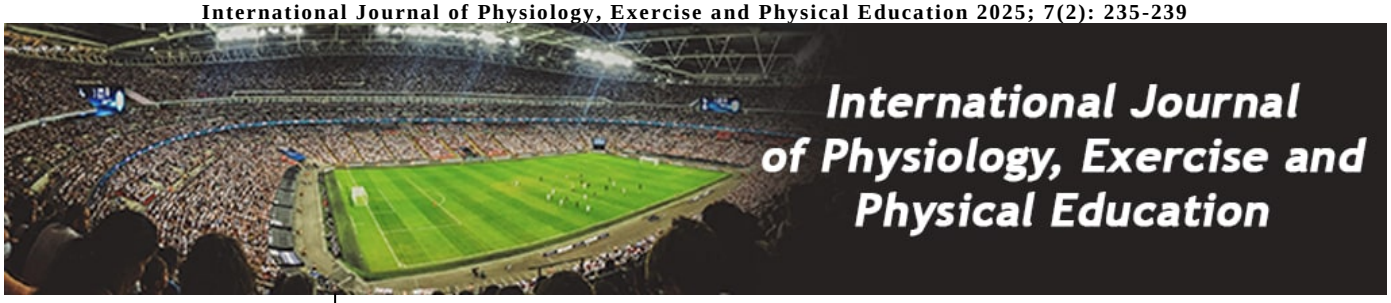

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Changes in physical fitness indices among five 12-14-year-old female swimmers: A two-year longitudinal analysis

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Abstract
Objective: This study tracked changes in multiple physical fitness indices among five female swimmers (aged 12-14) over the 2023-2024 period to evaluate trends in physical development.
Methods: This employed a longitudinal research design featuring nine measurement sessions. The assessed indices included shoulder flexibility (cm), the sit-and-reach test, Counter Movement Jump height (CMJ, cm), sit-ups (reps) (40 pace/min), 3-Repetition Maximum (3-RM) for Squat and Bench Press, vital capacity (L), and times (s) for the 2,000 m mixed style and 3,000 m freestyle swimming tests. Data collection procedures for strength and conditioning followed the NSCA methodology. Statistical analysis utilized descriptive statistics, line charts, and the Friedman test (non-parametric repeated measures ANOVA).
Results: Performance in the strength and conditioning tests (sit-ups, bench press, squat, vital capacity, sit-and-reach, CMJ) and specific swimming tests (2,000 m mixed style and 3,000 m freestyle) generally showed an upward trend across sessions, with shoulder flexibility markedly improving. Friedman tests revealed significant differences across measurement times for all variables ($\chi 2 \approx 32$-40; $p<0.001$), accompanied by large effect sizes (Kendall's $W \approx 0.8$-1.0). Wilcoxon comparisons between 2023 and 2024 indicated a slower rate of improvement in 2024; however, these differences were not statistically significant at the 0.05 level. Rapid gains occurred primarily early in 2023, followed by flatter curves suggesting the presence of plateaus.
Conclusion: The two-year training program resulted in substantial improvements in muscular strength, flexibility, and endurance. The rate of improvement peaked in 2023 and decelerated in 2024, indicating potential plateaus and the necessity to adjust the current training regimen.

Keywords: young swimmers, fitness development, longitudinal analysis, pubertal age

Introduction

1.1 General context

Swimming is a fundamental sport requiring optimisation of muscular strength, cardiorespiratory endurance, joint flexibility and technical skills. In sports science, monitoring the physical development of young athletes is key to planning effective training and predicting potential. Ages 12-14 mark the pubertal period in girls, a time when the body grows rapidly and is highly responsive to training stimuli (Aylin Kim Post, 2024). During this window bone mineral accumulation peaks; physical activity helps consolidate musculoskeletal tissue (Gómez-Bruton, 2016) [10]

