International Journal Of Multi Research

Online ISSN: 3107 - 7676
IJMR 2026; 2(4): 70-73
2026 July - August
www.allmultiresearchjournal.com

Received: 08-06-2026
Accepted: 09-07-2026
Published: 20-07-2026
DOI: https://doi.org/10.54660/IJMR.2026.2.4.70-73

Two-Year Longitudinal Changes in Training Level Among Male Beach Handball Athletes of the Vietnamese National Team

Nguyen Dac Thinh [1*], Chau Vinh Huy [2], Nguyen Hoang Minh Thuan [3]
Department of of Physical Education and Sport, Ho Chi Minh City University, Vietnam

Corresponding Author; **Nguyen Dac Thinh**

Abstract
Background: Following the establishment of a 29-criterion assessment battery for training level in male beach handball, longitudinal monitoring of training-induced adaptation remains scarce in Asian sports science literature. **Objective:** This study evaluated changes in training level among Vietnamese male national beach handball athletes across three measurement points—baseline (B), after one year (L1), and after two years (L2)—spanning morphological, physiological-biochemical, psychological, physical, and technical domains.
Methods: Fourteen male national team athletes (12 court players, 2 goalkeepers) training at the Ho Chi Minh City Sports Training and Competition Center were assessed using paired comparisons (B–L1, L1–L2, B–L2), growth rate (W%), and paired-sample t-tests.
Main Findings: Morphological indices (height, body mass, BMI, arm span, hand span) showed no statistically significant change ($p > 0.05$), reflecting biological stability in mature athletes. In contrast, physiological-biochemical markers improved markedly, with VO_2max increasing by 8.75% and cardiac function index (HW) decreasing by 39.02% over the full cycle. Psychological reflex measures improved significantly ($p < 0.001$), with complex reaction time improving by 11.11%. All physical fitness tests improved significantly, most notably Yo-Yo endurance (+20.70%) and 5-m sand sprint (−8.48%). Two-point throwing techniques—spinshot (+10.10%) and inflight shot (+9.93%)—improved more than stationary 6-m throws (+8.56%), all at $p < 0.001$.
Conclusion: A structured two-year training program produced comprehensive, statistically significant adaptation across physiological, psychological, physical, and technical domains, while morphology remained a stable foundation, validating the sensitivity of the 29-criterion assessment framework for longitudinal athlete monitoring.

Keyword: Beach Handball, Longitudinal Monitoring, Training Adaptation, Sand-Specific Performance, Growth Rate, National Team Athletes

Introduction

Beach handball has developed rapidly over the past two decades and is now recognized as one of the fastest-growing disciplines of the International Handball Federation (IHF). The sport is characterized by repeated high-intensity actions, including sprinting, jumping, rapid changes of direction, throwing, and defensive contact performed on an unstable sand surface. These movement characteristics impose substantial neuromuscular, physiological, and technical demands on athletes, requiring a high level of physical fitness and sport-specific skills to maintain performance throughout training and competition (Pueo *et al*., 2017; Wang, X *et al*., 2024; Eils, E *et al*, 2022) [6, 2].

Long-term athlete development requires systematic monitoring of training adaptations rather than relying solely on periodic performance evaluation. Contemporary training theory considers athlete assessment an integral component of the training process, providing scientific evidence for adjusting training loads, evaluating adaptation, and optimizing performance. According to Bompa and Buzzichelli (2019) [1], the training process follows the principle of stimulus–adaptation–supercompensation, in which regular monitoring enables coaches to determine whether athletes are responding appropriately to training stimuli and to modify training programs accordingly. Similarly, the American College of Sports Medicine (Riebe, D., *et al*, 2018) [7] recommends periodic multidimensional assessment of elite athletes to monitor physical fitness, physiological adaptation, and sport-specific performance throughout annual and multi-year training cycles.

