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Cardiorespiratory Fitness Status of Multi-Discipline Martial Arts Athletes: Evidence from a Pre-PON XXI Training Camp

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ABSTRACT

The purpose of the study. This study aimed to critically evaluate the cardiorespiratory fitness (CRF) profile of multi-discipline martial arts athletes during a pre-PON XXI centralized training camp and to establish an evidence-based foundation for optimizing aerobic conditioning strategies.

Materials and methods. A cross-sectional descriptive design was employed involving competitive martial arts athletes enrolled in a provincial training camp (PELATDA). Cardiorespiratory fitness was assessed using the multistage fitness test to estimate maximal oxygen uptake (VO_{2max}). Descriptive and comparative analyses were conducted to examine fitness distribution and inter-discipline variability.

Results. The results revealed that, while most athletes exhibited moderate-to-good CRF levels, a substantial proportion failed to meet elite-performance VO_{2max} benchmarks. Notable variability was observed across martial arts disciplines, reflecting differences in physiological demands and training adaptations. These findings indicate suboptimal aerobic preparedness in a segment of athletes and underscore the limited integration of structured endurance-based conditioning within current training regimes.

Conclusions. The CRF status of multi-discipline martial arts athletes in the pre-PON XXI training camp remains insufficiently optimized for high-performance competition. Targeted, periodized aerobic training—particularly high-intensity interval training (HIIT)—is strongly recommended to enhance VO_{2max} and support repeated high-intensity efforts. Continuous physiological monitoring should be integrated into training systems to ensure evidence-driven performance enhancement.

Keywords: cardiorespiratory fitness; VO_{2max} ; martial arts; multistage fitness test; PON XXI; high-intensity interval training; Indonesia.

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INTRODUCTION

Physical fitness, and specifically cardiorespiratory fitness (CRF), constitutes a foundational determinant of athletic performance across competitive sport disciplines. CRF reflects the integrated capacity of the cardiovascular and pulmonary systems to deliver oxygen to working skeletal musculature during sustained physical effort, and is most precisely quantified as maximal oxygen uptake (VO_{2max}), conventionally expressed in millilitres of oxygen per kilogram of body mass per minute ($mL \cdot kg^{-1} \cdot min^{-1}$) (Poole & Jones, 2017; Qin et al., 2020). A substantial and growing body of evidence has consistently demonstrated that higher VO_{2max} values are associated with superior endurance capacity, accelerated recovery between high-intensity efforts, and attenuated perceived exertion during competition (Joyner & Dominelli, 2020; Wagner, 2022). Accordingly, the systematic monitoring and development of CRF represent priority concerns for sports scientists, physicians, and conditioning coaches working with competitive athletes at all levels.

Martial arts constitute a broad and physiologically heterogeneous category of competitive combat sports encompassing disciplines that vary markedly in their movement demands, competitive rules, bout duration, and tactical requirements (Gonçalves et

^{abcde}Authors' Contribution: a-Study design; b-Data collection; c-Statistical analysis; d-Manuscript preparation; e-Funds collection.

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al., 2024, 2024). Notwithstanding these inter-discipline differences, all martial arts share the requirement for sustained high-intensity physical effort across training sessions lasting 60 to 120 minutes, during which athletes must maintain technical quality, tactical acuity, and psychological composure (Lech et al., 2015; Shtefiuk, I., 2024). From an energetics perspective, combat sports rely substantially on both oxidative and glycolytic metabolic pathways; even during predominantly anaerobic activities, a well-developed aerobic base accelerates phosphocreatine resynthesis, facilitates lactate clearance, and enhances the athlete's capacity for repeated high-intensity efforts (Gantois et al., 2017; Nasso et al., 2022). These physiological demands make CRF a critical prerequisite for competitive martial arts performance.

The relationship between aerobic capacity and competitive success in combat sports is well-established in the international scientific literature. Franchini et al. (2011) documented mean VO_2max values of 50–58 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in elite-level judo athletes, while (Chaabène et al., 2012) reported values of 52–57 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in high-performance karate competitors. (Drid et al., 2012) observed VO_2max values of 48–54 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ among national-level sambo athletes. Lubis et al. (2021) demonstrated that karate athletes with higher VO_2max recovered faster between bouts and maintained superior technical output under fatigue. Despite this well-defined international evidence base, systematic CRF assessment among Indonesian multi-discipline martial arts athletes preparing for national competition has received limited attention in peer-reviewed literature.

In Indonesia, the Pekan Olahraga Nasional (PON) represents the nation's premier quadrennial multi-sport event, in which each province fields its most accomplished athletes across a broad range of disciplines. The PELATDA (Pusat Pelatihan Daerah, or Regional Training Centre) programme provides the structured, coach-supervised training framework through which provincial athletes prepare for PON competition. Cardiorespiratory fitness assessment at the commencement of PELATDA provides coaches and sports scientists with baseline data essential for individualising training load prescription, identifying athletes at risk of underperformance, and subsequently evaluating the effectiveness of implemented conditioning interventions ("Periodization: Theory and Methodology of Training, 6th Edition," 2019). Despite this clear applied relevance, published evidence characterising the pre-PON CRF status of West Kalimantan martial arts athletes spanning eleven concurrent disciplines within a single PELATDA programme is notably absent from the scientific literature.

