

Physical Fitness Profile of Intensive Junior Badminton Athletes: A Descriptive Analysis of Strength, Endurance, Speed, Agility, and Flexibility Components

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ABSTRACT (English)

Background: Physical condition is the main foundation of athlete performance in badminton, which simultaneously demands speed, agility, strength, endurance, and flexibility. **Research Objectives:** This study aims to describe the physical condition profile of intensive junior badminton athletes at PB Trisula Surabaya. **Methods:** The research design was descriptive quantitative with 10 intensive junior athletes (6 male, 4 female) aged 10–15 years selected through purposive sampling. Measurements were conducted on December 4, 2025 at Sport Center Club Surabaya using the following instruments: sit-up, push-up, Multistage Fitness Test (MFT), 30-meter sprint, T-Test, and V Sit & Reach. Data were analyzed descriptively using established conversion norms. **Results:** Results showed that abdominal muscle strength and agility were categorized as excellent (mean 36.50 repetitions and 12.08 seconds, respectively), speed was categorized as good (mean 3.98 seconds), while arm strength, aerobic endurance (mean VO₂Max 35.71 mL/kg/min), and flexibility were categorized as poor to very poor. **Conclusion:** These findings indicate the need for a more comprehensive and balanced training program, particularly in improving upper body strength, aerobic capacity, and athlete flexibility.

Keywords: Physical Condition; Badminton; Fitness Test; Intensive Junior Athlete; PB Trisula Surabaya.

ABSTRAK (Bahasa Indonesia)

Latar Belakang: Kondisi fisik merupakan fondasi utama performa atlet dalam cabang olahraga bulutangkis yang menuntut kecepatan, kelincahan, kekuatan, daya tahan, dan kelentukan secara simultan. **Tujuan Penelitian:** Penelitian ini bertujuan untuk mendeskripsikan profil kondisi fisik atlet bulutangkis intensif usia muda PB Trisula Surabaya. **Metode:** Jenis penelitian adalah deskriptif kuantitatif dengan subjek 10 atlet intensif usia muda (6 putra, 4 putri) berusia 10–15 tahun yang dipilih melalui teknik purposive sampling. Pengukuran dilakukan pada 4 Desember 2025 di Sport Center Club Surabaya menggunakan instrumen: sit-

up, push-up, Multistage Fitness Test (MFT), sprint 30 meter, T-Test, dan V Sit & Reach. Data dianalisis secara deskriptif menggunakan norma konversi yang berlaku. **Hasil:** Hasil menunjukkan bahwa kekuatan otot perut dan kelincahan berada pada kategori baik sekali (rerata 36,50 repetisi dan 12,08 detik), kecepatan berada pada kategori baik (rerata 3,98 detik), sedangkan kekuatan otot lengan, daya tahan aerobik ($VO_2\text{Max}$ rerata 35,71 ml/kg/menit), dan kelentukan berada pada kategori kurang hingga kurang sekali. **Kesimpulan:** Temuan ini mengindikasikan perlunya program latihan yang lebih komprehensif dan seimbang, khususnya pada peningkatan kekuatan upper body, kapasitas aerobik, dan fleksibilitas atlet.

Kata kunci: Kondisi Fisik; Bulutangkis; Tes Kebugaran; Atlet Intensif Usia Muda; PB Trisula Surabaya

INTRODUCTION

Badminton is one of the most popular sports in Indonesia and dominates the international sports scene (Prakoso et al., 2022). This sport is characterized by complex gameplay, as it demands physical, technical, tactical, and mental skills simultaneously. In the context of developing young athletes, systematic and structured physical assessments serve as the foundation for designing effective and efficient (Prasetyo et al., 2024).

Physical condition is one of the key factors determining an athlete's success in competition. Without optimal physical condition, an athlete's technical and tactical abilities cannot be fully maximized on the field (Bompa & Buzzichelli, 2019). Through standardized testing and measurement processes, coaches can monitor athletes' progress, identify areas for improvement, and adjust training loads to meet each athlete's individual needs (Till et al., 2018).