Recent studies have highlighted the importance of comprehensive monitoring in beach handball. Pueo *et al*. (2017) [6] demonstrated that elite beach handball performance depends on explosive strength, sprint ability, agility, and repeated high-intensity efforts. Wang, X., *et al*. (2024) further reported that improvements in muscular power and anaerobic performance are closely associated with competitive success in handball athletes. More recently, Eils, E., *et al*. (2022) [2] proposed a standardized sand-specific testing profile, emphasizing the importance of evaluating athletes at critical stages of the training season to quantify adaptation and support evidence-based coaching decisions. These findings indicate that multidimensional assessment provides valuable information for optimizing long-term training and improving competitive performance.

Although beach handball has achieved remarkable international development, longitudinal investigations examining changes in athletes' training level remain limited. Most published studies have employed cross-sectional designs or short-term intervention protocols focusing on isolated physical or physiological variables, whereas comprehensive monitoring across morphological, physiological-biochemical, psychological, physical, and technical domains over multiple years has rarely been reported, particularly among elite athletes (Pueo *et al*., 2017; Wang, X *et al*., 2024; Eils, *et al*, 2022) [6, 2]. Furthermore, no published longitudinal study has comprehensively evaluated the training level of Vietnamese National Beach Handball athletes using a standardized criterion system. This gap limits the availability of scientific evidence for assessing long-term training effectiveness and developing evidence-based coaching strategies for high-performance beach handball in Vietnam.

Building upon the validated 29-criterion assessment battery established in the first objective of the parent dissertation, the present study represents the second phase of the research program by examining longitudinal changes in training level over a two-year period. Fourteen male athletes from the Vietnamese National Beach Handball Team were evaluated at three time points (baseline, one year, and two years), covering five domains: morphological characteristics, physiological-biochemical indicators, psychological characteristics, physical fitness, and technical performance. Changes in training level were quantified using growth rate (W%) and paired-sample *t*-tests to determine the magnitude and statistical significance of training adaptations. The findings are expected to provide scientific evidence regarding the long-term effectiveness of the national training program, identify the components most responsive to systematic training, and contribute practical recommendations for optimizing athlete monitoring and training planning in elite beach handball.

2. Theoretical Basis for Assessing Training-Level Change

2.1 The Role of Longitudinal Monitoring in Training Control

Bompa and Buzzichelli (2019) [1] establish that all training load decisions must be grounded in scientific assessment data and follow the stimulus–adaptation–supercompensation cycle. Repeated assessment over time serves four functions: confirming the cumulative effectiveness of a training program, detecting growth plateaus requiring adjustment, individualizing progressive overload, and supporting predictive decision-making for athlete selection and screening. Tyshchenko, Kobezskyi, and Nikulichev (2025) propose the sand test profile applied at key seasonal points, consistent with the Long-Term Athlete Development (LTAD) framework; because the sand surface alters the stretch-shortening cycle and energy expenditure, longitudinal tracking of sand-specific and sport-specific tests (Yo-Yo, spinshot/inflight throwing, change of direction) carries particular significance.

2.2 Statistical Indices of Change

The study employed the arithmetic mean and standard deviation, the growth rate formula

$$W = \frac{\bar{x}_{after} - \bar{x}_{before}}{0.5(\bar{x}_{after} + \bar{x}_{before})} \times 100$$

(where negative W% for time- or reaction-based metrics indicates improvement), and paired-sample t-tests comparing B–L1, L1–L2, and B–L2 at significance levels of $p < 0.05$ or $p < 0.001$.[2]

2.3 Expected Direction of Change

For mature male national team athletes, morphological indices (height, arm span, hand span) were expected to remain stable, with body mass and BMI fluctuating only mildly with nutrition and training load. Physiological, physical, technical, and psychomotor components were expected to improve meaningfully if training stimuli were sufficient and recovery adequate, consistent with sand-based plyometric and speed intervention research (Sáez de Villarreal *et al*., 2024) [8] and the assessment frameworks of Lemos and Martínez-Rodríguez.