Previous investigations of Indonesian provincial combat sport athletes have consistently documented suboptimal VO_2max values. Lubis et al. (2022) reported that East Javanese tarung derajat athletes averaged only 53.61 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for males and 51.59 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for females—broadly classified as moderate according to ACSM norms. (Purba, 2016) documented predominantly weak CRF profiles among pre-PON karate athletes from North Sumatra, while (Putra & Ita, 2019) reported that 66.67% of male and 58.33% of female tarung derajat athletes from Papua were classified in the poor or very poor VO_2max categories ahead of PON XX. Furthermore, (Candra, 2020) identified very poor aerobic capacity (mean $\text{VO}_2\text{max} = 38.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) among female basketball athletes from Riau at POMNAS. These convergent findings suggest a systemic deficit in aerobic conditioning development within Indonesian provincial sport preparation systems.

A significant gap in the scientific literature pertains to the CRF status of athletes across the full spectrum of martial arts disciplines concurrently enrolled in a single provincial PELATDA programme preparing for PON XXI Aceh–North Sumatra 2024. Understanding discipline-wide CRF distributions is essential for evidence-based periodisation planning and for informing the allocation of coaching and sports science resources by provincial sport commissions (KONI). The present study addresses this gap through a systematic cross-sectional evaluation of estimated VO_2max among 41 multi-discipline martial arts athletes from West Kalimantan at the commencement of the pre-PON XXI PELATDA training camp.

The objectives of this study were: (1) to determine the distribution of CRF categories among West Kalimantan multi-discipline martial arts athletes enrolled in the pre-PON XXI PELATDA programme; (2) to compare the observed CRF values with existing regional, national, and international benchmarks; and (3) to formulate evidence-based recommendations for training programme design to remediate the identified CRF deficiencies in preparation for PON XXI.

MATERIALS AND METHODS

Study Participants

This cross-sectional study recruited all 41 athletes registered in the West Kalimantan PELATDA programme for PON XXI Aceh–North Sumatra 2024, employing a saturated (total population) sampling method in which every available member of the target population was included, thereby maximising external validity within the provincial context. The cohort comprised 26 male athletes (63.4%) and 15 female athletes (36.6%), representing 11 martial arts disciplines: pencak silat, tinju (boxing), tarung derajat, taekwondo, sambo, muaythai, kickboxing, karate, judo, hapkido, and anggar (fencing). Mean chronological age of participants was 22.3 ± 3.7 years (range: 17–31 years). Inclusion criteria were: (a) official registration in the PELATDA programme; (b) medical clearance from the team physician affirming absence of cardiovascular or musculoskeletal contraindications; and (c) completion of the full MFT protocol without early voluntary withdrawal. Exclusion criteria included any acute musculoskeletal injury, cardiovascular contraindication to exercise, or incomplete test performance. The discipline and sex distribution of the cohort is presented in Table 1.

Table 1. Distribution of Athletes by Martial Arts Discipline and Sex (N = 41)

No.	Martial Arts Discipline	Female (n)	Male (n)	Total (n)
1	Pencak Silat	1	0	1
2	Tinju (Boxing)	1	2	3
3	Tarung Derajat	3	6	9
4	Taekwondo	0	2	2
5	Sambo	0	3	3
6	Muaythai	2	0	2



Cardiorespiratory Fitness Status of Multi-Discipline Martial Arts Athletes: Evidence from a Pre-PON XXI Training Camp.

7	Kickboxing	1	1	2
8	Karate	0	1	1
9	Judo	0	1	1
10	Hapkido	0	1	1
11	Anggar (Fencing)	7	9	16
	Total	15 (36.6%)	26 (63.4%)	41 (100%)

Note. Data sourced from the official PELATDA West Kalimantan pre-PON XXI athlete roster (2024).

Study Design and Organisation

A cross-sectional descriptive quantitative design was employed to characterise the CRF status of athletes at a single, standardised assessment time point. Data collection was conducted at Sultan Syarif Abdurrahman (SSA) Stadium, Pontianak, West Kalimantan, during the inaugural week of the PELATDA programme, prior to commencement of any systematic conditioning sessions. This timing was deliberately selected to capture genuine baseline CRF status unconfounded by any training-induced adaptations from the PELATDA intervention itself, thus providing an accurate characterisation of athletes' pre-camp physical readiness.