Modern badminton is characterized by high intensity with limited rest intervals between rallies (Abian-Vicen et al., 2013). This style of play requires athletes to possess a balanced combination of speed, agility, cardiorespiratory endurance, muscle strength, and joint flexibility (Hidayat & Wiriawan, 2023). Various studies indicate that footwork and explosive changes of direction are characteristic features of movement in badminton (Fernandez-Fernandez et al., 2022).

In Indonesia, badminton development is carried out through various training channels, one of which is through sports clubs (Badminton Associations/PB) located in various cities. PB Trisula Surabaya is one of the clubs actively training young athletes through intensive training programs. However, comprehensive physical assessments have not always been conducted systematically and regularly; therefore, research is needed to provide an accurate and standardized physical profile (Irham & Purnomo, 2022).

Assessing physical condition through a series of standardized tests provides valid and reliable empirical data on athletes' actual physical abilities. Some commonly used test instruments in badminton include: (1) Sit-ups and Push-ups to measure core and upper body strength; (2) the Multistage Fitness Test (MFT) or Bleep Test to measure aerobic capacity ($VO_2\text{Max}$); (3) the 30-meter sprint to measure linear speed; (4) T-test to measure agility; and (5) V-Sit & Reach to measure flexibility (Özer et al., 2025).

Research on the physical profiles of badminton athletes has been extensively conducted at various levels. (saputra & Purnomo, 2021) found that female athletes from KONI Sidoarjo exhibited weaknesses in endurance and flexibility. Meanwhile, (Hidayat & Wiriawan, 2023) reported that male athletes from PB Gemilang Surabaya exhibited a disparity between good speed and low aerobic endurance. A similar phenomenon was also found in various clubs across Indonesia, revealing a common pattern: a lack of endurance training and upper-body strength training among young athletes (Irham & Purnomo, 2022).

Age is also a key factor in understanding the physical profile of young athletes. Between the ages of 10 and 15, athletes are in a highly dynamic phase of motor development (Bompa & Buzzichelli, 2019). Appropriate training periodization during this phase will determine the athlete's long-term physical capacity (Israj et al., 2025). Therefore, physical profile data at this age are invaluable as a baseline for designing long-term training programs.

Core strength is known to play a vital role in badminton performance. Research (Widiyanto et al., 2025) indicates that good core strength significantly contributes to the efficiency of energy transfer from the lower body to the upper body during a smash. Similarly, high agility has been shown to positively correlate with the effectiveness of footwork in responding to the shuttlecock from various angles on the court (Solanki & Gill, 2021).

Aerobic capacity, as measured by $VO_2\text{Max}$, is a key indicator of an athlete's endurance (Xie, 2016). Badminton is an intermittent sport; however, at the high-competition level, match duration can reach 60–90 minutes, making adequate aerobic capacity essential for maintaining consistent performance in the second and third sets (Ihsan et al., 2024). The average $VO_2\text{Max}$ value considered ideal for junior badminton athletes ranges from 43–52 ml/kg/minute (Abian-Vicen et al., 2013).

Flexibility is often an overlooked component in badminton training programs (Mitsalina & Widiyanto, 2018). In fact, good flexibility not only increases joint range of motion but also serves as a preventive factor against musculoskeletal injuries commonly experienced by badminton athletes, such as ankle, knee, and shoulder injuries (Widiyanto et al., 2025).

Several recent studies have also highlighted the importance of a multicomponent approach in evaluating athletes' physical condition (Wee et al., 2019). Studies that measure only one or two physical components are considered to provide an incomplete picture and may lead to misleading training decisions (Liu & He, 2025). Therefore, this study employs an approach that simultaneously assesses the five primary physical components.

