

Development of A Training Model For Race Walking Technique And Endurance in Athletes Aged 14–18 Years

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Abstract

This study aimed to develop a training model for race walking technique and endurance for athletes aged 14–18 years. The research employed the Research and Development (R&D) method based on the Borg and Gall model. The research participants consisted of race walking athletes from Southeast Sulawesi, Indonesia. A total of 16 athletes participated in the small-group trial, 35 athletes in the large-group trial, and 32 athletes in the effectiveness test. Data were collected through field observations, interviews, questionnaires, race walking technique assessment tests, and endurance testing using the Balke Test. The findings revealed that: (1) a race walking technique and endurance training model specifically designed for athletes aged 14–18 years was successfully developed; (2) expert validation confirmed that 15 training models were feasible and appropriate for implementation; and (3) the developed training model was proven to be effective in improving both race walking technique and athletes' endurance after its implementation. These findings indicate that the developed training model can serve as an effective and practical training guideline for coaches in enhancing the technical performance and endurance capacity of young race walking athletes.

Keywords: Training Model; Race Walking Technique; Endurance.

Introduction

1. BACKGROUND OF THE STUDY

Race walking is one of the most technically demanding events in athletics because success depends not only on physiological fitness but also on strict adherence to competition rules governing continuous ground contact and knee extension during the support phase. Unlike running, race walking requires athletes to maintain efficient movement patterns while sustaining high levels of aerobic endurance over long distances. Consequently, athletes must simultaneously develop technical proficiency and physical endurance to achieve optimal performance without committing technical violations. Previous studies have demonstrated that technical efficiency and endurance are the two primary determinants of race walking performance, particularly among adolescent athletes whose physical and motor development is still progressing (World Athletics, 2023; Bompa & Buzzichelli, 2019). Therefore, structured training models that integrate technical and physiological components are essential to support long-term athlete development.

Adolescence, particularly between the ages of 14 and 18 years, represents a critical period for athletic development. During this stage, athletes experience rapid growth in musculoskeletal structure, neuromuscular coordination, cardiovascular capacity, and cognitive abilities, all of which influence sport performance. According to the Long-Term Athlete Development (LTAD) framework, training programs designed for adolescents should emphasize progressive skill acquisition, movement efficiency, and aerobic conditioning rather than early specialization or excessive training loads (Balyi et al., 2013). In race walking, improper training during this developmental stage may lead to inefficient gait mechanics, reduced endurance capacity, increased fatigue, and a greater likelihood of disqualification during competition due to technical infractions (World Athletics, 2023).

Technical mastery is fundamental in race walking because even physically superior athletes may fail to perform successfully if their walking technique violates competition regulations. World Athletics specifies that race walkers must maintain visible contact with the ground and keep the advancing leg straight from the moment of first contact until it passes beneath the body. These technical requirements demand precise motor coordination, balance, flexibility, and rhythm, all of which require systematic and repetitive practice over an extended period (World Athletics, 2023). Research in motor learning also suggests that technical skills improve more effectively when training follows structured progression and incorporates continuous feedback, demonstration, and

performance evaluation (Schmidt & Lee, 2019). Therefore, developing an evidence-based training model that systematically enhances race walking technique is highly important for adolescent athletes.

Besides technical proficiency, endurance is another essential determinant of race walking performance. Race walking competitions require athletes to maintain moderate-to-high intensity exercise over prolonged periods, making aerobic endurance the primary physiological component supporting performance. Athletes with higher aerobic capacity can sustain optimal walking speed while delaying fatigue and maintaining technical consistency throughout the race. According to Kenney, Wilmore, and Costill (2021), endurance training improves cardiovascular efficiency, oxygen utilization, muscular endurance, and recovery capacity, all of which contribute significantly to endurance-based sports. Similarly, endurance development among youth athletes should be planned progressively according to age, biological maturation, and training experience to avoid overtraining while maximizing physiological adaptation.

Although race walking has long been included in national and international athletics competitions, many training programs continue to separate technical practice from endurance development. Coaches frequently emphasize either technical drills or physical conditioning without integrating both components into a comprehensive training model. Such fragmented approaches often limit athletes' ability to maintain correct walking mechanics under fatigue, even though technical deterioration commonly occurs during the latter stages of endurance events. Bompá and Buzzichelli (2019) argue that modern athletic training should integrate technical, tactical, physical, and psychological elements within a unified training system to maximize performance adaptation. Consequently, integrated training models are increasingly recognized as more effective than isolated training methods.