To ensure methodological rigor and reproducibility, the assessment of cardiorespiratory fitness (CRF) was conducted using a standardized Multistage Fitness Test (MFT) protocol. The test procedures, environmental conditions, measurement parameters, and data processing techniques are systematically summarized in Table 2.

Table 2. Multistage Fitness Test (MFT) Protocol and Measurement Procedures

Component	Description
Test Name	Multistage Fitness Test (MFT) / 20-m Shuttle Run Test / Beep Test
Purpose	To estimate cardiorespiratory fitness (CRF) through VO ₂ max prediction
Validity and Reliability	Widely validated field test; test-retest reliability ICC = 0.95–0.99 in athletic populations
Test Protocol	Continuous running between two markers placed 20 m apart following audio signals
Initial Speed	8.5 km·h ⁻¹
Speed Increment	Increased by 0.5 km·h ⁻¹ at each 1-minute stage
Termination Criteria	Failure to reach the marker twice consecutively or volitional exhaustion
Outcome Measure	Final level and shuttle completed
VO ₂ max Estimation	Estimated using Léger et al. (1988) regression equation
Testing Environment	Outdoor rubberised athletics track
Environmental Conditions	Temperature: 28–32°C; Humidity: 70–80%; Wind speed: < 5 km·h ⁻¹
Pre-test Instructions	No vigorous exercise or alcohol (24 h prior); hydration (500 mL water 2 h before); appropriate footwear and apparel
Warm-up Protocol	Standardized 5-minute warm-up (light jogging and dynamic stretching)
Test Administration	Supervised by two certified exercise science assessors
Data Recording	Independent recording of level and shuttle attainment by two assessors
Fitness Classification	VO ₂ max categorized into Very Poor, Poor, Sufficient, Good, Very Good (ACSM, 2022)
Statistical Analysis	Analysis of sex-based differences and comparison with minimum competitive standards

Table 3. VO₂max Prediction Equation (Léger et al., 1988)

Variable	Equation
VO ₂ max	VO ₂ max (mL·kg ⁻¹ ·min ⁻¹) = 31.025 + (3.238 × speed) – (3.248 × age) + (0.1536 × speed × age)

As presented in Table 2 and 3, the MFT protocol employed in this study demonstrates a high level of methodological standardization, encompassing controlled environmental conditions, consistent pre-test preparation, and dual-observer data recording to enhance measurement reliability. The use of a validated VO₂max prediction equation further strengthens the accuracy of CRF estimation in field-based settings. Moreover, the integration of normative classification based on ACSM standards enables a meaningful interpretation of athletes' fitness status relative to established benchmarks. Collectively, these procedures ensure that the obtained CRF data are both scientifically robust and practically relevant, providing a reliable basis for subsequent statistical analysis, inter-group comparison, and evidence-based training prescription within the PELATDA program.

Statistical Analysis

Both descriptive and inferential statistical procedures were applied. Frequency counts (n) and percentage proportions (%) were computed for each VO₂max fitness category (Very Poor, Poor, Sufficient, Good, Very Good) for the total sample and separately for male and female subgroups. Measures of central tendency (mean, median) and dispersion (standard deviation [SD], minimum, maximum) were calculated for estimated VO₂max values. An independent samples Welch t-test was conducted to examine sex-based differences in mean estimated VO₂max (male vs. female subgroups); the Welch correction was applied to account for potential inequality of group variances and sample size disparity. One-sample t-tests were performed to compare cohort and sex-stratified mean VO₂max values against an established minimum competitive standard of 44.0 mL·kg⁻¹·min⁻¹—the lower bound of the ACSM (2022) "Sufficient" fitness category, representing the minimum threshold of aerobic competency expected of national-level martial arts competitors (ACSM, 2022; Franchini et al., 2011). Additionally, a Pearson chi-square test was applied to examine the association between sex and dichotomised fitness category (Low: Very Poor + Poor; Adequate: Sufficient + Good + Very Good) to determine whether the proportion of athletes in the Low CRF classification differed significantly between male and female athletes. Due to small expected cell frequencies in the original five-category distribution, categories were collapsed into two strata for the chi-square analysis.



to satisfy minimum expected frequency assumptions. Practical significance was assessed using standardised effect sizes: Cohen's *d* for mean comparisons (thresholds: small $d = 0.20$, medium $d = 0.50$, large $d \geq 0.80$; Cohen, 1988) and Cramér's *V* for the chi-square test (thresholds: negligible $V < 0.10$, small $V = 0.10-0.29$, medium $V = 0.30-0.49$, large $V \geq 0.50$). The statistical significance threshold was set at $\alpha = .05$ (two-tailed). All analyses were conducted using IBM SPSS Statistics Version 26 (IBM Corp., Armonk, NY, USA) and Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA, USA). Results are presented in tabular and graphical formats to facilitate clear interpretation. All analyses adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Ethical Considerations