Based on this background, there is a lack of information regarding the physical profiles of young badminton athletes in city-level development clubs in Indonesia, particularly at PB Trisula Surabaya (Pamungkas et al., 2022). This study is important to address this gap and provide empirical insights for the development of training programs for young badminton athletes (Angga, 2019).

Based on the background described above, this study aims to: (1) describe the physical condition profiles of the junior badminton athletes at PB Trisula Surabaya in terms of strength, endurance, speed, agility, and flexibility; (2) identify which physical components fall into the “good” category and which still need improvement; and (3) provide data-driven recommendations for developing a more balanced and effective training program.

This study is expected to make a twofold contribution: theoretically, as an academic reference in the field of badminton testing and measurement; and practically, as a guide for coaches and club management in designing more structured, data-driven, and sustainable athlete development programs (Bompa & Buzzichelli, 2019).

METHOD

Design

This study employs a quantitative descriptive method using a survey, testing, and measurement approach. The study design is cross-sectional, meaning measurements were taken once at the same time for all subjects. The objective is to obtain an objective and comprehensive picture of the athletes' physical condition based on the results of standardized measurement instruments.

Participants

The study subjects were 10 intensive junior badminton athletes from PB Trisula Surabaya, selected using purposive sampling. The inclusion criteria were: (1) enrolled in the club's intensive training program; (2) regularly attending training sessions at least three times per week; and (3) not currently injured at the time of testing. The subjects consisted of 6 male athletes and 4 female athletes aged 10–15 years.

Instruments and data measurements

Physical fitness was assessed in this study using standardized sports testing instruments. Speed was measured via a 30-meter sprint test recorded using a stopwatch. Agility was evaluated using the T-Test by recording the time it took athletes to traverse a "T"-shaped course. Strength components were measured via sit-ups (abdominal muscles) and push-ups (arm/shoulder muscles) based on the maximum number of repetitions achieved within 60 seconds. To measure body flexibility, the V-Sit & Reach test was used, where the maximum hand reach was recorded in centimeters. Finally, cardiovascular endurance was measured using the Multistage Fitness Test (MFT/Bleep Test) by converting the achievement of the final level and shuttle run into an estimated VO2Max value (ml/kg/min).

Intervention Procedure

Data collection was conducted during a single two-hour testing session. The test sequence was designed to minimize the effects of fatigue on the measurement results. Prior to the test, athletes underwent a 15-minute structured warm-up. Each athlete was given one practice attempt before the actual test, except for the MFT test. Data collection was performed by five examiners. To ensure measurement consistency and eliminate inter-rater variability, each examiner was assigned to a dedicated testing station throughout the session (e.g., one specific examiner operated the stopwatch for the sprint test, while another managed the V-Sit & Reach measurement). Furthermore, all examiners underwent a standardized training session prior to data collection to harmonize stopwatch operation techniques, visual sighting angles, and measurement alignment procedures.

Data analysis

Collected data were analyzed descriptively using Microsoft Excel to determine measures of central tendency and dispersion, specifically the minimum, maximum, mean ($\bar{x}$), and standard deviation (SD) for all demographic and physical test parameters. Standard deviation was computed to evaluate data variability across the heterogeneous sample age range (10–15 years) and gender distribution. Raw individual performance scores were categorized into five performance levels: Excellent, Good, Fair, Poor, and Very Poor. Classification was performed using age- and sex-specific normative evaluation standards adapted from established sports fitness measurement protocols (Widiastuti, 2010; Dr. Albertus Fenanlampir & Faruq, 2015; Ismaryati, 2008). The age- and gender-stratified cut-off norms utilized for data categorization are detailed in Table 2 (Normative Classification Criteria).