1.2 Related research

Recent systematic reviews indicate that youth swimming performance is primarily determined by factors such as muscle strength, power, lean body mass, and both anaerobic and aerobic capacities (Todd Price, 2024).Intervention studies conducted on athletes aged 10-12 have shown that following a structured training regimen, subjects exhibit reduced body mass and Body Mass Index (BMI) (Mariusz Kuberski, 2024) [11], which reflects improved body composition. Specifically, dry-land training programs have been demonstrated to enhance functional strength and contribute to improved in-water swimming performance (Kutlukhan Yagmur Ozeker).Pilot studies comparing 12-13-year-old swimmers to non-athlete counterparts report that swimmers possess superior endurance, speed, strength,

and flexibility (Paulina Rogowsk, 2023) [12]. Furthermore, authors frequently recommend the integration of swimming with strength training to optimize performance gains (Line Fone, 2022) [13]. Conversely, some researchers posit that strength training should be intensified after the age of 13, suggesting that initiating such training too early may be less efficacious (Demirkan E, 2023) [14]. Physiologically, strength training during the 13-14 age bracket is understood to particularly promote the development of anaerobic abilities and speed (Andrei R. Vorontsov, 2015) [15].

1.3 Research gap

Most previous work focuses on a few indices or uses cross-sectional designs. Longitudinal monitoring of multiple fitness indices in the same group across repeated measurements to detect trends and plateaus is rare. In Viet nam, literature on female swimmers aged 12-14 is particularly scarce, so training remains largely experience-driven. Thus, longitudinal research providing empirical data is needed.

1.4 Objective and research questions

This study aims to fill the gap by following five female swimmers aged 12-14 across nine measurement sessions over two years to analyse changes in fitness indices. The main objective is to assess improvement trends, identify plateaus or declines and compare progress between 2023 and 2024. Research questions: (1) How do the indices (shoulder flexibility, sit-and-reach, CMJ jump, sit-ups, squat, bench press, vital capacity, 2 000 m and 3 000 m swimming) change across nine sessions? (2) Are there plateaus or declines? (3) Does improvement in 2024 differ from 2023?

2 Methods

2.1 Participants

Five young female swimmers from a junior team were followed. At baseline they were aged 12-14 years; mean height was 156.85 ± 5.94 cm and body mass 50.42 ± 4.81 kg.

2.2 Design and procedure

The longitudinal study consisted of nine measurement sessions: session 1 (early 2023), session 2 (late March 2023), session 3 (late June 2023), session 4 (late September 2023), session 5 (mid-December 2023), session 6 (late March 2024), session 7 (late June 2024), session 8 (late September 2024) and session 9 (early December 2024). Strength and Conditioning tests were measured according to NSCA methods: shoulder flexibility, sit-and-reach, CMJ jump, sit-ups, squat, bench press, vital capacity; CMJ vertical jump using the Smart Jump system; sit-ups (number of repetitions in 40 pace per 60 s); squat and bench press 1-RM using Eleiko weights; vital capacity using a spirometer; and time for 2 000 m mixed style (s) and 3 000 m freestyle (s) using a stopwatch.

2.3 Data analysis

Statistical analyses were conducted in Python (pandas and SciPy) and comprised three main steps:

1. **Descriptive statistics:** data from each athlete at each session were aggregated, and the mean and standard deviation were computed. The mean provides a typical value for the group at a given time, while the standard deviation reflects variability among athletes.
2. **Visualisation:** line charts were drawn for each index to observe temporal trends. Each point on the line indicates the mean at a session; connecting lines enable identification of periods of rapid increase, plateau or decline.
3. **Hypothesis testing:** given the small sample size (n = 5) and potential non-normality, non-parametric tests were used:

- **Friedman test:** a non-parametric analogue of repeated-measures ANOVA. Instead of assuming normality, it ranks data to evaluate whether there are significant differences across sessions. The Friedman statistic follows a χ^2 distribution with (k - 1) degrees of freedom (here, k = 9 sessions). We also computed Kendall's W, an effect size ranging from 0 (no consistency) to 1 (perfect consistency). Higher W indicates similar patterns of change across athletes.
- **Wilcoxon signed-rank test:** used to compare mean differences between two phases (2023 comprising five sessions and 2024 comprising four sessions) and between specific pairs of sessions (e.g., session 1 vs session 5; session 6 vs session 9). This test ranks the magnitudes and signs of paired differences and is suitable for small samples with non-normal data. A significance level $\alpha = 0.05$ was applied.