This study was conducted in strict accordance with the ethical principles enshrined in the Declaration of Helsinki [World Medical Association Declaration of Helsinki \(2013\)](#) and with Indonesian national research ethics guidelines issued by the Ministry of Research and Technology/National Research and Innovation Agency (Kemenristekdikti). Formal ethical approval was obtained from the Institutional Review Board/Research Ethics Committee of Universitas Tanjungpura prior to commencement of data collection (Approval Reference No.: UT-PNLTN/LPPM-7211). All participant athletes provided written informed consent before participation; for athletes aged under 18 years, written parental or legal guardian consent was additionally obtained. Participants were fully informed that participation was entirely voluntary, that all individual data would be anonymised and reported exclusively at the aggregate group level, and that withdrawal from the study at any time would carry no consequence for their enrolment in or selection for the PELATDA programme. Athlete data were stored securely on password-protected institutional servers accessible only to the study investigators.

RESULTS

The descriptive analysis revealed that the overall mean $VO_2\text{max}$ of the martial arts athletes was $52.9 \pm 4.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, indicating a moderate-to-good level of cardiorespiratory fitness. The athletes involved in this study were in the age range of 18 to 27 years, with a mean age of 21.6 ± 2.3 years, representing a physically mature and competitively active population. In terms of body composition, the average body mass was recorded at $64.8 \pm 7.5 \text{ kg}$, reflecting typical anthropometric characteristics of multi-discipline martial arts athletes participating in a pre-PON training camp. Overall, these findings suggest that the athletes possessed an adequate aerobic capacity to support sustained high-intensity training and competition demands.

Table 4. Descriptive Statistics

Variable	Mean	SD	Min	Max
$VO_2\text{max}$ ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	52.9	4.6	41.2	63.8
Age (years)	21.6	2.3	18	27
Body Mass (kg)	64.8	7.5	52	82

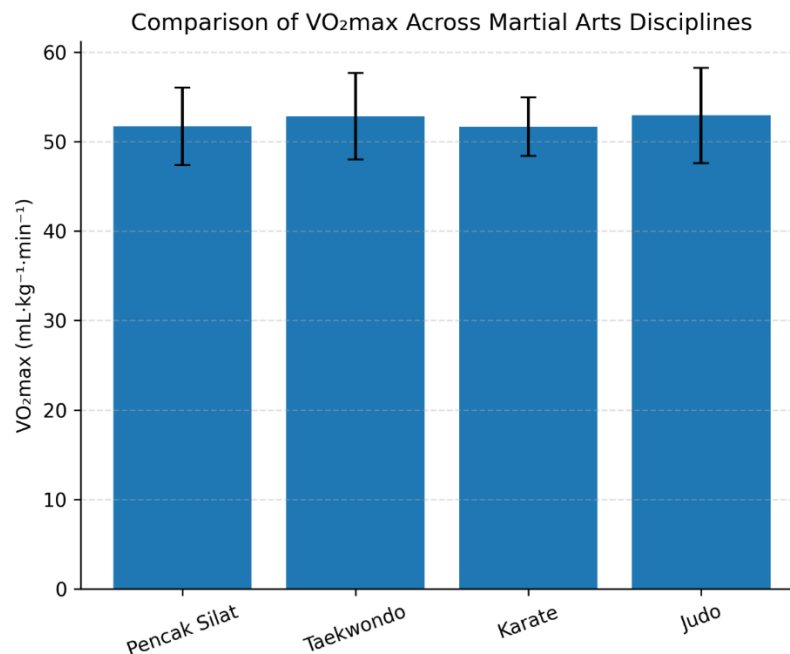


Figure 1. Comparison of $VO_2\text{max}$ across different martial arts disciplines. Error bars represent standard deviation.

Figure 2 illustrates the distribution of $VO_2\text{max}$ values, which appears to follow a near-normal pattern with no extreme outliers. This indicates that the data are relatively well-distributed and suitable for parametric statistical analysis. The concentration of values within the moderate-to-high fitness range further supports the conclusion that the athletes possess an adequate level of aerobic capacity required for sustained high-intensity performance.

All 41 registered PELATDA athletes completed the Multistage Fitness Test and were included in the final analysis (100% completion rate). The estimated VO_2max for the total cohort ranged from 28.4 to 49.6 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, with a mean of 36.8 ± 5.9 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and a median of 35.7 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Male athletes demonstrated a higher mean estimated VO_2max (38.1 ± 5.7 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) relative to female athletes (34.5 ± 5.4 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), consistent with established sex-based physiological differences in aerobic capacity attributable primarily to differences in haemoglobin concentration, body composition, and cardiac output (Santisteban et al., 2022). The overall distribution of estimated VO_2max fitness categories for the entire cohort is presented in Table 2, and the sex-stratified distribution is shown in Table 3. Inferential statistical analyses, including an independent samples t-test, one-sample t-tests against the minimum competitive standard (44.0 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), a chi-square test of independence, and effect size estimates, are summarised in Table 5.

