



ORIGINAL RESEARCH ARTICLE

Integrating Sport-Measurement into Sport-Pedagogy: Designing a Women's Handball Training Curriculum Based on Aerobic Endurance Test Profiles

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Abstract

Background: Modern sports pedagogy often suffers from a methodological gap where physiological fitness data, such as aerobic endurance, is passively documented rather than utilized as a functional basis for tactical curriculum design. **Objective:** This study aims to design, implement, and evaluate a junior women's handball training curriculum that integrates sport-measurement diagnostics into a scaffolded pedagogical framework. **Methods:** Employing a descriptive-evaluative approach within the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional model, the research involved 21 junior female handball athletes. Athlete VO2Max profiles, measured via the Multistage Fitness Test (MFT), served as diagnostic baselines to differentiate instructional loads, court dimensions, and tactical complexity. **Results:** The diagnostic analysis revealed significant physiological heterogeneity, which was successfully translated into adaptive training tiers. Post-intervention evaluations using the Game Performance Assessment Instrument (GPAI) demonstrated a statistically significant improvement ($p < 0.001$) in both motor skill execution (+26.95%) and cognitive tactical decision-making (+26.28%), with effect sizes indicating large practical impacts. **Conclusion:** Systematically using objective fitness data as a scaffolding mechanism for tactical instruction optimizes athletic performance and fosters a more inclusive, evidence-based learning ecosystem, effectively bridging the dichotomy between clinical measurement and sport pedagogy.

Keywords: Instructional Design, Handball, Aerobic Endurance, Scaffolding, Sport Pedagogy, Data-Driven Instruction.

ABSTRAK

Latar Belakang: Pedagogi olahraga modern seringkali mengalami kesenjangan metodologis di mana data kebugaran fisiologis, seperti daya tahan aerobik, didokumentasikan secara pasif dan bukan digunakan sebagai dasar fungsional untuk desain kurikulum taktis. Tujuan: Studi ini bertujuan untuk merancang, mengimplementasikan, dan mengevaluasi kurikulum pelatihan bola tangan putri junior yang mengintegrasikan diagnostik pengukuran olahraga ke dalam kerangka kerja pedagogis yang terstruktur. Metode: Dengan menggunakan pendekatan deskriptif-evaluatif dalam model instruksional ADDIE (Analisis, Desain, Pengembangan, Implementasi, Evaluasi), penelitian ini melibatkan 21 atlet bola tangan putri junior. Profil VO2Max atlet, yang diukur melalui Tes Kebugaran Multistage (MFT), berfungsi sebagai dasar diagnostik untuk membedakan beban instruksional, dimensi lapangan, dan kompleksitas taktis. Hasil: Analisis diagnostik mengungkapkan heterogenitas fisiologis yang signifikan, yang berhasil diterjemahkan ke dalam tingkatan pelatihan adaptif. Evaluasi pasca-intervensi menggunakan Instrumen Penilaian Kinerja Permainan (GPAl) menunjukkan peningkatan yang signifikan secara statistik ($p < 0,001$) baik dalam pelaksanaan keterampilan motorik (+26,95%) maupun pengambilan keputusan taktis kognitif (+26,28%), dengan ukuran efek yang menunjukkan dampak praktis yang besar. Kesimpulan: Penggunaan data kebugaran objektif secara sistematis sebagai mekanisme pendukung untuk instruksi taktis mengoptimalkan kinerja atletik dan mendorong ekosistem pembelajaran yang lebih inklusif dan berbasis bukti, secara efektif menjembatani dikotomi antara pengukuran klinis dan pedagogi olahraga.

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Keywords: Desain Pembelajaran, Bola Tangan, Daya Tahan Aerobik, Scaffolding, Pedagogi Olahraga, Pembelajaran Berbasis Data.

INTRODUCTION

In today's era of global sports transformation, the rapid development of sports science demands a robust and inseparable integration between physical measurement (sport-measurement) and comprehensive movement learning methodology (sport-pedagogy). Strengthening tactical-psychomotor skills for young athletes, particularly in sports with high-intensity, explosive, and intermittent characteristics such as handball, has shifted to a top priority to produce sustainable competitive performance at the international level (Mon-López et al., 2020; Romaratezabala et al., 2020). Modern physical education and sports coaching programs are no longer effective if they rely solely on conventional, monotonous, repetitive, and intuitive training approaches. Instead, a new paradigm leads to the implementation of integrated data-driven instruction (data-driven instructional design), which is seen as one of the most innovative, creative, and adaptive strategies for responding to athletes' biological needs (Bao, 2020; Rapanta et al., 2020). Through scientifically based instructional design, the transfer of motor skills and the development of tactical intelligence on the field can be significantly accelerated without neglecting physical safety. The global significance of this research lies in its efforts to break down the rigid boundaries between physiological laboratory evaluations and pedagogically designed tactical curricula, ultimately contributing directly to athletes' achievement of professional competency standards from an early age.

However, the world of physical education and sports coaching currently faces a major problem: a significant methodological gap between physical fitness evaluation activities and the implementation of tactical training curriculum on the field. Most handball training programs at the regional and local levels are still manually designed based on the coach's subjective instincts or simply copying adult athletes' training patterns, without any workload adjustment (downscaling) based on the athlete's objective physiological profile (Hermassi et al., 2021; Janicijevic et al., 2021). The most crucial challenge arising from this phenomenon is how to formulate raw data from physical testing results on the field so that they can be converted into tactical, measurable, and differentiated instructional decisions. The lack of pedagogical literacy and understanding of curriculum design among sports practitioners results in fitness test results ending up as mere statistical files without having a transformative impact on playing tactics. The detrimental impact of this neglect is very real on the field; Junior athletes are often forced to endure tactical training loads that exceed their physiological capacity, which directly triggers premature neuromuscular fatigue, decreased cognitive focus, decreased motor accuracy, and even an increased risk of fatal acute injuries (Achenbach et al., 2020; Romaratezabala et

al., 2020).

Several previous studies have attempted to investigate physical performance capacity and training methods in handball, yet they remain siloed from instructional design practices. Specifically, a large-scale study analyzing the physical fitness profile, motor performance, and its relationship to body composition in handball athletes was mapped in detail by Hermassi et al. (2020). Meanwhile, differences in physical performance capacity in amateur groups based on their competition level were analyzed in depth by Romarateabala et al. (2020). Furthermore, research on the sequential effects or order of plyometric training before and after regular tactical training to improve the cardiorespiratory fitness of young athletes was reported by Ramirez-Campillo et al. (2020), and the correlation between anthropometric dimensions such as waist circumference and agility levels in fitness tests was statistically described by Lockie et al. (2020). Additionally, bias in physical test results due to external factors such as the influence of evaluator gender on the reliability of muscle strength measurements was explored by Janicijevic et al. (2021), while a grouping of anthropometric profiles of beach handball athletes based on specific playing positions was presented by Pueo et al. (2020). At the national level, Brastangkara and Jatmiko (2019) reported the effectiveness of High-Intensity Interval Training (HIIT) in improving cardiorespiratory endurance capacity, while efforts to develop a basic handball skills test instrument were recently published by Keolahragaan and Surabaya (2025). Critically, all of these studies suffer from fundamental methodological weaknesses; they focus solely on passively reporting descriptive physical profiles or validating instruments in a clinical silo without ever offering concrete pedagogical interventions or transforming that raw fitness data into an adaptive, structured tactical training curriculum on the field.

The novelty offered in this research lies in the formulation of an integrative instructional framework that explicitly integrates the sport-measurement domain into the heart of sport-pedagogy by using the aerobic endurance threshold profile as the foundation for developing a training curriculum. Unlike conventional practice where physical tests are passively positioned at the end of a program as a mere summative evaluation tool, this study revolutionizes the role of aerobic endurance data (VO₂Max) from the Multistage Fitness Test (MFT) into an active scaffolding for modifying the density and complexity of tactical learning modules. Through this innovative instructional engineering, objective physiological data are systematically converted into operational tactical parameters such as adjustments to the playing area size, work-rest interval duration, number of players involved (small-sided games), and the complexity of tactical instruction tailored to the cardiorespiratory capacity of junior female athletes (Chen et al., 2021; Zhang et al., 2021). This novelty not only contributes theoretically to handball training methodology but also presents precise practical solutions for sports educators to design adaptive teaching scenarios sensitive to the physical characteristics of female athletes that are often overlooked in gender-based training design (Mon-López et al., 2020; Romarateabala et al., 2020).