In Indonesia, particularly in regional athletics development programs, standardized training models specifically designed for adolescent race walkers remain limited. Coaches often rely on personal coaching experience or general athletics training programs that have not been scientifically validated for race walking events. This situation creates inconsistencies in training implementation and limits opportunities to optimize athlete performance during the developmental stage. Furthermore, there is relatively little research focusing on the development and validation of race walking training models that simultaneously address technical skills and endurance improvement among athletes aged 14–18 years. This gap highlights the need for research that produces practical, validated, and effective training models suitable for coaches and young athletes.

The Research and Development (R&D) approach proposed by Borg and Gall provides a systematic framework for producing educational and training products that undergo expert validation, field testing, revision, and effectiveness evaluation before implementation (Borg & Gall, 2003). This methodology is particularly appropriate for sports science because it ensures that newly developed training models are theoretically sound, practically applicable, and empirically validated. Through iterative development processes involving expert judgment, small-group trials, large-group trials, and effectiveness testing, the resulting training model can better meet the actual needs of athletes and coaches.

In this study, the proposed training model combines structured race walking technique exercises with progressive endurance training specifically designed for athletes aged 14–18 years. The development process incorporates observations, interviews, questionnaires, technical performance assessments, and endurance measurement using the Balke Test. The resulting product consists of fifteen validated training models that emphasize correct walking mechanics, movement efficiency, aerobic endurance, and progressive skill development. Integrating these components is expected to improve both technical execution and physiological performance while providing coaches with practical training guidelines that are adaptable to adolescent athletes.

Considering the importance of integrating technical proficiency and endurance development during adolescence, this study seeks to address the existing gap by developing and validating a comprehensive training model for young race walkers. Specifically, the objectives of this study are (1) To develop a training model for race walking technique and endurance for athletes aged 14–18 years, (2) To determine the feasibility of the developed training model through expert validation and field testing; and (3) To examine the effectiveness of the developed training model in improving race walking technique and endurance performance among athletes aged 14–18 years.

2. LITERATURE REVIEW

2.1 Race Walking

Race walking is a competitive athletics discipline characterized by specific technical regulations that distinguish it from running. According to World Athletics (2023), race walking requires athletes to maintain continuous contact with the ground while ensuring that the advancing leg remains straight from the moment of first ground contact until it passes beneath the body. These rules make race walking one of the most technically demanding endurance events because athletes must maintain legal movement patterns while sustaining high walking speeds over long distances.

Unlike conventional walking, race walking combines biomechanical efficiency, aerobic endurance, neuromuscular coordination, and technical precision. Athletes who fail to maintain proper technique are subject to warnings and eventual disqualification during competition. Consequently, race walking performance depends not only on physiological fitness but also on mastery of technical movement patterns developed through systematic training.

Research conducted by Pavei et al. (2014) explains that race walking technique is characterized by efficient stride length, controlled stride frequency, pelvic rotation, hip mobility, and minimal vertical oscillation of the body's center of mass. These biomechanical characteristics enable athletes to increase speed while complying with race walking regulations. The authors further emphasize that stride length contributes more substantially to race walking speed than stride frequency, highlighting the importance of technique-oriented training. Therefore, race walking training programs should not only improve athletes' physical capacity but also systematically develop biomechanical efficiency and technical consistency throughout competition.

2.2 Race Walking Technique

Technique is one of the primary determinants of success in race walking competitions. Proper technique enables athletes to achieve greater movement efficiency while minimizing energy expenditure and reducing the likelihood of technical violations. According to World Athletics (2023), the fundamental components of race walking technique include: continuous ground contact, straight supporting knee, proper heel-to-toe foot placement, efficient hip rotation, coordinated arm movement and optimal stride length and cadence.

These technical elements function together to produce efficient locomotion while satisfying competition regulations. Biomechanical studies demonstrate that elite race walkers exhibit highly coordinated lower-limb and upper-body movements. Efficient pelvic rotation increases stride length without increasing flight time, while coordinated arm movements assist balance and forward propulsion. Additionally, minimizing unnecessary vertical displacement reduces energy expenditure and delays fatigue during prolonged exercise.

Motor learning theory also supports systematic technical development. Schmidt and Lee (2019) argue that complex motor skills improve through repetitive practice accompanied by feedback, correction, and progressive difficulty. Consequently, race walking technique should be trained progressively using structured drills specifically designed according to athletes' developmental stages.

2.3 Endurance in Race Walking

Endurance refers to the body's ability to sustain prolonged physical activity while delaying the onset of fatigue. In race walking, aerobic endurance represents the dominant physiological component because competitions require athletes to maintain moderate-to-high exercise intensity over extended distances. Kenney, Wilmore, and Costill (2021) define endurance as the physiological capacity to perform continuous muscular work through efficient oxygen delivery, cardiovascular function, and metabolic adaptation. Improvements in endurance are associated with increased maximal oxygen uptake ($\text{VO}_{2\text{max}}$), lactate threshold, cardiac output, and muscular oxidative capacity.