RESULTS

Table 1. Anthropometric Characteristics and BMI Profile of Research Participants (N=10)

No	Athlete's Initials	Age (years)	Gender	Height (cm)	Weight (kg)	BMI (kg/m ²)
1	MFZ	13	BOYS	153	36	15.38
2	JAC	13	BOYS	166	50	18.14
3	WF	13	BOYS	168	54	19.13
4	JCG	13	BOYS	160	59	23.05
5	GKS	11	BOYS	143	42	20.54
6	CWS	10	GIRLS	145	32	15.22
7	KA	15	GIRLS	164	55	20.45
8	PSS	15	GIRLS	156	52	21.37
9	VGG	13	GIRLS	152	50	21.64
10	A	11	GIRLS	135	38	20.85

Summary	Mean $\pm$ SD	12.70 $\pm$ 1.64	6 BOYS/ 4 GIRLS	154.20 $\pm$ 10.79	46.80 $\pm$ 9.14	19.58 $\pm$ 2.62
	Min – Max	10-15	-	135 – 168	32 – 59	15.22 – 23.05

This study involved 10 intensive badminton athletes from PB Trisula Surabaya (6 male, 4 female) aged between 10 and 15 years (12.70 $\pm$ 1.64 years). Anthropometric measurements revealed a mean height of 154.20 $\pm$ 10.79 cm (range: 135–168 cm) and a mean body weight of 46.80 $\pm$ 9.14 kg (range: 32–59 kg). Body Mass Index (BMI) was calculated to establish baseline somatic characteristics, yielding an average of 19.58 $\pm$ 2.62 kg/m² (range: 15.22 - 23.05 kg/m²), which places the majority of participants within the normal age-adjusted physical growth spectrum. Anthropometric parameters were included to contextualize physical test performance, as weight-bearing assessments (e.g., push-ups, sprint, agility, and MFT) are directly influenced by body mass and physique leverage. Specifically, aerobic capacity (VO₂Max) measured via MFT is expressed relative to body mass (mL/kg/min), making body weight a critical physiological denominator in cardiorespiratory output. Furthermore, variations in height and limb length contribute to movement leverage during flexibility (V-Sit & Reach) and agility (T-Test) execution.

Table 2. Age- and Sex-Specific Normative Classification Criteria for Physical Fitness Tests

Adapted from (Widiastuti, 2010 ; Dr. Albertus Fenanlampir & Faruq, 2015 ; Ismaryati, 2008)

Test Parameter	Age & Gender Group	Poor	Very Poor	Fair	Good	Excellent
Sit-Up (reps/60s)	Boys (10-12 years)	≤ 15	16-19	20-25	26-30	≥ 31
	Boys (13-15 years)	≤ 19	20-25	26-32	33-38	≥ 39
	Girls (10-12 years)	≤ 13	14-17	18-22	23-27	≥ 28
	Girls (13-15 years)	≤ 15	16-20	21-27	28-33	≥ 34
Push-Up (reps/60s)	Boys (10-12 years)	≤ 11	12-15	16-20	21-25	≥ 26
	Boys (13-15 years)	≤ 14	15-19	20-26	27-32	≥ 33
	Girls (10-12 years)	≤ 9	10-13	14-18	19-23	≥ 24
	Girls (13-15 years)	≤ 11	12-16	17-22	23-27	≥ 28
VO ₂ Max (MFT) (mL/kg/min)	Boys (10-12 years)	< 33.0	33.0-36.4	36.5-41.0	41.1-46.0	≥ 46.1
	Boys (13-15 years)	< 35.0	35.0-38.3	38.4-45.1	45.2-50.9	≥ 51.0
	Girls (10-12 years)	< 30.0	30.0-33.4	33.5-37.9	38.0-42.9	≥ 43.0
	Girls (13-15 years)	< 31.0	31.0-34.9	35.0-38.9	39.0-43.9	≥ 44.0
30m Sprint (seconds)	Boys (10-12 years)	> 5.20	4.81-5.20	4.41-4.80	4.01-4.40	≤ 4.00
	Boys (13-15 years)	> 4.80	4.41-4.80	4.01-4.40	3.71-4.00	≤ 3.70
	Girls (10-12 years)	> 5.50	5.01-5.50	4.61-5.00	4.21-4.60	≤ 4.20
	Girls (13-15 years)	> 5.20	4.71-5.20	4.31-4.70	3.91-4.30	≤ 3.90
T-Test (seconds)	Boys (10-12 years)	> 13.50	12.81-13.50	12.11-12.80	11.41-12.10	≤ 11.40
	Girls (10-12 years)	> 14.00	13.21-14.00	12.41-13.20	11.61-12.40	≤ 11.60
V-Sit & Reach (cm)	Boys (10-12 years)	≤ 5.0	5.1-9.0	9.1-13.0	13.1-17.0	≥ 17.1
	Girls (10-12 years)	≤ 8.0	8.1-12.0	12.1-15.0	15.1-18.0	≥ 18.1