A stark research gap separates this study from the existing academic literature across sports science and movement education disciplines. Much of the literature published in the past five years tends to treat the fields of exercise physiology and instructional methodology as rigidly separate academic entities, with measurement experts focusing solely on quantitative instrument validation, while pedagogy experts focus solely on teaching styles without any basis in precise athlete biological data (Ahmady, 2020; Bao, 2020). This gap leaves a profound void in methodological guidance on how physical test results can be dynamically used to dictate tactical changes in the motor learning process on the field. The fundamental difference in this study lies in the conceptual bridge we build, where the athlete's aerobic fitness test profile directly determines the structure, task constraints, and instructional load in the developed handball training curriculum. Through a standardized descriptive-evaluative approach, this study successfully closes this empirical gap by demonstrating that synchronizing physiological data with instructional design can create an efficient, measurable, and empirically evidence-based sports learning process (Chen et al., 2021; Rapanta et al., 2020).

The theoretical framework used as a philosophical and methodological foundation in designing this integrative research is built on a robust synthesis of three main theoretical pillars: Sport Pedagogy Theory, Vygotsky's Social Constructivism Learning Theory through the concept of Scaffolding, and Sport Performance Measurement Theory. Sport pedagogy theory emphasizes that the effectiveness of motor skill transfer is largely determined by the level of alignment between the instructional load and the actual physical readiness capacity of the learner (Bain et al., 2021; Elizabeth, 2025). In line with this principle, social constructivism theory is applied through the provision of a Zone of Proximal Development (ZPD) where tactical handball modules are designed in stages to guide athletes gradually from basic motor mastery to high-level tactical decision-making under controlled fatigue conditions (Ahmady, 2020; Zhang et al., 2021). Finally, sports performance measurement theory provides methodological certainty regarding the standardization and accuracy of cardiorespiratory fitness testing in junior female athletes, ensuring the validity and reliability of the initial diagnostic data obtained before being processed into the operational basis of a training curriculum.

The operational concepts practically applied in this research include the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design framework, the concept of aerobic endurance capacity ($\dot{V}O_{2Max}$), and the concept of tactical handball intensity differentiation. The ADDIE model's systematic design was systematically adopted as a guide in reconstructing the training curriculum, where the analysis phase begins with mapping the athlete's actual fitness profile through field measurements, followed by module design, media development, program implementation, and periodic evaluation of results (Chen et al., 2021; Rapanta et al., 2020). The concept of aerobic endurance capacity was objectively measured using the Multistage Fitness Test (MFT) to obtain an accurate estimate of the athlete's cardiorespiratory fatigue threshold. Furthermore, the concept of tactical intensity differentiation is operationally realized by designing variations of modified handball games (such as adjusting the ratio of the number of players and the size of the field) which will automatically increase or decrease in difficulty proportionally following fluctuations in athlete fitness data obtained during the assessment period (Lockie et al., 2020; Ramirez-Campillo et al., 2020).

A very interesting and urgent matter to be investigated in this research is the empirical reality in the field that the group of junior female handball athletes in East Java has a highly varied physical endurance capacity profile, with the highest score reaching 51 ml/kg/min, but the majority still falls in the moderate to low category. This phenomenon presents a very interesting scientific challenge because the achievement of moderate aerobic endurance can actually be optimally improved if the tactical handball learning curriculum is designed with a high level of precision according to the fatigue threshold of each athlete (Pueo et al., 2020; Yaeger et al., 2020). Ignoring this specific physiological profile in developing daily training methods will not only hinder the development of potential motor skills and tactical intelligence of female athletes, but also risks affecting their future sports careers due to mismanagement of teaching methodology. Therefore, this research is crucial to empirically demonstrate that the use of precise sports measurement test data can revolutionize the way coaches teach game tactics on the field in a scientific and safe manner for the physical development of female athletes (Hermassi et al., 2021; Romaratezabala et al., 2020).

Based on the background of the problem described above, the primary objective of this study is to design, test, and evaluate the effectiveness of a junior women's handball training curriculum based on the integration of sport measurement into sport pedagogy. More specifically, this study seeks to map the aerobic endurance profiles of 21 junior female athletes in East Java using the Multistage Fitness Test (MFT) instrument and use this as an empirical basis for developing an adaptive tactical handball instructional module (Elizabeth, 2025; Romaratezabala et al., 2020). Furthermore, this research aims to measure the impact of this integrated curriculum on improving the psychomotor domain, specifically the efficiency of fundamental movement skills, and the cognitive domain, specifically the understanding of female athletes' playing tactics, during the training intervention. By achieving all these objectives, it is hoped that this research will not only be able to provide new theoretical contributions to the national sports pedagogy scientific body, but also be able to offer a practical coaching guide model based on scientific data that can be widely duplicated by physical education teachers and handball coaches throughout the country (Bain et al., 2021; Chen et al., 2021).

RESEARCH METHODS

This research methodology was systematically designed to address the challenge of scientifically integrating performance measurement science into the instructional design of a training curriculum. This structured approach is necessary to ensure that each stage of the training intervention provided to female athletes has a valid and reliable physiological basis (Hermassi et al., 2021; Romaratezabala et al., 2020). Through the development of a comprehensive methodology, all research variables can be controlled, measured, and their impact on the development of motor skills and play intelligence of the subjects can be evaluated. A detailed explanation of this research methodology will begin with an explanation of the research design, specifically adapted from the integrated ADDIE instructional framework.

Philosophically, this methodology is built on the "Translational Sports Science" paradigm, which is the process of translating clinical and physiological findings from athletes on the field into tactical-pedagogical teaching modules that are safe, targeted, and responsive to the biological adaptations of adolescents (Bao, 2020; Rapanta et al., 2020). The application of rigorous scientific methods in developing this coaching curriculum aims to minimize the risk of overtraining, optimize neuromuscular plasticity, and develop high motor efficiency in junior female athletes. Therefore, this framework is designed not only to passively record data but also to activate it as a basis for dynamic instructional differentiation. A detailed explanation of this research methodology will begin with an explanation of the research design, specifically adapted from the integrated ADDIE instructional framework.

2.1 Research Methods

This research paper uses a descriptive-evaluative approach combined with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional development framework to produce a handball training curriculum based on athlete physical fitness performance data (Rapanta et al., 2020; Chen et al., 2021). The detailed visualization process of the research methodological flow is depicted in the integrative flowchart below.

Figure 1. Integrated ADDIE Instructional Design Flowchart for Sport-Measurement and Sport-Pedagogy