3 Results

3.1 Descriptive statistics

Table 1 presents the means and standard deviations at each session. Most strength and endurance indices increase gradually, and shoulder flexibility improves.

Table 1: Means and standard deviations at each session

Metric	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9
Shoulder flexibility (cm)	46.00 ± 17.8	43.30 ± 15.8	40.60 ± 13.9	37.89 ± 12	35.64 ± 10.5	32.49 ± 8.77	29.79 ± 7.58	27.08 ± 6.90	25.28 ± 6.83
Sit-and-reach (cm)	61.95 ± 7.67	62.51 ± 7.66	62.90 ± 7.69	63.39 ± 7.67	64.00 ± 7.66	64.33 ± 7.70	64.79 ± 7.79	65.42 ± 7.88	65.68 ± 7.92
CMJ (cm)	35.22 ± 3.18	35.44 ± 3.13	35.66 ± 3.07	35.87 ± 3.02	36.14 ± 3.03	36.45 ± 3.02	36.75 ± 3.04	37.04 ± 3.07	37.24 ± 3.10
Sit-ups (reps)	39.20 ± 10.6	41.40 ± 10.0	43.60 ± 10.0	46.00 ± 10.8	47.08 ± 10.4	49.67 ± 10.2	51.80 ± 10.5	53.53 ± 10.5	55.16 ± 10.4
Squat (kg)	51.40 ± 13.8	51.64 ± 13.8	51.87 ± 13.8	52.11 ± 13.8	52.38 ± 13.7	52.68 ± 13.7	53.02 ± 13.5	53.24 ± 13.6	53.45 ± 13.5
Bench press (kg)	30.40 ± 8.53	31.22 ± 7.81	32.01 ± 7.16	32.85 ± 6.52	33.67 ± 5.89	34.48 ± 5.58	35.24 ± 5.34	36.14 ± 5.16	36.66 ± 5.18
Vital capacity (L)	3.00 ± 0.48	3.03 ± 0.50	3.05 ± 0.51	3.08 ± 0.53	3.11 ± 0.54	3.20 ± 0.52	3.24 ± 0.54	3.27 ± 0.55	3.31 ± 0.56
2 000 m mixed style (s)	1851.20 ± 73.18	1845.70 ± 70.26	1840.20 ± 67.38	1834.70 ± 64.53	1829.20 ± 61.72	1823.70 ± 58.97	1818.20 ± 56.26	1812.70 ± 53.63	1807.20 ± 51.06
3 000 m freestyle (s)	2459.20 ± 122.53	2450.63 ± 123.43	2442.27 ± 124.28	2432.70 ± 125.89	2424.53 ± 126.73	2420.27 ± 125.36	2414.20 ± 125.21	2402.07 ± 128.18	2394.39 ± 128.86

Table 2: The change (percentage) of physical indicators between the 1st and 9th times

Metric	Shoulder flexibility (cm)	Sit-and-reach (cm)	CMJ vertical jump (cm)	Sit-ups (reps)	Squat (kg)	Bench press (kg)	Vital capacity (L)	2 000 m mixed style (s)	3 000 m freestyle (s)
Change SS 1 and SS 9 (%)	-45.0	6	5.7	40.7	4	20.6	10.3	-2.4	-2.6