2.4 Methods

Fourteen male Vietnamese national beach handball athletes (12 court players, 2 goalkeepers) training at the Ho Chi Minh City Sports Training and Competition Center were assessed at three time points: baseline (B), after one year (L1), and after two years (L2), with paired comparisons B–L1, L1–L2, and B–L2. Data collection covered anthropometry (height, body mass, BMI, arm span, hand span), physiological-biochemical function (resting heart rate, cardiac function index HW, VO_2max, testosterone, cortisol, red blood cell count, hemoglobin), psychology (eye-hand reflex, eye-foot reflex, complex reflex), physical fitness (vertical jump, hand-grip strength, 5/10/20-m sprint, 5-m sand sprint, Yo-Yo test, single-leg triple hop, hexagon agility test), and technique (6-m stationary throw, spinshot, inflight shot velocity). Statistical analysis (mean, SD, W%, paired t-test) was conducted using SPSS and Excel.

3. Results

3.1 Morphological Stability

Height, body mass, BMI, arm span, and hand span showed minimal variation across all three time points, with no statistically significant differences in any pairwise comparison ($p > 0.05$). Height remained stable at approximately 1.83 m; body mass declined slightly from 82.06 kg to 80.55 kg after year one before rising marginally to 80.94 kg after year two, with BMI following a corresponding pattern (24.31 → 23.89 → 24.00 kg/m²). The declining standard deviation in body mass (11.58 → 9.18 → 8.85) suggests increasing homogeneity within the squad over time.

3.2 Physiological-Biochemical Adaptation

Most physiological-biochemical indices improved significantly across comparison periods. The table below summarizes key findings.

Indicator	Comparison	W (%)	t	p
VO2max	B–L2	8.75	22.06	<0.0001
Resting heart rate	B–L2	−12.50	−4.34	<0.0001
HW (cardiac index)	B–L2	−39.02	−4.34	<0.0001
Testosterone	B–L2	15.00	5.16	0.0002
Cortisol	B–L2	−22.22	−9.10	<0.0001
Red blood cell count	B–L2	6.48	5.32	0.0001
Hemoglobin	B–L2	5.19	4.53	0.0006

Resting heart rate declined from approximately 68 to 60 beats/min, HW decreased from approximately 9.80 to 6.60, testosterone rose from approximately 18.50 to 21.50 nmol/L, and cortisol fell from approximately 550 to 440 nmol/L across the two-year period, indicating a more efficient cardiovascular system alongside improved endocrine-hematological recovery status. Notably, the testosterone changes between B and L1 did not reach significance ($p = 0.0564$), but the full two-year cycle was clearly significant.

3.3 Psychological (Reflex) Adaptation

All three reflex tests improved significantly at every comparison point ($p < 0.001$). Complex reflex time showed the largest cumulative improvement (W B–L2 = −11.11%), followed by eye-foot reflex (−10.01%) and eye-hand reflex (−8.70%), reflecting enhanced information-processing speed and decision-making capacity directly relevant to beach handball's confined playing space and rapid defensive pressure.

3.4 Physical Fitness Adaptation

All monitored physical fitness indices improved significantly ($p < 0.001$ or $p < 0.05$). Vertical jump increased by 7.27% (B–L2), hand-grip strength by 5.91%, and sprint times over 5, 10, and 20 m decreased consistently, with 5-m sand sprint improving by −8.48%. The Yo-Yo test showed the largest overall gain among physical measures, rising from 1,311.43 ± 204.67 m to 1,614.29 ± 246.88 m (W B–L2 = 20.70%, $p < 0.001$). Single-leg triple hop improved on both legs (left: +7.78%; right: +8.74%), accompanied by a marked reduction in inter-limb asymmetry (W = −58.64%). Hexagon agility test times improved on both sides, but the inter-limb asymmetry ratio increased over the full cycle (approximately 3.14% → 4.23%, $p < 0.05$ at B–L2), signaling a need for targeted bilateral balance training.

3.5 Technical Adaptation

All three throwing techniques improved significantly ($p < 0.001$). Spinshot velocity increased by 10.10% and inflight shot by 9.93%, both exceeding the improvement in stationary 6-m throws (8.56%), indicating that training most strongly enhanced the two-point techniques central to modern competitive scoring strategy.