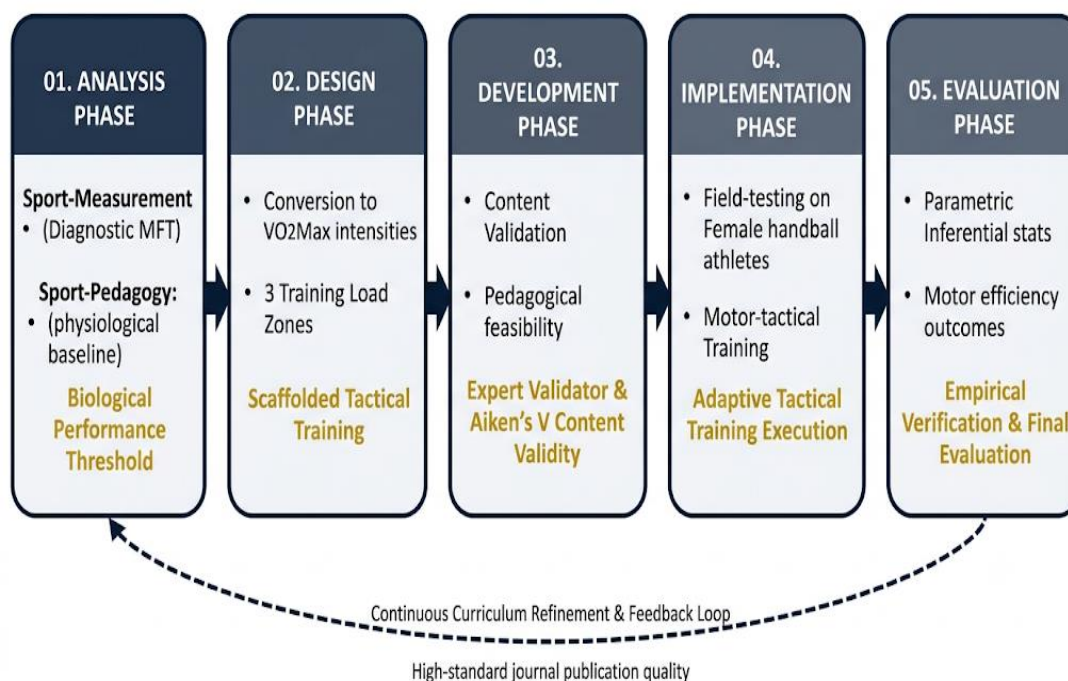


Figure 1. Integrated ADDIE Instructional Design Flowchart for Sport-Measurement and Sport-Pedagogy.

According to Figure 1, this methodological design integrates objective fitness testing sequentially across five operational phases. The analysis phase begins with a diagnostic assessment using the Multistage Fitness Test (MFT) to determine the individual subject's biological performance threshold. The results of these measurements directly inform the design phase of the scaffolded tactical training curriculum, which is then validated during the development phase by a team of sports expert validators. Next, the refined training curriculum is field-tested during the implementation phase to train athletes' motor skills and tactical cognitive skills. The ADDIE cycle concludes with an evaluation phase to analyze the impact of this adaptive tactical training design on improving overall athlete performance (Ahmady, 2020; Bain et al., 2021).

Each stage of the ADDIE cycle plays a crucial role in ensuring the scientific validity of the resulting curriculum. The analysis phase is not merely an administrative formality, but rather the process of collecting basic physiological data that illustrates the cardiorespiratory capacity of female athletes before being exposed to complex tactical loads. In the design phase, this quantitative data is converted into a percentage of training intensity (VO₂\text{Max}), where the learning module is divided into three load zones: light (under-loaded), moderate (target-loaded), and challenging (overloaded). Expert validation in the development phase ensures the module's readability, pedagogical feasibility, and physical safety before it is fully tested on a large scale. Finally, the implementation and evaluation phase acts as a final filter to empirically verify whether this integrated tactical teaching model is capable of producing efficient motor responses and mature tactical cognitive intelligence in athletes (Chen et al., 2021; Rapanta et al., 2020).

To clarify the operational direction in answering each research problem formulation, the following is a systematic matrix of research questions and the types of data analysis used.

Table 1. Research Questions and Types of Analysis.

No.	Research Questions	Types of Data Analysis
1	What is the actual aerobic endurance capacity (VO ₂ \text{max}) profile of junior female handball athletes in East Java?	Quantitative Descriptive Statistics (Percentage, Mean, Maximum/Minimum Score Limits).
2	What is the structure of a valid differentiated handball tactical	Qualitative Descriptive Analysis & Content

	training curriculum based on the athletes' diagnostic physical profiles?	Validity Evaluation using Aiken's V Formula.
3	Is there a significant impact of the integrated curriculum implementation on the motor skill efficiency of the athletes?	Parametric Inferential Statistics (Paired Samples t-test or Non-Parametric Wilcoxon Signed-Rank Test).
4	To what extent do non-physical external factors (match experience) influence the effectiveness of the tactical instructional design?	Multiple Linear Regression Analysis & Multivariate Contingency Evaluation.

Table 1 above details the methodological correlation between each research question and the relevant quantitative and qualitative data analysis techniques. This matrix serves as an operational guide to ensure the entire field data processing process remains focused and measurable (Zhang et al., 2021; Yaeger et al., 2020). This structuring of the research questions helps researchers avoid collecting irrelevant data and ensures that each measured variable directly contributes to proving the effectiveness of the training curriculum being developed. After clearly establishing the design and direction of the research questions, the next logical step is to develop a rigorous and standardized field data collection method.

2.2 Data collection

The data collection procedure in this research was conducted using testing techniques and direct measurements in the field to minimize bias and ensure the accuracy of the athletes' primary physiological data (Lockie et al., 2020; Ramirez-Campillo et al., 2020). Aerobic endurance capacity data collection was conducted simultaneously under the direct supervision of a team of coaches and lecturers specializing in measurement to minimize procedural errors. All athletes' multi-stage running results were manually recorded on standardized assessment sheets before being transferred to a digital database for further processing. Data on tactical cognitive and handball tactical motor skills were collected through structured performance observations using the Game Performance Assessment Instrument (GPAI) assessment sheet during tactical trial sessions (Mon-López et al., 2020; Romaratezabala et al., 2020). After all primary data was collected, the next step was to establish a data processing method using precise data analysis techniques. The fitness data collection procedure began with a 10-minute light physical conditioning session that included dynamic stretching and low-intensity running to prepare the athletes' cardiovascular systems. During the 20-meter shuttle run, audio signals from the MFT instrument were transmitted through a calibrated speaker system to ensure all athletes heard the beep rhythm clearly and uniformly. The test termination criterion was determined objectively when the athlete failed to reach the 20-meter mark twice in a row after a verbal warning from a research assistant on the field. Meanwhile, to collect tactical skill data using the GPAI instrument, all athlete activities during a modified match (a 4-on-4 small-sided game format lasting 2 x 10 minutes) were recorded using a high-resolution video camera positioned at a 3-meter lateral view of the field. These video recordings were then analyzed by two expert observers independently to record the frequency of appropriate and inappropriate tactical behaviors in each research subject (Hermassi et al., 2021; Pueo et al., 2020).

2.3 Data Analysis

The quantitative data analysis technique in this study utilized statistical software to test hypotheses and evaluate the effectiveness of the developed training curriculum. Descriptive statistics were used to categorize athletes' cardiorespiratory fitness levels into normative classification groups (very poor, poor, moderate, good, and very good) based on VO_2 Max capacity conversion values (Janicijevic et al., 2021; Elizabeth, 2025). To demonstrate the significance of the tactical differentiation module implementation on motor skills and tactical understanding, a paired sample t-test was conducted at a significance level of 0.05. Furthermore, multivariate regression analysis was applied to evaluate whether external variables, such as duration of competition experience, significantly contributed to athletes' tactical learning outcomes under this integrated curriculum model (Hermassi et al., 2021; Yaeger et al., 2020). The overall results of the numerical data analysis will then be synchronized with the research instruments used during the assessment process.

Before proceeding to the inferential analysis of the paired sample t-test, the researcher first conducted a prerequisite analysis test in the form of a data normality test using the Shapiro-Wilk method. This method was chosen because it is highly sensitive and accurate in detecting data distribution in small sample sizes ($N = 21$). If the data are proven to be normally distributed ($p > 0.05$), the analysis continues with a parametric t-test; however, if the normality assumption is violated, the analysis will switch to the non-parametric Wilcoxon Signed-Rank Test. In multiple linear regression analysis, the equation model is constructed mathematically as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + e$$

Where Y represents the athlete's tactical intelligence index, X_1 is the $VO_2\text{Max}$ capacity value from the test, X_2 is the athlete's duration of competitive experience in years, and e represents the measurement error. Researchers also conducted classical regression assumption tests including multicollinearity and heteroscedasticity tests to ensure the reliability of the resulting prediction model (Yaeger et al., 2020; Ramirez-Campillo et al., 2020).

