases in lower limb maximum strength among male adolescents following a three-times-weekly regimen. Similarly, Rodrigues (2000), documented enhanced upper limb maximum strength in pre-pubescent youths after an 8-week training intervention. Moreover, investigations by Braga (2007), focusing on grip dynamometry strength in pre-pubescent school-age individuals, concluded that notable gains in maximum strength could be achieved within a short timeframe, consistent with the outcomes observed in our study.

Despite the valuable insights obtained from this study, it is imperative to acknowledge certain limitations. Within our sample, it is plausible that the development of strength parameters may have been influenced by extracurricular activities beyond the scope of PE classes, as some students may engage in school sports or pursue athletic endeavors outside of the educational environment. Moreover, the utilization of materials that may not offer the same level of reliability as those found in laboratory settings. Due to resource constraints, and the reliance on peer observation for tallying repetitions in the 1-minute push-up and sit-up tests, owing to time limitations, represent potential constraints. As a prospective avenue for further inquiry, exploring the impact of varying frequencies and durations of weekly classes on the progression of diverse strength parameters throughout an academic year could yield valuable insights. Such investigations could also delve into gender disparities, variations in instructional units, and temporal considerations within the school calendar. In future research endeavors, prioritizing the use of instruments with enhanced fidelity and, where feasible, individually quantifying repetitions performed by each participant, provided that sufficient time resources permit, would enhance the robustness of findings.

In light of the parameters set within a structured PE curriculum spanning six weeks, our findings substantiate the efficacy of targeted interventions in bolstering resistance strength indices among year 6 students. Through weekly 90-minute sessions focusing on gymnastics and martial arts, participants demonstrated notable enhancements in metrics such as push-up and sit-up performance, alongside augmented maximum hand dynamometry strength. Furthermore, concurrent with these strength gains, individuals experienced significant growth in stature, as evidenced by increases in height and seated

height, coupled with expansions in wingspan and maximum arm circumference. While body mass and arm circumference exhibited a tendency to maintain stable values throughout the intervention period, it is noteworthy that back extension values experienced a marginal, albeit statistically non-significant decline. This nuanced understanding highlights the multifaceted interplay between structured PE activities and physiological adaptations, prompting further inquiry into optimizing curricular frameworks for comprehensive physical development among youth.

5. Conclusion

Our analysis reveals that female year 6 students exhibit superior anthropometric measurements compared to their male counterparts, boasting higher values in height, seated height, wingspan, and weight. Interestingly, both genders displayed similar relative increases in height, seated height, and wingspan over the assessment period. While females showed a slight, non-significant increase in weight, males experienced a marginal, non-significant decrease. Notably, arm circumference and maximum arm circumference remained unchanged across genders, with a negligible, non-significant decline observed in back extension. Despite the apparent physical advantages of female students, male counterparts demonstrated higher strength values across all tests, notwithstanding their smaller stature and lower weight. Specifically, male students outperformed females in sit-ups, push-ups, and hand grip dynamometry tests, with notable increases observed in all metrics. However, the increases in push-up values for females were statistically non-significant, mirroring the non-significant enhancements in sit-up scores among males. Notably, females exhibited relatively higher increases in push-up and hand grip dynamometry tests, while males demonstrated greater improvements in push-up tests. These findings shed light on gender-specific nuances in strength development among year 6 students and underscore the importance of tailored interventions to optimize physical performance across diverse populations.

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