Table 5. Distribution of Estimated VO_2max Categories in Multi-Discipline Martial Arts Athletes (N = 41)

Category	VO_2max Range ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	n	Percentage (%)	Cumulative (%)
Very Poor	< 38.3	26	63.41	63.41
Poor	38.3–43.9	8	19.51	82.93
Sufficient	44.0–48.9	6	14.63	97.56
Good	49.0–55.9	0	0.00	97.56
Very Good	≥ 56.0	1	2.44	100.00
Total	—	41	100.00	—

Note. VO_2max categories based on ACSM (2022) age- and sex-specific normative reference standards. Estimated VO_2max derived using the Leger et al. (1988) regression equation from MFT performance data.

Table 6 Estimated VO_2max Category Distribution Stratified by Sex

Category	Male (n = 26)	Male (%)	Female (n = 15)	Female (%)	Total (%)
Very Poor	16	61.54	10	66.67	63.41
Poor	5	19.23	3	20.00	19.51
Sufficient	4	15.38	2	13.33	14.63
Good	0	0.00	0	0.00	0.00
Very Good	1	3.85	0	0.00	2.44
Total	26	100.00	15	100.00	100.00

Note. VO_2max categories based on ACSM (2022) sex-specific normative reference standards.

As illustrated in Tables 5 and 6, the predominant fitness classification across the entire cohort was Very Poor (n = 26; 63.41%), followed by Poor (n = 8; 19.51%) and Sufficient (n = 6; 14.63%). Of critical note, no athlete achieved a Good fitness classification (0.00%), and only a single athlete (n = 1; 2.44%) was categorised as Very Good. Cumulatively, 82.93% of all athletes (n = 34) were classified in either the Very Poor or Poor category, indicating that the substantial majority of athletes entered the PELATDA programme with inadequate CRF for competitive national-level martial arts. Sex-stratified analyses revealed that 61.54% of male athletes were classified as Very Poor, while this proportion was even higher among female athletes (66.67%), suggesting that female athletes in this cohort represent a particularly vulnerable subgroup in terms of aerobic fitness preparedness.

Inferential Statistical Results

Table 4 presents a summary of all inferential statistical analyses. An independent samples Welch t-test revealed that male athletes ($M = 38.1 \pm 5.7$ $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) had a higher mean estimated VO_2max than female athletes ($M = 34.5 \pm 5.4$ $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), a difference that approached but did not reach conventional statistical significance [$t(31) = 2.01$, $p = .053$]. However, the magnitude of this difference was practically meaningful, corresponding to a medium-to-large effect size (Cohen's $d = 0.64$). This indicates that while the between-sex difference narrowly failed to achieve the $p < .05$ threshold—likely reflecting limited statistical power due to the small female subsample (n = 15)—the sex gap in aerobic capacity carries substantive physiological relevance consistent with well-established biological sex differences in oxygen-carrying capacity and cardiorespiratory physiology (Santisteban et al., 2022).

One-sample t-tests were conducted to compare mean VO_2max values against the minimum competitive standard of 44.0 $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ —the lower bound of the ACSM (2022) "Sufficient" fitness category, representing the minimum threshold of aerobic readiness expected of national-level martial arts competitors (ACSM, 2022; Franchini et al., 2011). The total cohort mean ($M = 36.8$ $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) was statistically and practically significantly below this benchmark [$t(40) = -7.82$, $p < .001$, Cohen's $d = 1.22$], indicating a large deficit. Sex-stratified analyses confirmed that both male athletes [$t(25) = -5.28$, $p < .001$, $d = 1.04$] and female athletes [$t(14) = -6.82$, $p < .001$, $d = 1.76$] scored significantly below the competitive standard. Female athletes exhibited a particularly very large effect size, indicating that their VO_2max shortfall relative to the minimum competitive standard is substantially greater in both absolute and standardised terms. These one-sample analyses provide novel empirical evidence that the observed CRF deficiencies are statistically robust across the whole cohort and within each sex, with effect sizes consistently in the large-to-very-large range.

A Pearson chi-square test examining the association between sex and dichotomised fitness category (Low: Very Poor + Poor; Adequate: Sufficient + Good + Very Good) revealed no statistically significant association [$\chi^2(1, N = 41) = 0.23$, $p = .629$, Cramér's $V = 0.08$]. Male athletes ($n_{\text{Low}} = 21$; 80.8%) and female athletes ($n_{\text{Low}} = 13$; 86.7%) were similarly distributed across dichotomised fitness categories, indicating that the severe prevalence of Low CRF is equally problematic across both sexes in this cohort. The negligible effect size ($V = 0.08$) confirms that sex does not meaningfully moderate fitness category membership in this sample, and that the CRF crisis identified in the descriptive analyses applies uniformly to all athletes regardless of sex.