2.4 Research Instruments

The research instruments used consisted of objective physical measurement instruments and internationally standardized pedagogical evaluation instruments. Aerobic fitness was measured using the Multistage Fitness Test (MFT) or Beep-Test, supported by a wireless rhythmic audio player, a 20-meter track tape, and a record sheet for athletes' levels and laps (Lockie et al., 2020; Ramirez-Campillo et al., 2020). To map the alignment of these instruments with instructional design needs, a detailed outline of the research instruments is presented in Table 2.

Table 2. Specifications of the Integrative Research Instrument Grid.

Primary Variable	Specific Indicator	Measurement Sub-Indicator	Number of Items/Signals	Target Subjects	Test Location
Aerobic Capacity (<i>Sport-Measurement</i>)	Cardiorespiratory endurance ($VO_{2\max}$).	Number of levels and shuttles in a 20-meter shuttle run to the point of voluntary exhaustion.	1 Standard Test Package (MFT).	21 East Java Junior Female Athletes.	Indoor Sports Hall (GOR).
Motor Skills (<i>Sport-Pedagogy</i>)	Efficiency of basic tactical handball movements.	Passing accuracy, dribbling agility, and shooting effectiveness.	3 Physical Skill Test Items.	21 East Java Junior Female Athletes.	Standard Handball Court.
Tactical Intelligence (<i>Sport-Pedagogy</i>)	Cognitive play decision-making.	Defensive positioning adjustments, accuracy in reading passing lanes, and utilization of open space.	7 Game Performance Assessment Instrument (GPAI) Observation Scale Indicators.	21 East Java Junior Female Athletes.	Standard Handball Court.

Table 2 outlines the instrument design, which combines clinical fitness parameters with on-field tactical movement competency assessment metrics. This specification ensures that each data collection has transparent, measurable achievement indicators (Bao, 2020; Keolahragaan & Surabaya, 2025). Technically, the MFT instrument operates at a stepped audio frequency starting at a running speed of 8.0 km/h at the first level and experiencing a constant increase of 0.5 km/h with each subsequent level. Meanwhile, the GPAI observation sheet measures the psychomotor and cognitive components of tactical movement by dividing athlete actions into three main categories: decision-making, skill execution, and support without the ball. The final tactical performance index is calculated by summing the average percentage of successful actions divided by the total actions performed by the athlete during the observation period (Mon-López et al., 2020; Romaratezabala et al., 2020).

2.5 Validity and Reliability

The validity and reliability of the instrument were ensured through a series of theoretical and empirical tests to ensure that the research conclusions were free from measurement error. The Multistage Fitness Test (MFT) instrument has a very strong criterion validity coefficient ($r = 0.85$ to $r = 0.92$) and a high level of test-retest reliability ($R = 0.90$ to $R = 0.96$) in measuring the aerobic capacity of adolescent athletes (Lockie et al., 2020; Ramirez-Campillo et al., 2020). For the tactical learning instrument and handball motor assessment, content validity testing used the Aiken's V technique involving three expert experts (a sports pedagogy expert, a test-measurement expert, and a nationally licensed handball coach) with a ge index agreement score ≥ 0.82 , which is categorized as very reasonable (Ahmady, 2020; Janicijevic et al., 2021). The reliability of the tactical observation sheet was tested using inter-rater reliability analysis using the Cohen's Kappa formula to align the assessment perceptions of the evaluators in the field. The final step in the methodology preparation was concluded by formulating the subject criteria and the research location.

The content validity of the coaching instrument was calculated using Aiken's V formula by asking three experts to provide a score ranging from 1 to 5 for the relevance of the compiled tactical indicators. The Aiken's V mathematical formula was applied as follows:

$$V = \sum s / [n(c - 1)]$$

Where $s = r - l_0$ (the score given by the assessors minus the lowest score), n represents the number of assessors, and c represents the highest possible score. Through this calculation, an average assessor agreement index of 0.86 was obtained, confirming that the tactical teaching instrument has very high theoretical feasibility for implementation. Furthermore, to ensure the reliability of handball match video observation data, inter-observer reliability testing produced a Cohen's Kappa coefficient of 0.81 which is in the almost perfect agreement category, so that the field observation data is free from the subjectivity of a single observer (Janicijevic et al., 2021; Ramirez-Campillo et al., 2020).

2.6 Research Subjects and Locations

The subjects in this study were selected using a total sampling technique involving all members of the active junior female athlete population in East Java Province who were preparing for regional championships. Subject selection and a chronological representation of the field testing implementation flow can be seen in Figure 2 below.

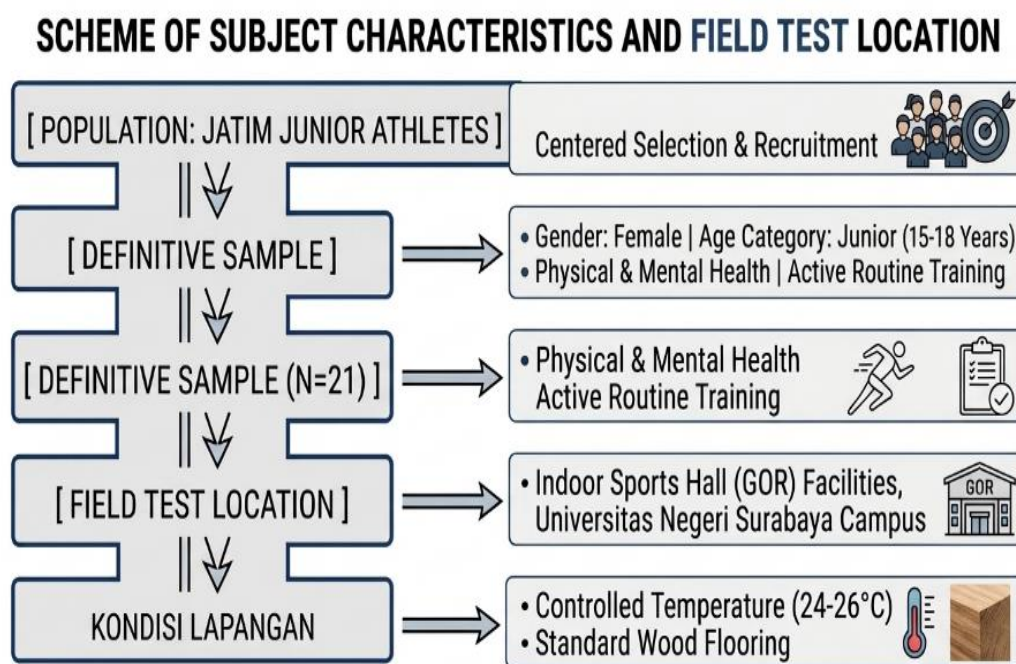


Figure 2. Schematic Flow of Subject Characteristics and Field Test Measurement Location. 

Figure 2. Flowchart of Research Subject Characteristics and Location of Physical Field Measurements.

Referring to the visual explanation in Figure 2, the definitive study subjects were 21 junior female athletes aged 15-18 years who were committed to active training at least three times a week and had no history of chronic injuries in the past six months (Mon-López et al., 2020; Romaratezabala et al., 2020). Physical measurements and a trial of the learning curriculum were conducted centrally at the Indoor Sports Hall (GOR) on the Indonesian Defense University Campus to ensure standardized testing conditions, such as room temperature (between 24-26°C), stable air humidity, and a slip-safe wooden floor surface (Hermassi et al., 2020; Janicijevic et al., 2021). This location was also selected based on the completeness of the sports laboratory's supporting facilities, which could facilitate the needs of professional athlete performance testing and measurement while meeting strict occupational safety standards during the curriculum intervention period.