3.2 Trend charts

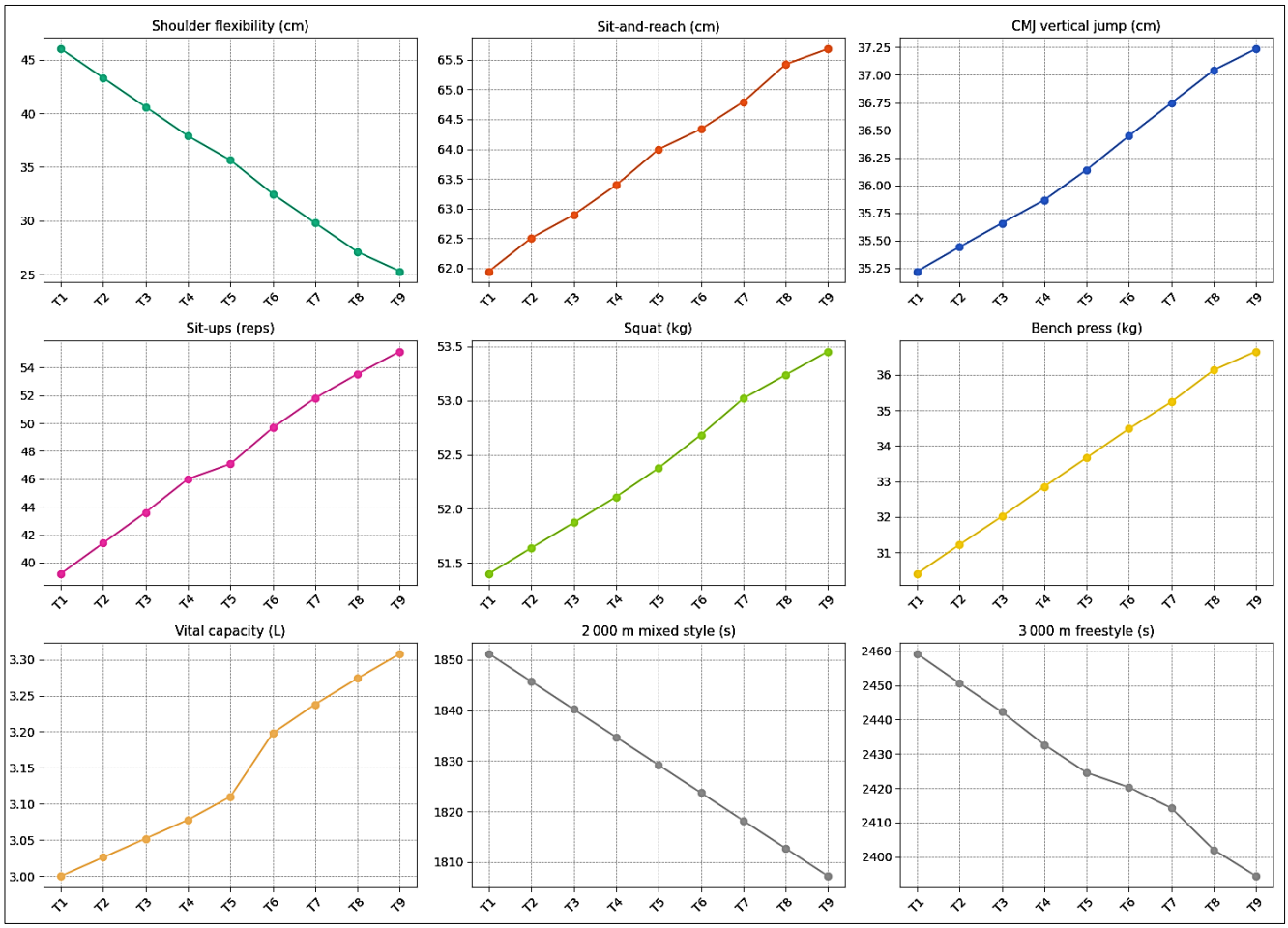

Fig 1: Illustrates trends for selected indices:

Description of the trends

Shoulder flexibility (cm): Mean values improves from roughly 46 cm to 25 cm across the nine sessions. In this test a lower number indicates greater flexibility, so the downward trend shows a substantial improvement, especially in the early sessions.

Sit-and-reach (cm) and CMJ (cm): Both indicators rise steadily. Sit-and-reach increases from about 62 cm to 66 cm, reflecting better flexibility of the lower back and hamstrings. CMJ jump height grows slightly but consistently, indicating improved leg power.

Sit-ups (reps), Squat (kg) and Bench press (kg): These strength measures increase noticeably. Sit-ups climb from around 39 to 55 repetitions in 30 seconds; squat and bench press loads climb modestly but steadily, demonstrating the athletes' growing muscular strength.