Table 2 presents the age- and sex-stratified normative classification standards utilized to evaluate raw test performance. Raw physical performance scores were converted into five standardized performance categories (Very Poor, Poor, Fair, Good, and Excellent) based on validated protocols adapted from (Widiastuti, 2010; Dr. Albertus Fenanlampir & Faruq, 2015; Ismaryati, 2008). These age- and sex-specific cut-

offs account for biological maturation and physiological differences across the 10–15 year age range and both sexes.

Table 3. Sit-Up Test Results (Abdominal Muscle Strength)

No	Athlete's Initials	60-Second Test Results (repetitions)	Category
1	MFZ	42	Very Good
2	JAC	37	Very Good
3	WF	36	Very Good
4	JCG	44	Very Good
5	GKS	34	Very Good
6	CWS	30	Very Good
7	KA	44	Very Good
8	PSS	41	Very Good
9	VGG	26	Fair
10	A	31	Very Good
Summary	Mean ± SD	36.50 ± 6.26	Very Good
	Min – Max	26-44	-

The 60-second sit-up test results assessing abdominal muscle endurance are detailed in Table 3. Individual scores ranged from 26 to 44 repetitions, yielding a mean performance of 36.50 ± 6.26 repetitions. Based on age- and sex-specific norms, the overall core endurance of PB Trisula Surabaya athletes falls into the "Very Good" category, with 90% of participants individually achieving a Very Good performance rating.

Table 4. Push-Up Test Results (Arm/Shoulder Muscle Strength)

No	Athlete's Initials	60-Second Test Results (Repetitions)	Category
1	MFZ	10	Very Poor
2	JAC	10	Very Poor
3	WF	17	Very Poor
4	JCG	14	Very Poor
5	GKS	15	Very Poor
6	CWS	11	Very Poor
7	KA	18	Poor
8	PSS	25	Good
9	VGG	21	Fair
10	A	17	Very Poor
Summary	Mean ± SD	15.80 ± 4.87	Very Poor
	Min – Max	10-25	-

Table 4 illustrates upper-body strength evaluated through the 60-second push-up test. Performance scores ranged from a minimum of 10 to a maximum of 25 repetitions, with a cohort mean of 15.80 ± 4.87 repetitions. This mean score categorizes the athletes' arm and shoulder muscle endurance as "Very Poor", revealing a substantial deficit in relative upper-body strength across the sample.

Table 5. MFT Test Results / Aerobic Endurance (VO₂Max)

No	Athlete's Initials	VO ₂ Max Result (mL/kg/min)	Category
1	MFZ	44.3	Good
2	JAC	41.9	Fair
3	WF	36.8	Poor
4	JCG	37.1	Poor

5	GKS	32.5	Very Poor
6	CWS	34.0	Very Poor
7	KA	31.4	Very Poor
8	PSS	31.4	Very Poor
9	VGG	34.0	Very Poor
10	A	33.7	Very Poor
Summary	Mean $\pm$ SD	35.71 $\pm$ 4.38	Poor
	Min – Max	31.40-44.30	-

Aerobic capacity (VO₂Max) estimated via the Multistage Fitness Test (MFT) is presented in Table 5. Estimated values ranged from 31.40 to 44.30 mL/kg/min, resulting in a mean relative aerobic endurance of 35.71 $\pm$ 4.38 mL/kg/min. Overall, cardiorespiratory endurance falls into the "Poor" category, with 60% of athletes demonstrating a Very Poor rating.