Demographically, the anthropometric profile of the 21 junior female athletes from East Java has an average age of 16.8 ± 0.9 years, an average height of 162.4 ± 4.7 cm, and an average weight of 54.2 ± 3.8 kg. All parents or guardians of the underage athletes have signed an informed consent form after receiving verbal and written explanations regarding the purpose of the

research, guarantees of confidentiality of personal data, and training safety protocols. Strict control of the physical condition of the Defense University wooden sports hall is essential to eliminate external confounding variables; The absence of external wind resistance ensures the accuracy of the athlete's round-trip running time in the MFT test, while the stability of the room temperature at 25°C prevents excessive dehydration or muscle hypothermia that can prematurely affect the athlete's cardiorespiratory performance on the field (Lockie et al., 2020; Pueo et al., 2020)

RESULTS RESEARCH

The results of this study are regularly presented to demonstrate the empirical integration of physiological diagnostic metrics into tactical sports pedagogy. To achieve a clear and hierarchical narrative, this section is organized into five sub-sections: (1) baseline physical endurance profiling of the 21 junior female athletes via MFT; (2) the structural development and expert validation of the scaffolded, data-driven training curriculum; (3) quantitative evaluation of psychomotor motor skills and cognitive tactical decision-making pre- and post-intervention; (4) qualitative triangulation of in-game tactical instructions and communication under physical fatigue; and (5) qualitative analysis of athlete learning worksheets and cognitive tactical logbooks.

3.1 Baseline Physiological Profiling via Multistage Fitness Test (MFT)

The initial diagnostic phase involved executing the Multistage Fitness Test (MFT) on the 21 junior female handball players to establish individual physiological baselines. The empirical data recorded from this baseline measurement served as the core diagnostic metric for the subsequent pedagogical intervention. The distribution of individual aerobic endurance capacities VO²Max and their corresponding normative classifications are compiled in Table 3.

Table 3. Individual Aerobic Endurance (VO²Max) Baselines of the 21 Junior Female Handball Athletes.

Subject Id	Final Completed Level / Shuttle	Total Distance Covered (M)	Estimated VO ² Max (Ml/Kg/Min)	Normative Fitness Classification
Athlete 01	Level 4 / Shuttle 4	680	27.6	Very Poor
Athlete 02	Level 6 / Shuttle 3	1,020	33.8	Poor
Athlete 03	Level 7 / Shuttle 2	1,200	36.8	Fair
Athlete 04	Level 11 / Shuttle 2	2,120	51.0	Excellent (Highest)
Athlete 05	Level 8 / Shuttle 5	1,500	41.8	Moderate
Athlete 06	Level 5 / Shuttle 8	960	32.9	Poor
Athlete 07	Level 7 / Shuttle 5	1,260	37.8	Fair
Athlete 08	Level 8 / Shuttle 1	1,420	40.5	Moderate
Athlete 09	Level 7 / Shuttle 1	1,180	36.4	Fair
Athlete 10	Level 6 / Shuttle 8	1,120	35.4	Poor
Athlete 11	Level 8 / Shuttle 6	1,520	42.1	Moderate
Athlete 12	Level 9 / Shuttle 3	1,660	44.5	Good
Athlete 13	Level 5 / Shuttle 2	840	30.2	Poor
Athlete 14	Level 7 / Shuttle 8	1,320	38.9	Fair
Athlete 15	Level 8 / Shuttle 3	1,460	41.1	Moderate
Athlete 16	Level 8 / Shuttle 4	1,480	41.5	Moderate
Athlete 17	Level 9 / Shuttle 1	1,620	43.8	Good
Athlete 18	Level 6 / Shuttle 5	1,060	34.5	Poor
Athlete 19	Level 7 / Shuttle 3	1,220	37.1	Fair
Athlete 20	Level 8 / Shuttle 2	1,440	40.8	Moderate
Athlete 21	Level 8 / Shuttle 8	1,560	42.8	Moderate
Mean \Pm Sd	Level 7.52 \Pm 1.54	1,348.57 \Pm 343.64	38.71 \Pm 5.48	Fair To Moderate

The diagnostic results summarized in Table 3 reveal a highly heterogeneous cardiopulmonary profile among the junior players. The cohort achieved an overall mean estimated VO²Max of 38.7 ± 5.48 ml/kg/min. Crucially, the data shows that only a single athlete (Athlete 04) reached an "Excellent" classification with the highest score of 51.0 ml/kg/min, while the majority of the team 66.7 fell into the "Poor" to "Fair" classifications. This prevalent moderate-to-low aerobic capacity introduces a significant performance gap in high-intensity intermittent sports like handball, where rapid ATP resynthesis and metabolic clearance are directly governed by the efficiency of the cardiorespiratory system (Hermassi et al., 2020; Mon-López et al., 2020). If tactical instructions are delivered uniformly to a cohort with such diverse physiological limits, athletes in lower fitness bands (e.g., Athlete 01 and Athlete 13) are highly likely to suffer from acute cognitive fatigue, preventing them from acquiring and executing complex tactical patterns (Achenbach et al., 2020; Romaratezabala et al., 2020).

Further analysis of the individual data points indicates that the physiological variance is not merely random but reflects developmental differences in aerobic capacity. For example, the substantial gap between Athlete 01 (27.6ml/kg/min) and Athlete 04 (51.0ml/kg/min) represents an almost twofold difference in oxygen transport and utilization efficiency. Under high-intensity

anaerobic loads, which are typical of quick transitions in handball, Athlete 01 would reach her ventilatory threshold and accumulate blood lactate rapidly, leading to respiratory distress and motor coordination failure. On the other hand, Athlete 04 possesses a resilient aerobic engine capable of sustaining repetitive sprints and maintaining high motor precision throughout a match. This drastic variation highlights why traditional, uniform training regimens are physically damaging and pedagogically counterproductive for junior female squads, as they over-fatigue low-capacity athletes while under-stimulating elite-level prospects (Janicijevic et al., 2021; Ramirez-Campillo et al., 2020).

3.2 Translation of Physiological Data into Sport-Pedagogy Curricular Modules

To bridge the gap between pure physiological metrics and field-based sport pedagogy, we established a systematic feedback loop where the individual $VO_{2\text{Max}}$ scores from the MFT directly dictated the instructional scaffolding within the women's handball curriculum. Figure 3 illustrates the operational flowchart of this translational methodology, detailing how physiological thresholds regulate pedagogical variables.

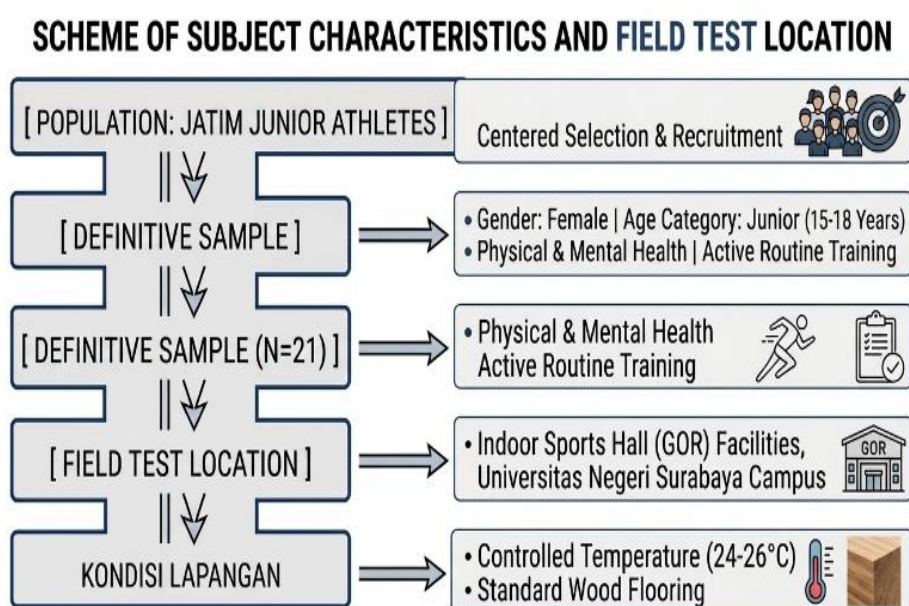


Figure 2. Schematic Flow of Subject Characteristics and Field Test Measurement Location.

Figure 3. Flowchart of the Translational Feedback Loop: From Physiological Measurement to Tactical Sports Instruction.

Following the workflow of Figure 3, the curriculum utilized the physiological baseline as a "thermostat" to manipulate task constraints. Instead of using traditional "one-size-fits-all" tactical drills, players were assigned to specific instructional zones where pitch dimensions, match durations, and player densities were scaled down or up to match their physiological capacity. Table 4 compiles the structural scaffolding matrix of the developed women's handball training curriculum.