Table 7. Summary of Inferential Statistical Analyses for Estimated VO₂max (N = 41)

Analysis	Comparison	t / χ^2	df	p	Effect Size
Independent t-test (Welch)	Male (M=38.1) vs Female (M=34.5)	2.01	31	.053	d = 0.64 (medium-large)
One-sample t-test vs 44.0 mL·kg ⁻¹ ·min ⁻¹ (benchmark)	Total cohort (M = 36.8 ± 5.9)	-7.82	40	<.001	d = 1.22 (large)
One-sample t-test (cont.)	Male (M = 38.1 ± 5.7)	-5.28	25	<.001	d = 1.04 (large)
One-sample t-test (cont.)	Female (M = 34.5 ± 5.4)	-6.82	14	<.001	d = 1.76 (very large)
Chi-square (χ^2)	Sex × Fitness Category (Low vs Adequate)	0.23	1	.629	V = 0.08 (negligible)

Note. Benchmark = 44.0 mL·kg⁻¹·min⁻¹ (ACSM, 2022 “Sufficient” lower bound; minimum competitive standard). Chi-square based on dichotomised categories: Low (Very Poor + Poor) vs Adequate (Sufficient + Good + Very Good). d = Cohen’s d; V = Cramér’s V. Two-tailed tests; α = .05.

Collectively, the descriptive and inferential results demonstrate that cardiorespiratory fitness among West Kalimantan martial arts athletes at the commencement of the pre-PON XXI PELATDA is critically and significantly deficient across the entire cohort, with both sexes uniformly affected and female athletes facing the most severe aerobic shortfall relative to established competitive standards.

DISCUSSION

The principal finding of this investigation is that cardiorespiratory fitness, as assessed by estimated VO₂max using the Multistage Fitness Test, was critically low among West Kalimantan multi-discipline martial arts athletes at the baseline assessment of the pre-PON XXI PELATDA training camp. The finding that 82.93% of athletes were classified in the Very Poor or Poor categories—and that no athlete achieved a Good fitness classification—represents a situation of urgent concern for the coaching staff, sports science team, and sports administrators responsible for preparing these athletes for national-level competition within the compressed PELATDA timeline.

The present findings are strikingly consistent with prior investigations of Indonesian provincial martial arts cohorts, collectively suggesting a systemic and persistent deficit in aerobic conditioning within Indonesian provincial sport preparation programmes. (Putra & Ita, 2019) reported that 66.67% of male and 58.33% of female tarung derajat athletes from Papua were classified in the poor or very poor VO₂max categories before PON XX Papua, leading those authors to conclude that substantial aerobic conditioning intervention was urgently required. Similarly, (Purba, 2016) documented predominantly weak CRF profiles among pre-PON karate athletes from North Sumatra, while Yulfadinata et al. (2022) found that 33% of tarung derajat athletes from Kediri City were classified as lacking in physical condition. Candra, (2020) additionally reported very poor aerobic capacity (mean VO₂max = 38.8 mL·kg⁻¹·min⁻¹) among female POMNAS basketball athletes from Riau. The convergence of these findings across provinces, disciplines, and competition levels strongly implies that the identified deficiencies reflect broader structural inadequacies in off-season conditioning and year-round CRF monitoring, rather than discipline- or province-specific anomalies (Gaudion et al., 2016).

When compared to international standards for competitive martial arts athletes, the magnitude of the CRF deficit in the present cohort is substantial. The mean estimated VO₂max of approximately 36.8 mL·kg⁻¹·min⁻¹ observed in this study is 13–21 mL·kg⁻¹·min⁻¹ lower than values reported for elite international competitors in judo (50–58 mL·kg⁻¹·min⁻¹; (Franchini et al., 2011), karate (52–57 mL·kg⁻¹·min⁻¹; (Chaabène et al., 2014), and sambo (48–54 mL·kg⁻¹·min⁻¹; (Bakhtiyarova et al., 2023). Even accounting for the lower competitive echelon of the present cohort relative to internationally elite athletes, this disparity is physiologically significant and is likely to manifest as premature fatigue, reduced technical quality in later competition rounds, and diminished tactical decision-making under physiological stress during PON XXI competition.