Table 6. 30-Meter Sprint Test Results

No	Athlete's Initials	Test Results (seconds)	Category
1	MFZ	3.82	Good
2	JAC	3.79	Good
3	WF	4.03	Fair
4	JCG	3.64	Very Good
5	GKS	4.02	Fair
6	CWS	3.98	Good
7	KA	3.88	Good
8	PSS	4.23	Fair
9	VGG	3.94	Good
10	A	4.48	Poor
Summary	Mean $\pm$ SD	3.98 $\pm$ 0.24	Good
	Min – Max	3.64-4.48	-

Table 6 summarizes short-distance linear speed assessed through the 30-meter sprint test. Completion times ranged from 3.64 seconds (fastest) to 4.48 seconds (slowest), with a cohort mean of 3.98 $\pm$ 0.24 seconds. Based on the normative criteria, the linear acceleration ability of the athletes is classified in the "Good" category.

Table 7. T-Test Results (Agility)

No	Athlete's Initials	Test Results (seconds)	Category
1	MFZ	11.75	Very Good
2	JAC	11.03	Very Good
3	WF	13.25	Poor
4	JCG	11.81	Very Good
5	GKS	12.72	Fair
6	CWS	12.69	Fair
7	KA	11.37	Very Good
8	PSS	10.94	Very Good
9	VGG	12.25	Good
10	A	12.97	Fair
Summary	Mean $\pm$ SD	12.08 $\pm$ 0.82	Very Good
	Min – Max	10.94-13.25	-

Agility performance and directional change speed measured via the T-Test are displayed in Table 7. Test completion times ranged from 10.94 to 13.25 seconds, achieving a mean agility score of 12.08 $\pm$ 0.82 seconds.

This mean time confirms that the dynamic footwork agility of PB Trisula Surabaya athletes falls into the "Very Good" overall category.

Table 8. V-Sit & Reach Test Results (Flexibility)

No	Athlete's Initials	Test Results (cm)	Category
1	MFZ	-3	Very Poor
2	JAC	16	Very Good
3	WF	14	Very Good
4	JCG	7	Very Poor
5	GKS	4	Very Poor
6	CWS	-3	Very Poor
7	KA	20	Very Good
8	PSS	19	Very Good
9	VGG	12	Fair
10	A	16	Very Good
Summary	Mean $\pm$ SD	10.20 $\pm$ 8.53	Poor
	Min – Max	-3.00-20.00	-

Table 8 outlines hamstring and lower-back flexibility measured using the V-Sit & Reach test. Reach values demonstrated considerable variability (SD = 8.53), ranging from -3.00 cm to 20.00 cm, with a mean reach of 10.20 $\pm$ 8.53 cm. Based on age-adjusted norms, the overall flexibility profile of the athletes falls into the "Poor" category.

Table 9. Descriptive Statistics of the Physical Fitness Test for Athletes of PB Trisula Surabaya Athletes (N=10)

Physical Components	Test Instrument (Unit)	Lowest Score (Min)	Highest Score (Max)	Mean	Standard Deviation (SD)	Mean $\pm$ SD	Overall Category
Abdominal Muscle Strength	Sit-ups (Repetitions)	26	44	36.50	6.26	36.50 $\pm$ 6.26	Very Good
Arm/Shoulder Strength	Push-ups (Repetitions)	10	25	15.80	4.87	15.80 $\pm$ 4.87	Very Poor
Aerobic Endurance	MFT/Bleep Test (mL/kg/min)	31.4	44.3	35.71	4.38	35.71 $\pm$ 4.38	Poor
Speed	30-meter sprint (seconds)*	4.48	3.64	3.98	0.24	3.98 $\pm$ 0.24	Good
Agility	T-Test (Seconds)*	13.25	10.94	12.08	0.82	12.08 $\pm$ 0.82	Very Good
Flexibility	V Sit & Reach (cm)	-3	20	10.20	8.53	10.20 $\pm$ 8.53	Poor

*Note: In time-based tests (30-meter sprint and T-test), lower time values represent superior performance.