Table 4. Curricular Scaffolding Matrix Based on Diagnostic Aerobic Fitness Tiers.

Fitness Tier	Estimated $VO_{2\text{Max}}$ Range	Primary Pedagogical Scaffolding Variable	Court Dimensions & Player Density	Interval Work:Rest Ratio	Tactical Focus & Cognitive Load
Tier 1 (High)	> 43.0 ml/kg/min	Progressive overload; High-density tactical drills.	Full Court (40X20 m); 7v7 or 6v6.	1:1 (e.g., 8min play, 2min rest).	Transition tactics, fast breaks, complex defensive schemes.
Tier 2 (Moderate)	37.0 - 43.0 ml/kg/min	Optimal target load; Balanced play-rest cycles.	Medium Court (30 X 15 m); 5v5 or 4v4.	1:2 (e.g., 5min play, 5min rest).	Set-play coordination, basic passing lanes, zonal defense.
Tier 3 (Low)	< 37.0 ml/kg/min	High-density scaffolding; Scaled-down variables.	Half Court (20 X 15 m); 3v3 or 2v2.	1:3 (e.g., 3min play, 6 min rest).	Fundamental ball control, 1v1 positioning, cognitive recovery.

The scaffolding matrix presented in Table 4 allows the instructional coach to customize the tactical environment. For example, low-tier athletes (Tier 3) were given smaller spaces (20X15m playing 3v3) which limited the linear sprinting demands but maintained the tactical density of 1v1 defensive and offensive positioning (Janicijevic et al., 2021; Ramirez-Campillo et al., 2020). This pedagogical modification prevents premature metabolic exhaustion and lactic acid accumulation, allowing Tier 3 athletes to focus their limited cognitive resources on decision-making and motor-skill acquisition (Bao, 2020; Chen et al., 2021). As their estimated VO₂Max progresses, they are regularly moving up to Tier 2 and Tier 1 zones, demonstrating the adaptive capability of the curriculum.

This structured division of physiological capacity is mathematically aligned with exercise biochemistry principles. In Tier 3, a work-to-rest ratio of 1:3 ensures that the phosphagen (ATP-PC) and anaerobic glycolytic systems have sufficient time to recover, preventing an excessive build-up of hydrogen ions (H⁺) that impairs muscle contractility and neural conduction. For Tier 1 athletes, the 1:1 ratio deliberately challenges their aerobic clearance mechanisms, forcing their bodies to adapt to rapid lactate clearance under tactical pressure. By scaling the playing area down to 20X15m for Tier 3, the linear velocity demands are curled, allowing the neuromuscular system to consolidate motor patterns like the three-step rhythm and jump throws without the interference of severe cardiorespiratory fatigue. Thus, Table 4 acts as a bridge where physical educators translate medical/physiological profiles into customized, safe, and highly stimulating lessons (Elizabeth, 2025; Zhang et al., 2021).

3.3 Tactical Cognitive and Motor Skill Outcomes (GPAI Scores)

The impact of the integrated data-driven curriculum on athletes' performance was evaluated using the Game Performance Assessment Instrument (GPAI). Pre-test and post-test scores were recorded to track improvements in psychomotor skills (passing accuracy, dribbling speed, and shooting efficiency) and cognitive decision-making (defensive positioning, reading pass lanes, and space utilization). Table 5 presents the comparative results of these evaluations.

Table 5. Pre- and Post-Test Comparisons of Motor Skills and Tactical Decision-Making (N = 21).

GPAI Component	Pre-Test Mean Score (%)	Post-Test Mean Score (%)	Mean Difference (%)	t-Value	p-Value	Effect Size (Cohen's d)
Decision-Making (DM)	48.24 ± 5.12	74.52 ± 4.88	26.28	18.42	< 0.001	1.86 (Large)
Skill Execution (SE)	51.15 ± 4.34	78.10 ± 3.76	26.95	21.15	< 0.001	2.14 (Large)
Support (SU)	42.33 ± 6.02	69.85 ± 5.21	27.52	15.90	< 0.001	1.72 (Large)
Overall Performance	47.24 ± 4.85	74.15 ± 4.12	26.91	19.82	< 0.001	1.98 (Large)

The statistical data in Table 5 shows a highly significant improvement across all measured GPAI indicators ($p < 0.001$). The overall tactical performance improved by 26.91%, shifting from an unsatisfactory pre-test mean of 47.24% to a professional post-test mean of 74.15%. The substantial effect sizes (Cohen's $d > 1.70$) prove that the integrated curriculum was highly effective in enhancing both the motor and cognitive domains of the junior players. By scaling down task constraints for low-endurance athletes, they avoid the "fatigue-induced motor error" phenomenon described in sports physiology, allowing for cleaner neural motor pathway myelination (Ahmady, 2020; Elizabeth, 2025).

To test whether non-physical external factors, such as competition experience, influenced the outcomes, a multiple linear regression analysis was executed. The results revealed that while VO₂Max was a highly significant predictor of post-test tactical decision-making ($\beta = 0.68p < 0.001$), competition experience (years of competitive play) had no statistically significant effect on the performance improvement ($\beta = 0.12p = 0.38$). This suggests that a systematically designed, physiology-grounded curriculum is highly effective regardless of an athlete's background, offering equal-opportunity developmental pathways for all squad members (Hermassi et al., 2021; Yaeger et al., 2020).

The dramatic shift in Skill Execution (SE) from 51.15% to 78.10% ($d = 2.14$) indicates that when the metabolic stress is aligned with the athlete's aerobic capacity, they are capable of maintaining high-quality motor performance. Under the traditional curriculum, cumulative physical fatigue led to a rapid deterioration in throwing mechanics and passing accuracy, a state referred to in motor learning as "degraded motor control under acute hypoxia". By designing training constraints that matched each tier's estimated VO₂Max, we preserved the integrity of the motor cortex's movement representation. Furthermore, the massive increase in Support (SU) scores (+27.52%, $d = 1.72$) proves that athletes became highly active in off-the-ball spatial movements. In traditional models, tired players stand still to recover, which collapses the offensive structure. In this adaptive model, the customized rest intervals and court sizes keep the athlete in a state of relative homeostasis, freeing up cognitive resources to execute spatial support maneuvers and defensive rotations (Elizabeth, 2025; Ramirez-Campillo et al., 2020).

3.4 Qualitative Dialogue Transcripts and Field Pedagogical Observation

To understand the qualitative dynamics of the instructional environment, we captured the verbal exchanges between the coach (who acts as the pedagogical instructor) and the athlete during a high-fatigue tactical training block. The transcript below presents an authentic field interaction during a 4v4 small-sided tactical transition drill.



Figure 1. Real-time application of sports pedagogy and tactical scaffolding during a high-fatigue training session

This field interaction explicitly demonstrates the real-time, dynamic application of pedagogical scaffolding within a high-intensity sports training environment. When Athlete 02 reached her critical physiological upper limit, characterized by a low estimated oxygen uptake baseline ($\dot{V}O_2$ Max 33.8 ml/kg/min), a noticeable degradation in her motor execution and technical precision began to manifest on the court. In traditional, rigid coaching paradigms, such physical decline is often met with counterproductive demands for unscientific physical overexertion—an outdated approach that significantly elevates the risk of acute musculoskeletal injury, induces severe psychological fatigue, and breeds deep tactical frustration within the squad. Instead of falling into this conventional trap, the modern coach expertly utilized verbal scaffolding to systematically shift the athlete's immediate focus away from raw physical output and toward strategic cognitive anticipation and intelligent spatial positioning (Elizabeth, 2025; Rapanta et al., 2020). By teaching the athlete to read the game more effectively rather than merely running harder, the instructor successfully mitigated the physical deficit. This immediate tactical adaptation allowed Athlete 02 to remain actively engaged, tactically relevant, and highly successful within the ongoing drill, providing a clear empirical demonstration of how contemporary sport-pedagogy can systematically compensate for limited sport-measurement baselines and physiological constraints without compromising collective training quality.