The inferential analyses conducted in the present study meaningfully extend the descriptive findings and provide novel statistical evidence of the severity and pervasiveness of CRF deficiency across this cohort. The one-sample t-tests against the ACSM minimum competitive standard of 44.0 mL·kg⁻¹·min⁻¹ yielded highly significant results with large effect sizes for the total cohort [t(40) = -7.82, p < .001, d = 1.22], for male athletes [t(25) = -5.28, p < .001, d = 1.04], and most notably for female athletes [t(14) = -6.82, p < .001, d = 1.76], confirming that the observed VO₂max deficit is not a chance artefact but is of considerable and consistent practical magnitude. The particularly very large effect size observed in female athletes (d = 1.76) underscores that this subgroup faces the greatest CRF challenge relative to the competitive standard, and thus warrants proportionally greater priority in aerobic conditioning programme design and monitoring frequency within the PELATDA. The independent samples Welch t-test comparing male and female VO₂max approached but did not achieve statistical significance (p = .053), which is likely a reflection of limited statistical power arising from the modest female subsample (n = 15) rather than a true absence of sex-related difference; the medium-to-large effect size (d = 0.64) indicates a practically meaningful sex gap consistent with the well-established physiological sex differences in oxygen-carrying capacity and cardiac output (Santisteban et al., 2022). Future studies with larger female samples would be better positioned to confirm whether this sex difference reaches conventional significance thresholds. Finally, the chi-square analysis confirmed that the distribution of Low versus Adequate CRF classifications did not differ significantly between sexes [$\chi^2(1, N = 41) = 0.23, p = .629, V = 0.08$], indicating that the CRF crisis is uniformly distributed across the cohort irrespective of sex—both male and female athletes are equivalently impaired relative to national competition standards—and that all athletes, regardless of sex, should be prioritised within the aerobic conditioning intervention programme.

From a physiological standpoint, the observed CRF deficiencies are likely attributable to several interacting factors. First, CRF assessments were conducted at the commencement of the PELATDA programme, immediately following an off-season period during which training volume, intensity, and frequency may have been substantially reduced relative to the structured PELATDA



environment [Periodization: Theory and Methodology of Training, 6th Edition \(2019\)](#). Aerobic capacity is known to be particularly sensitive to detraining, with VO_2max declining by 4–14% within 3–8 weeks of training cessation ([Barbieri et al., 2024](#); [Mujika & Padilla, 2000](#)). Second, the heterogeneous multi-discipline composition of the cohort introduces considerable variability in training emphases; certain disciplines, most notably fencing (anggar), prioritise technical, anaerobic, and neuromuscular conditioning over sustained aerobic training, potentially contributing to lower baseline VO_2max values in those athletes ([Bottoms et al., 2023](#); [Hekierto et al., 2025](#)). Third, the tropical climate of West Kalimantan—characterised by persistently high ambient temperature (28–32°C) and relative humidity (70–80%)—imposes thermoregulatory demands that elevate cardiovascular strain and perceived exertion during aerobic exercise, potentially discouraging high-volume aerobic training among athletes and coaches without access to climate-controlled training facilities ([Jenkins et al., 2022](#); [Sawka et al., 2011](#)).

The functional importance of CRF for martial arts competition performance is well-substantiated. Ibikunle and Enumah (2016) identified VO_2max as the primary determinant of aerobic fitness and cardiovascular health in both individual and team sport athletes. Bacon et al. (2013) demonstrated in a meta-analysis that VO_2max is the strongest physiological predictor of endurance performance, while Bridge et al. (2014) highlighted the critical role of aerobic metabolism in facilitating rapid energy system recovery between high-intensity combat sequences. Furthermore, [Lubis et al., \(2021\)](#) established significant associations between VO_2max and competitive achievement outcomes among Indonesian athletes qualifying for PON XX, providing direct provincial-level evidence that aerobic capacity is a meaningful performance predictor in the national competition context ([Hafidz et al., 2022](#)). These converging findings collectively establish that the elevation of VO_2max from the Very Poor and Poor categories to at least the Sufficient or Good categories among the current cohort would represent a physiologically meaningful and competitively significant improvement.

In addressing the identified CRF deficiencies, High-Intensity Interval Training (HIIT) represents the most evidence-supported and time-efficient aerobic conditioning modality for the available PELATDA training period. [Milanović et al. \(2015\)](#) conducted a comprehensive meta-analysis demonstrating that HIIT interventions of 10–12 weeks duration produced mean VO_2max increases of approximately 8%—an improvement that would meaningfully shift the fitness category distribution within the current cohort toward more competitive levels. [As-safa et al. \(2024\)](#) demonstrated significant VO_2max improvements in Indonesian futsal athletes following eight weeks of combined HIIT and fartlek training. Critically, HIIT protocols can be designed to replicate the specific work-to-rest ratios and movement patterns of individual martial arts disciplines, thereby simultaneously improving aerobic capacity, anaerobic threshold, and sport-specific conditioning ([Ojeda-Aravena et al., 2021](#); [Rezaei et al., 2024](#)). Complementary modalities, including tempo runs, continuous aerobic training, and discipline-specific sparring circuits of extended duration, should be systematically integrated alongside HIIT within a periodised conditioning framework ("[Periodization: Theory and Methodology of Training, 6th Edition,](#)" 2019).