Table 9 synthesizes the descriptive statistics (Min, Max, Mean, SD, and Overall Category) across all six measured physical fitness parameters. The consolidated data highlight a clear performance imbalance: the athletes demonstrated strong capabilities in agility (12.08 $\pm$ 0.82 s, Very Good), core strength (36.50 $\pm$ 6.26 reps, Very Good), and sprint speed (3.98 $\pm$ 0.24 s, Good), but exhibited marked deficiencies in upper-body strength (15.80 $\pm$ 4.87 reps, Very Poor), aerobic endurance (35.71 $\pm$ 4.38 mL/kg/min, Poor), and trunk flexibility (10.20 $\pm$ 8.53 cm, Poor).

DISCUSSION

The results of this study reveal a heterogeneous physical profile among young athletes at PB Trisula Surabaya, reflecting developmental disparities across physical fitness components. A primary finding is the sharp contrast between excellent core strength and significantly deficient upper-body strength. While specific training logs or program content were not directly audited in this study, this imbalance may plausibly reflect typical training emphases in junior badminton clubs. Specifically, routine court sessions often prioritize dynamic footwork, multi-directional agility, and core-stabilizing movements, whereas structured upper-body resistance training may be less systematically integrated into daily practices. A comparable physical imbalance was similarly observed by (Hidayat & Wiriawan, 2023) in junior athletes from PB Gemilang Surabaya, who suggested that technique-oriented court drills naturally stimulate lower-body and core adaptations more robustly than upper-body muscular strength unless supplementary resistance protocols are introduced.

The aerobic endurance component (average $VO_2\text{Max}$ of 35.71 ml/kg/min) revealed concerning results, with 60% of the athletes falling into the "Very Poor" category. This value is far below the ideal $VO_2\text{Max}$ standard for junior badminton athletes, which ranges from 43–52 ml/kg/min according to (Abian-Vicen et al., 2013). This finding is consistent with the results reported by (saputra & Purnomo, 2021)S, who noted a similar deficit among female athletes from KONI Sidoarjo and attributed it to a lack of continuous running and interval training sessions in their weekly training programs. The practical implication of low $VO_2\text{Max}$ is a decline in performance quality during long matches, particularly in the second and third sets, where athletes with low endurance tend to make more technical errors due to accumulated fatigue (Baiget et al., 2015).

On the other hand, the agility component yielded highly satisfactory results, with an average T-test time of 12.08 seconds falling into the "Very Good" category and 50% of the athletes achieving this top category individually. These findings align with broader evidence from racket sports literature e.g., in youth tennis players (AbdiOğlu et al., 2024), which demonstrates that routine multi-directional footwork and high-intensity court movements inherently drive agility development. Because repetitive footwork drills form the core of daily badminton court training, agility is naturally conditioned through routine practice, even in the absence of specialized supplementary conditioning protocols. This high baseline agility serves as a vital athletic foundation that should be systematically maintained and refined within long-term athlete development frameworks (Fuchs et al., 2014).

Flexibility is another component that requires serious attention. The average V-Sit & Reach score of 10.2 cm, with 40% of athletes falling into the "Very Poor" category (including negative scores), indicates a significant flexibility deficit. Research (Zhannisa et al., 2018) shows that low flexibility in young badminton athletes is associated with an increased risk of acute injuries such as hamstring strains and shoulder injuries. Structured static and dynamic stretching programs need to be integrated into daily training routines as part of the cool-down and as separate sessions at least twice a week (Putra et al., 2023).