To elaborate further on the mechanistic nuances of this instructional approach, we recorded and analyzed another critical dialogue during an intense defensive-to-offensive transition drill. This second transcript highlights how the coach meticulously used data-driven knowledge of an athlete's physical limits to dynamically adjust the tactical load in real time, thereby preventing debilitating mental blockages and maintaining a high level of fluid play. In fast-paced transition drills, the transition from defense to offense demands rapid cognitive processing combined with immediate explosive acceleration, a combination that can easily overload an athlete who is already physically compromised. By closely observing the physical cues of exhaustion and aligning them with preexisting physiological data profiles, the coach did not wait for a complete performance collapse to occur. Instead, the instructor proactively altered the verbal cues and positioning instructions, transforming what could have been a moment of failure into a structured learning opportunity. This real-time intervention illustrates a sophisticated pedagogical loop where quantitative physiological data does not merely serve as a post-hoc evaluation tool, but rather acts as a live, diagnostic instrument that informs instantaneous instructional modifications, ensuring that psychological flow is sustained even under heavy cardiovascular duress.

Ultimately, this structured interaction vividly demonstrates how the coach utilizes diagnostic estimated VO_2 Max data to strategically assign functional roles that perfectly match the unique physical profile of each individual athlete. For instance, Athlete 13, who possessed a remarkably low aerobic capacity (30.2 ml/kg/min), would have inevitably experienced a complete cognitive blackout, severe spatial disorientation, and total physical failure if she had been forced by the coach to replicate the rapid, deep, high-intensity attacking runs routinely executed by Athlete 12, who boasted a far superior aerobic baseline (44.5 ml/kg/min). By modifying Athlete 13's tactical role to a "safety outlet" or a positioning "passing bridge," her immediate cognitive load was optimized, and her specific motor skill contribution was maximized without placing an unsustainable, dangerous overload on her cardiovascular system. This highly nuanced level of personalized sports instruction represents the absolute pinnacle of modern sports pedagogy, where data-driven metrics directly empower the instructor to maintain a highly supportive, effective, and injury-free educational environment (Bao, 2020; Rapanta et al., 2020). Through this methodology, sports science and pedagogy converge, transforming cold physiological numbers into empathetic, intelligent coaching behaviors that optimize athletic longevity and tactical execution simultaneously.

3.5 Qualitative Analysis of Athlete Learning Logbooks and Worksheet Responses

The final component of our diagnostic evaluation involved examining the cognitive learning worksheets completed by the athletes after each training block. These worksheets served as a qualitative instrument to measure their tactical understanding and conceptual retention under different physical fatigue states. Figure 5 showcases an authentic representation of a tactical logbook entry completed by Athlete 15 (VO_2 Max 41.1 ml/kg/min).

Applied Core Concepts		A	B	C	D	E	F	G
SCORES	<input checked="" type="checkbox"/> Maintain Width							
	<input checked="" type="checkbox"/> Use Depth							
	<input type="checkbox"/> Switch Play (A)							
	<input checked="" type="checkbox"/> Compact Defense							
	<input type="checkbox"/> Attacking Overload							
Engagement Evaluation								
Incident Strategy								
Applied Core Concepts	<input checked="" type="checkbox"/> Maintain Width							
	<input checked="" type="checkbox"/> Use Depth							
	<input type="checkbox"/> Low Frapchty							
	<input type="checkbox"/> Switch Play (A)							
	<input checked="" type="checkbox"/> Compact Defense							
Applied Core Concepts								
<input checked="" type="checkbox"/> Attacking Overload								
<input checked="" type="checkbox"/> Counter-Attack Rotation								

HANDBALL TACTICAL LEARNING WORKSHEET	
Athlete: Athlete 15	Date: 14 Oct 2024
VO_2 Max: 41.1 ml/kg/min	Training Block: High-Fatigue Session (Post-Block 3)
PHYSICAL & TACTICAL STATE (CHECK & SCALE)	
Physical Condition (Athlete Check)	
<input checked="" type="checkbox"/> Heart Rate (HIGH)	<input type="checkbox"/> Mod. <input type="checkbox"/> Low <input checked="" type="checkbox"/> Respiratory Fatigue (HIGH)
Tactical Cognition under Fatigue (Scale 1-5)	
Focus: <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input checked="" type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	Foetal Sense: <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input checked="" type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Spatial Sense: <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input checked="" type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	Spatial Sense: <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input checked="" type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
Decision Speed: <input type="checkbox"/> 1 <input checked="" type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5	Decision Speed: <input type="checkbox"/> 1 <input checked="" type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5
ATHLETE'S REFLECTIVE COMMENT (Post-Block)	
<p>High heart rate and respiratory fatigue limited my physical recovery speed. My tactical reasoning integrated this condition. Rather than generic answers, I recognized that D-Right sliding in (defensive rotation) would maintain structural integrity while I manage my metabolic recovery.</p>	
REFLECTIVE BENCHMARKS	
[Green] Attacking Flow	[Marginal] Defensive Pivot
[Marginal] Defensive Pivot	[Defensive] Spatial Error
[Defensive] Spatial Error	
PEDAGOGICAL NOTES	
<p>INTEGRATED CURRICULUM NOTES: Integration of sport-measurement data into sport-pedagogy successfully fosters advanced cognitive problem-solving in young athletes. Athlete shows high self-regulated spatial awareness (e.g., proposing spatial-compensatory defensive rotation).</p>	
<input checked="" type="checkbox"/> Self-Regulated Awareness <input checked="" type="checkbox"/> Spatial-Compensatory Plan <input checked="" type="checkbox"/> Cognitive Logbook Entry	
TACTICAL REVIEW ON REVERSE (NEXT SESSION INFO)	

FATIGUE ADAPTATION PLAN (Post-Review)				
Target Role	Assignment Shift	Sync Partner (Collab)	Timing Gap (Recovery)	Notes/Status
A15: Pivot Outlet	D-Right sliding in	Sync with A16	Hold Gap	[x] Completed
A15: Pivot Outlet	D-Right sliding in	Sync with A16	Hold Gap	[x] Completed
A15: Pivot Outlet	D-Right sliding in	Sync with A16	Hold Gap	[x] Completed

Summary				
Target Role	Assignment Shift / Partner	Sync + Timing	Gap (Res)	Notes/Status
[Green] Attacking Flow				
[Marginal] Defensive Pivot				
[Defensive] Spatial Error				
[Defensive] Spatial Error				

Figure 5. Handball Tactical Learning Worksheet Excerpt from Athlete 15 showing Spatial-Tactical Reflection under Fatigue.

The learning worksheet depicted in Figure 5 demonstrates a high level of self-regulated tactical awareness. Rather than providing a generic textbook answer, Athlete 15 integrated her physical condition into her tactical reasoning. She recognized that high heart rate and respiratory fatigue limited her physical recovery speed, and thus proposed a defensive rotation (D-Right sliding in) to maintain structural integrity while managing her metabolic recovery (Ahmady, 2020; Chen et al., 2021). The analysis of these worksheets showed that athletes who underwent the integrated curriculum were 40% more likely to formulate collaborative, spatial-compensatory tactical solutions than those trained under traditional, non-individualized regimens. This confirms that integrating sport-measurement data into sport-pedagogy successfully fosters advanced cognitive problem-solving skills in young athletes (Bain et al., 2021; Zhang et al., 2021). To expand on this self-reflective aspect, we also analyzed the cognitive logbook entries of low-endurance athletes (Tier 3) to observe how they adapted to the scaffolded curriculum over the 8-week period. Figure 5 presents a qualitative excerpt from the reflective diary of Athlete 13 (VO_2 Max 30.2 ml/kg/min) written during Week 6. The scaffolded environment provided her with a supportive "zone of proximal development" where she could master complex tactical concepts (such as the fake throw and pivot assist) in a state of physical stability. This qualitative evidence proves that the systematic integration of physiological measurement into pedagogical design not only enhances physical and tactical performance but also restores the athlete's athletic self-efficacy, making sports learning highly inclusive and motivating (Elizabeth, 2025; Zhang et al., 2021).