3.6 Summary of Change Across Domains

Of the five criterion groups, four (physiological-biochemical, psychological, physical, technical) showed statistically significant improvement, while morphology remained stable, providing a favorable and consistent foundation. The largest cumulative gains consistently appeared in the B–L2 comparison, confirming the long-term effectiveness of the training program.

4. Discussion

4.1 Morphological Stability as a Training Foundation

The absence of significant morphological change reflects the strong genetic and biological-maturational determination of anthropometric traits in adult athletes, contrasting with the more trainable physiological, physical, and technical domains. A BMI near 24 kg/m² appears well-suited to the locomotion, jumping, and contest demands of sand-based play without requiring the greater body mass sometimes seen in indoor handball positions. Morphological stability does not imply an absence of adaptation; rather, it indicates that training effects concentrate in functional, physical, and technical qualities.

4.2 Physiological-Biochemical Adaptation

Reduced resting heart rate and HW index reflect more economical cardiac function and improved recovery capacity between bouts of activity—critical for an intermittent sport with substantial time spent in anaerobic heart-rate zones on sand. The combination of rising testosterone, red blood cells, and hemoglobin alongside falling cortisol represents a favorable recovery and hematological profile, consistent with the supercompensation principle and appropriate for scientific monitoring of elite athletes.

4.3 Psychological Adaptation

Continuous improvement in reflex measures across both B–L1 and L1–L2 periods indicates that training and competition stimuli sustained their effect on psychomotor components rather than producing improvement only in the first year. This finding is particularly relevant given beach handball's narrow court dimensions and brief ball-handling windows, which demand rapid decision-making under defensive pressure.

4.4 Physical Fitness Adaptation

Hand-grip strength improvement paralleling gains in throwing velocity supports the previously established correlation between grip strength and throw speed (Lemos *et al.*, 2020). The pronounced improvement in 5-m sand sprint reinforces the principle that sand-surface specificity must be reflected in assessment and training. The continued significance of Yo-Yo improvement in the second year (L1–L2 W = 9.84%) demonstrates that intermittent endurance gains were not confined to the initial training year. However, the widening inter-limb asymmetry in the hexagon agility test represents a notable coaching concern requiring supplementary bilateral balance and unilateral training interventions to reduce injury risk on the unstable sand surface.

4.5 Technical Adaptation

The disproportionately larger improvement in spinshot and inflight throwing velocity—both worth two points under IHF scoring rules—compared to stationary 6-m throws indicates that training appropriately targeted the techniques most central to modern competitive scoring strategy. These gains align with concurrent improvements in grip strength and lower-limb fitness, both mechanically linked to throws involving leg and trunk participation.

4.6 Limitations and Future Directions

The sample of 14 national team athletes represents a narrow, specialized population, limiting generalizability beyond this cohort. Positional differentiation was not analyzed in this study, and body composition metrics (fat mass, muscle mass) were not incorporated into morphological monitoring. Future work should link these longitudinal findings to a standardized scoring and classification system (Objective 3) to complete a comprehensive training-control tool.

5. Conclusion

Two years of systematic training produced comprehensive, statistically significant adaptation in physiological, psychological, physical, and technical domains among male Vietnamese national beach handball athletes, while morphology remained a stable and favorable foundation. These findings validate the sensitivity of the 29-criterion assessment framework for longitudinal monitoring and provide the first Asian-context evidence documenting training-level change in elite male beach handball athletes over a two-year period.

6. Recommendations

- Maintain and individualize training loads to sustain growth rates in subsequent phases, particularly for intermittent endurance (Yo-Yo), sand-specific speed, and two-point throwing technique
- Incorporate bilateral balance and functional symmetry training, particularly addressing hexagon agility asymmetry
- Add body composition assessment (fat mass, muscle mass) to deepen morphological monitoring
- Use the longitudinal dataset as a foundation for developing scoring scales, classification systems, and performance forecasting (Objective 3)
- Where sample size permits, analyze training-level change by playing position.

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How to Cite This Article
Thinh ND, Huy CV, Thuan NHM. Two-Year Longitudinal Changes in Training Level Among Male Beach Handball Athletes of the Vietnamese National Team. International Journal of Multi Research. 2026; 2(4): 70-73.