Vital capacity (L): This respiratory measure rises from about 3.0 L to 3.3 L, signalling enhanced lung capacity and oxygen uptake important for endurance events.

2 000 m mixed style (s) and 3 000 m freestyle (s): Times for these runs decrease progressively (from ~1851 s to 1807 s and from ~2459 s to 2394 s), showing that the swimmers can cover the distances more quickly. The larger time reductions in the first year and the gentler decreases later imply a plateau after an initial period of rapid improvement.

3.3 Friedman test results

Table 2: Summarises the Friedman test results for each index. All indices differ significantly across sessions ($p<0.001$). Kendall's W values range from 0.80 (bench press) to nearly 1.0, indicating strong consistency in the direction of change across athletes.

Metric	χ^2	p-value	Kendall W
Shoulder flexibility (cm)	40.00	0.000003	1.00
Sit-and-reach (cm)	40.00	0.000003	1.00
CMJ (cm)	40.00	0.000003	1.00
Sit-ups (reps)	39.88	0.000003	0.997
Squat (kg)	40.00	0.000003	1.00
Bench press (kg)	32.00	0.000093	0.80
Vital capacity (L)	39.36	0.000004	0.98
2 000 m mixed style (s)	40.00	0.000003	1.00
3 000 m freestyle (s)	38.88	0.000005	0.97

3.4 Comparison between 2023 and 2024

To evaluate annual differences, means from the five 2023 sessions were compared with the four 2024 sessions using Wilcoxon tests. Although all indices continued to improve in 2024, p-values (~0.06) were above the 0.05 threshold; thus the rate of improvement slowed and was not significantly different from 2023. The flattening curves in Figure 1 reflect this plateau.

4 Discussion

4.1 Interpretation of findings

The longitudinal analysis demonstrates marked improvements in strength and endurance indices. High χ^2 and very small p-values in the Friedman tests confirm systematic changes rather than random fluctuations. Kendall's W near 1 for most variables suggests that athletes shared similar patterns of improvement.

The trend charts reveal non-uniform progression: early 2023 saw rapid gains, especially in sit-ups and bench press, while increases slowed in 2024, suggesting a plateau—a phenomenon consistent with the idea that after an initial period of adaptation the body reaches a performance ceiling (Andrei R. Vorontsov, 2015) [15]. Meanwhile, standard deviations decline slightly for some variables (e.g., bench press SD drops from 8.53 kg to 5.18 kg), indicating increased homogeneity within the group a positive outcome of team-based training.

The continuous decline in shoulder flexibility contrasts with other indices. This may result from a programme emphasising strength without sufficient stretching, or from increased muscle mass reducing range of motion. Previous research highlights the importance of flexibility for swimming performance, especially in 12-13-year-old female athletes (Paulina Rogowsk, 2023) [12]. Therefore the reduction in flexibility warrants attention and suggests incorporating stretching and yoga into training.

4.2 Comparison with previous literature

These results support evidence that strength and power are key determinants of youth swimming performance (Todd Price, 2024). Dry-land training has been shown to improve strength and swim performance (Kutlukhan Yagmur Ozeker), (Line Fone, 2022) [13], consistent with the observed gains in sit-ups and bench press. Though some authors caution against early strength training (Erkan Demirkan, 2023) [14], our findings show improvements occur but slow after the first year, supporting the need for progressive overload and varied exercises as athletes approach their limits.

5 Conclusion

This study followed five female swimmers aged 12-14 years over two years and nine measurement sessions. Results show substantial improvements in strength (sit-ups, squat, bench press), Flexibility and endurance (vital capacity, swimming specific test), especially in 2023; improvements slowed in 2024, suggesting plateaus. Friedman tests confirmed significant changes with very large effect sizes. These findings highlight the value of continuous monitoring of multiple indices and suggest adjustments to training programmes to sustain progress and balance strength, endurance and flexibility (Todd Price, 2024) (Paulina Rogowsk, 2023) [12].

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