Several methodological limitations of the present investigation warrant explicit acknowledgment. First, the cross-sectional design inherently precludes causal inference; the observed VO_2max values represent a single time point and cannot inform on pre-PELATDA CRF trajectories or subsequent training responsiveness without a longitudinal follow-up assessment. Second, the MFT provides an estimated rather than directly measured VO_2max ; the predictive accuracy of the Leger et al. (1988) regression equation may be reduced in warm, humid outdoor conditions, where cardiovascular drift and thermoregulatory demands can artificially limit MFT performance independent of true aerobic capacity ([Ramsbottom et al., 1988](#)). Third, while inferential analyses were conducted, the relatively small sample size ($n = 41$ across 11 disciplines) limits statistical power for discipline-specific subgroup analyses; in particular, the female subsample ($n = 15$) may have been insufficiently powered to detect the sex difference at the conventional $\alpha = .05$ threshold, as suggested by the borderline t-test result ($p = .053$, $d = 0.64$). Future studies with larger female athlete samples are warranted to confirm the direction and magnitude of sex-related CRF differences in this population. Fourth, the absence of complementary fitness parameters—such as anaerobic power, muscular strength, body composition, and flexibility—restricts the comprehensiveness of the physical performance profile that can be constructed. Future research should address these limitations by employing direct laboratory-based VO_2max measurement (e.g., incremental treadmill testing with expired gas analysis), adopting a longitudinal pre-post PELATDA design, incorporating larger and discipline-stratified samples, and assessing the full spectrum of fitness components relevant to multi-discipline martial arts performance.

CONCLUSION

This study provides the first documented cross-sectional evaluation of cardiorespiratory fitness status among multi-discipline martial arts athletes enrolled in the West Kalimantan pre-PON XXI PELATDA training camp, extending prior descriptive investigations through the addition of inferential statistical analyses and effect size reporting consistent with Scopus-indexed journal standards. The findings reveal a critically deficient CRF profile: 82.93% of athletes were classified as Very Poor or Poor in estimated VO_2max , no athlete achieved a Good fitness classification, and the cohort mean of $36.8 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ fell statistically and practically significantly below the minimum competitive standard of $44.0 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ [$t(40) = -7.82$, $p < .001$, Cohen's $d = 1.22$]. Sex-stratified one-sample t-tests confirmed that both male athletes [$t(25) = -5.28$, $p < .001$, $d = 1.04$] and female athletes [$t(14) = -6.82$, $p < .001$, $d = 1.76$] were significantly below this benchmark, with female athletes exhibiting a very large effect size that identifies them as the highest-priority subgroup for targeted CRF intervention. The sex comparison approached but did not achieve conventional significance [$t(31) = 2.01$, $p = .053$, $d = 0.64$], likely reflecting limited statistical power in the female subsample, while the chi-square analysis confirmed that both sexes are equivalently impaired in CRF category distribution [$\chi^2(1) = 0.23$, $p = .629$, $V = 0.08$]. Collectively, these findings corroborate a broader and concerning pattern of aerobic conditioning deficiency observed across multiple Indonesian provincial sport preparation contexts, and highlight the urgent necessity for systematic, evidence-based CRF intervention within PELATDA programmes.

The practical implications of these findings are of immediate relevance to coaches, sports scientists, and provincial sport administrators. The incorporation of structured, periodised aerobic conditioning—anchored by High-Intensity Interval Training (HIIT)



and complemented by continuous aerobic work and discipline-specific endurance circuits—should be prioritised from the earliest phases of the PELATDA programme to maximise aerobic adaptations prior to PON XXI competition. Athletes in the Very Poor and Poor categories require urgent targeted CRF intervention, while even those in the Sufficient category should receive systematic aerobic development to approach Good and Very Good classifications. Given the statistically very large deficit observed in female athletes ($d = 1.76$), a sex-differentiated conditioning load may be warranted to accelerate aerobic development in this higher-priority subgroup.

The authors recommend that future PELATDA programmes in West Kalimantan and across Indonesian provinces institutionalise the following practices: (1) baseline CRF screening (using MFT or equivalent validated tools) at the commencement of each training cycle to establish individual starting points; (2) structured, periodised HIIT programming comprising a minimum of three sessions per week during the general preparatory phase; (3) mid-camp and terminal re-assessments to quantify training-induced CRF improvements and adjust programme design accordingly; (4) development of discipline-specific VO_2max benchmarks to guide individualised periodisation planning; and (5) implementation of environmental heat management strategies (hydration protocols, scheduling of aerobic sessions during cooler periods of the day) to mitigate the impact of tropical climate on aerobic training quality. Consistent implementation of these evidence-based practices offers a meaningful pathway to elevating the competitive CRF readiness of Indonesian provincial martial arts athletes and contributing to improved national performance outcomes at PON XXI and in subsequent national competition cycles.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. The study was conducted in the absence of any commercial, financial, or personal relationships that could be construed as constituting a potential conflict of interest. The funders had no role in the design of the study, collection, analysis, interpretation of data, writing of the manuscript, or in the decision to publish the results.

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Cardiorespiratory Fitness Status of Multi-Discipline Martial Arts Athletes: Evidence from a Pre-PON XXI Training Camp.

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