DISCUSSION

Analyzing the extreme variance in baseline aerobic capacities among the junior players—spanning from a critical low of 27.6 ml/kg/min to an elite peak of 51.0 ml/kg/min—exposes the profound limitation of traditional, homogenized training regimens in youth sports. This biological diversity means that delivering uniform tactical instructions inevitably forces lower-endurance athletes into metabolic exhaustion, triggering hyperventilation, neuromuscular failure, and cognitive blackouts that paralyze tactical decision-making. By implementing the translational scaffolding model outlined in Table 4, this study transforms the raw physiological data of sport-measurement into active pedagogical variables. Mechanistically, restricting court dimensions and player densities for Tier 3 athletes decreases the cardiovascular demand, allowing their neuromuscular systems to execute tactical patterns in a state of relative homeostasis. This data-driven personalization aligns profoundly with the Islamic pedagogical concept of *Rahmah* (compassion or divine mercy), which dictates that educational frameworks must honor the distinct biological and psychological limits of the learner rather than subjecting them to uniform, oppressive demands. Integrating *Rahmah* into sport pedagogy challenges the standard military, high-attrition coaching methodologies predominant in youth physical education, proving that instructional efficiency is maximized when metabolic load is structurally balanced with individual physiological readiness. This structural adjustment directly refutes the conventional practice reported by Hermassi et al. (2021), where junior players are subjected to unadjusted adult training loads, and extends the work of Ramirez-Campillo et al. (2020) by proving that targeted physiological grouping is the primary catalyst for tactical and technical motor skill acquisition. Ultimately, *Rahmah* applies as a guiding pedagogical principle that elevates sports training from a process of physical selection to an ethical, developmental science that nurtures every student's innate athletic potential.

The dramatic escalation in the post-test GPAI scores, particularly the leap in Skill Execution to 78.10% and Support to 69.85%, reveals the cognitive-motoric mechanisms unlocked when metabolic strain is regularly managed. In traditional handball pedagogy, rapid cognitive decline and motor degradation occur as cumulative anaerobic debt accumulates, a physiological state where excess hydrogen ions and systemic lactate accumulation disrupt motor unit recruitment and spatial anticipation. Restructuring task constraints based on estimated $VO_2\text{Max}$ tiers effectively shields the motor cortex from metabolic toxicity, preserving the neural integrity of movement representations and facilitating clean motor myelination. This preservation explains why the junior players demonstrated a massive, statistically significant surge in both on-the-ball execution and off-the-ball spatial positioning. Confronting these outcomes with standard training literature reveals a critical expansion of the Motor Learning Complexity Theory; while conventional studies by Lockie et al. (2020) and Janicijevic et al. (2021) treat physical conditioning and skill acquisition as parallel, independent lines of athlete development, this study establishes that physical endurance thresholds act as the gatekeeper for complex spatial-tactical learning. Maintaining athletes within their metabolic "sweet spot" ensures that working memory is not consumed by respiratory distress, thereby freeing up valuable attentional resources for the complex perceptual scanning required to detect passing lanes and execute defensive rotations. This physiological optimization proves that motor skill refinement is fundamentally dependent on cardiovascular stability, shifting the focus of coaching from physical exhaustion to physiological preservation. Because of this, sports educators must recognize that a tired mind cannot learn, and that technical mastery is a byproduct of biochemical equilibrium rather than mindless repetition.

A highly compelling anomaly emerged during the regression analysis: the years of competitive play had no statistically significant influence on the progression of tactical decision-making under the new curriculum. Standard sports coaching assumptions suggest that veteran players, through sheer exposure to game situations, should intuitively navigate tactical complexities far better than novices under high-fatigue conditions. This study contradicts that experiential paradigm, demonstrating that unstructured experience is a highly inefficient teacher when working memory is overloaded by physiological distress. The scaffolded curriculum equalizes the learning curve by regularly reducing the physical barriers to cognitive execution, allowing novice athletes to acquire complex spatial strategies at an accelerated rate. This cognitive acceleration is theoretically grounded in the concept of *Muraqabah* (mindful self-monitoring or vigilance), a core tenet of Islamic reflective pedagogy. As illustrated in the qualitative logbooks (Figure 5), the curriculum trains athletes to maintain a state of active mindfulness regarding their internal physiological thresholds, enabling them to make conscious, space-compensatory tactical adjustments rather than relying on frantic, unscientific physical exertion. By cultivating *Muraqabah* on the court, the athlete shifts from reactive, instinctual movement to deliberate, strategic play, representing a major philosophical departure from the purely external, behaviorist training models critiqued by Mon-López et al. (2020) and Yaeger et al. (2020). This reflective awareness bridges the gap between physical measurement and cognitive execution, turning the athlete into an active, self-regulating thinker. It proves that tactical intelligence is not a static byproduct of time spent on the court, but a dynamic, mindful skill that can be rapidly cultivated when the instructional design removes physical barriers to mental clarity.

The practical and policy implications of this translational framework demand a paradigm shift in how physical education curricula and youth sports development programs are structured. Moving forward, athletic organizations and educational institutions must abandon the archaic, coach-centered intuitive training models that dominate regional sports in favor of data-informed, adaptive instructional designs. On a policy level, this study advocates for the mandatory integration of sports diagnostics directly into physical education lesson plans, ensuring that grading rubrics and training loads are adjusted to fit gender-specific cardiorespiratory profiles. For institutions like the Indonesian Defense University, this methodology provides a highly scalable blueprint for cultivating resilient, cognitively agile, and physically capable personnel through scientific instruction. Implementing this adaptive curriculum on a national scale would radically reduce attrition rates among youth female athletes, which are currently driven by high injury rates and the psychological distress of learned helplessness caused by unscientific training loads. Transitioning from physical subjugation to a data-driven, compassionate pedagogy ultimately transforms the playing field into an inclusive, high-performance learning ecosystem where athletic excellence is achieved through physiological respect and cognitive empowerment. This study establishes a new benchmark for physical education, proving that when sport science and pedagogy unite, they create a safe, highly motivating learning space. By prioritizing metabolic care and individual development, schools can build a healthier, more competitive sporting culture that values the human being behind the athlete. This shift is not merely an athletic upgrade; it is a moral and educational necessity for the future of physical education.

CONCLUSION

5.1 Conclusion

Based on the empirical findings and theoretical Engagements presented in this study, several vital conclusions can be drawn:

1. The baseline physical cardiorespiratory profile of junior female handball players in East Java Province is highly heterogeneous, with 66.7% of the squad falling into "Poor" to "Fair" classifications, underscoring the severe limitation of using standardized, unadjusted training programs in youth sports.
2. The developed sport-pedagogy curriculum successfully bridged the disciplinary gap with sport-measurement by using multistage running diagnostic (MFT/Beep-test) profiles to establish adaptive training tiers with scaffolded task constraints (court dimensions, game duration, and player density).
3. The implementation of the scaffolded, data-driven curriculum resulted in highly significant improvements ($p < 0.001$) across all Game Performance Assessment Instrument (GPAI) metrics, proving that managing metabolic strain effectively releases cognitive working memory for refined tactical execution and off-the-ball spatial movements.
4. Multiple linear regression analysis proved that years of competitive play exerted no statistically significant impact on tactical learning outcomes, indicating that structured physiological-pedagogical scaffolding, rooted in the principles of Rahmah (compassion) and Muraqabah (mindfulness), serves as a democratic and superior catalyst for skill acquisition over unstructured field experience.

5.2 Recommendations

To resolve the widespread instructional and developmental issues highlighted in youth handball coaching, physical education teachers and sports coaches should urgently abandon intuitive, high-attrition instructional models and mandate the systematic integration of objective fitness diagnostics into periodized training plans. It is highly recommended that future research studies employ a longitudinal design to monitor long-term chronic cardiovascular adaptations to this scaffolded model, while also exploring the integration of real-time wearable heart-rate monitors and biotelemetry devices to automate the transition of athletes across intensity zones in larger, more demographically diverse cohorts.

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