In addition to motor components, incorporating anthropometric analysis provides key physiological insights into test performance. The average BMI of 19.58 ± 2.62 kg/m² reflects healthy somatic development; however, individual variations in body mass directly impacted weight-dependent physical performance. In the Multistage Fitness Test (MFT), relative $VO_2\text{Max}$ scores inherently penalize higher body mass because aerobic power is expressed per kilogram of body weight (mL/kg/min). Athletes with higher body weight (e.g., JCG at 59 kg) demonstrated lower relative aerobic capacity despite absolute output. Similarly, relative upper-body strength in push-ups was constrained in athletes carrying higher body mass relative to muscular strength. Conversely, leaner athletes with lower BMI values (e.g., MFZ, BMI = 15.38 kg/m²) achieved superior relative aerobic output (44.3 mL/kg/min) and core endurance scores (42 sit-up reps), as lower body mass reduces gravitational resistance during bodyweight movements. These findings highlight that coaches must account for individual somatic growth and BMI fluctuations when evaluating physical test scores.

Overall, variations in physical fitness across this heterogeneous sample (aged 10–15 years, 6 males, 4 females) are heavily mediated by age, sex, and biological maturation. To prevent developmental bias in performance categorization, individual raw scores were strictly evaluated against age- and sex-stratified normative cut-offs (detailed in Table 2) adapted from validated national sports fitness standards. The application of these age- and gender-specific standards ensures that younger athletes (e.g., 10–11 years) and female participants are evaluated fairly relative to their specific physiological development stage, rather than being inherently penalized against older or male counterparts. For example, a raw sit-up score of 31 repetitions achieves a "Very Good" rating for an 11-year-old girl, whereas the same score yields a "Fair" rating for a 14-year-old boy. Nevertheless, subtle performance variations persist within age brackets because chronological age does not always align directly with biological maturity or pubertal timing. As highlighted by (Fernandez-Fernandez et al., 2023), individual differences in growth spurts and neuromuscular maturation can cause distinct physical capacity gaps even among peers of identical chronological age. Therefore, while age- and sex-adjusted norms provide a standardized evaluative baseline, coaches must supplement these normative classifications with individualized tracking of biological maturation stage and somatic growth when designing long-term physical conditioning programs.

CONCLUSION

Within this evaluated cohort ($n = 10$, purposive sampling), the preliminary physical condition profile of the participating junior athletes demonstrated relative strengths in agility, speed, and core strength, alongside observed weaknesses in upper-body strength, aerobic endurance, and flexibility. As an exploratory evaluation, these initial observations suggest that routine court practices emphasizing technical drills and footwork may benefit from a more balanced integration of secondary physical conditioning components. Given the small, non-random sample from a single club, these findings should be interpreted as preliminary and cannot be generalized to PB Trisula Surabaya athletes broadly or youth badminton athletes in Indonesia as a whole. Nevertheless, these preliminary insights provide actionable local guidance; coaches are encouraged to consider integrating targeted upper-body resistance training, aerobic conditioning, and structured flexibility routines into weekly practices, alongside periodic physical evaluations every three months to track individual progress.

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CONFLICT OF INTEREST

This study was conducted in accordance with the Declaration of Helsinki and ethical standards for research involving human participants. Prior to data collection, ethical clearance and protocol approval were granted by [Insert Name of Ethics Committee/Institutional Review Board, e.g., the Research Ethics



Committee of Universitas Negeri Surabaya / PB Trisula Surabaya Management]. Because all participants were minors aged 10–15 years, written informed consent was formally obtained from their parents or legal guardians prior to testing. Additionally, verbal and written assent was obtained directly from each minor athlete after explaining the test procedures, potential physical risks, and their right to withdraw from the study at any time without penalty.

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