Previous physiological research involving competitive race walkers found that performance is strongly associated with aerobic capacity and lactate threshold. Athletes possessing higher aerobic fitness are capable of maintaining faster race walking velocities while preserving technical efficiency throughout competition.

For adolescent athletes, endurance training should be developed progressively through age-appropriate exercise intensity, duration, and frequency. Long-term endurance development also contributes to improved recovery capacity, movement efficiency, and injury prevention.

2.4 Training Model

A training model is a systematic framework that organizes training activities according to scientific principles to achieve predetermined performance objectives. Training models integrate learning objectives, exercise progression, training methods, evaluation procedures, and performance outcomes into a structured program. Bompa and Buzzichelli (2019) explain that effective athletic training models integrate physical conditioning, technical skills, tactical preparation, and psychological development through systematic periodization. Well-designed training models allow coaches to deliver progressive learning experiences that optimize athlete adaptation while minimizing excessive fatigue and injury risk.

For adolescent athletes, training models should consider biological maturation, motor development, and individual differences. Therefore, training activities must progress from simple to complex movement patterns while maintaining appropriate training loads. Within race walking, an integrated training model combining technical exercises and endurance development is expected to produce superior performance compared with conventional approaches emphasizing only isolated physical or technical training.

2.5 Development of Training Models through Research and Development (R&D)

Research and Development (R&D) is a research methodology aimed at producing educational or training products through systematic design, validation, revision, and effectiveness testing. According to Borg and Gall (2003), the R&D model consists of several sequential stages, including: 1) Research and information gathering, 2) Planning, 3) Product development, 4) Preliminary field testing, 5) Product revision, 6) Main field testing, 7) Operational product revision, 8) Operational field testing, 9) Final product revision and 10) Dissemination and implementation.

Unlike experimental research, R&D emphasizes both product development and empirical validation. The resulting product must demonstrate practicality, feasibility, and effectiveness before implementation.

Within sports science, R&D has become increasingly popular because it allows researchers to develop scientifically validated training models capable of addressing practical coaching problems.

2.6 Long-Term Athlete Development (LTAD)

The Long-Term Athlete Development (LTAD) framework provides scientific guidance for designing age-appropriate athletic training programs.

According to Balyi, Way, and Higgs (2013), athletes aged 14–18 years generally enter the Train to Train and Train to Compete stages. During these stages, training should emphasize: refinement of sport-specific techniques, aerobic endurance development, movement efficiency, coordination, tactical understanding and gradual increases in training volume and intensity.

LTAD also recognizes that biological maturation varies considerably among adolescents; therefore, coaches should individualize training progression according to athletes' developmental characteristics rather than chronological age alone. The proposed race walking training model in this study aligns with LTAD principles because it integrates technical mastery and endurance development appropriate for adolescent athletes.

2.7 Motor Learning Theory

Motor learning theory explains how individuals acquire, refine, and retain movement skills through practice and experience. Schmidt and Lee (2019) describe motor learning as relatively permanent changes in movement capability resulting from structured practice. Effective motor learning involves repeated practice, augmented feedback, error correction, variability of practice, and gradual progression toward automatic performance.

Race walking represents a complex closed motor skill requiring high levels of coordination, rhythm, balance, and movement consistency. Consequently, coaches should provide structured technical drills with continuous performance feedback to facilitate long-term skill acquisition. Applying motor learning principles within a race walking training model enables athletes to improve movement efficiency while maintaining legal race walking mechanics under competitive conditions.

3. RESEARCH METHODOLOGY

3.1 Research Design

This study employed a quantitative Research and Development (R&D) approach using the Borg and Gall development model (Borg & Gall, 2003). The R&D approach was selected because it provides a systematic framework for designing, validating, revising, and evaluating educational or training products before implementation. In the present study, the product developed was an integrated training model focusing on race walking technique and endurance for athletes aged 14–18 years.

The development process consisted of ten sequential stages: (1) Research and information collection, (2) Planning, (3) Preliminary product development, (4) Preliminary field testing, (5) Product revision, (6) Main field testing, (7) Operational product revision, (8) Operational field testing, (9) Final product revision and (10) Dissemination and implementation. Throughout these stages, the training model underwent iterative revisions based on expert judgment and field-testing results to ensure its validity, practicality, and effectiveness.

The effectiveness of the developed model was subsequently evaluated using a quantitative pretest–posttest control group design. This design enabled comparison between athletes receiving the newly developed training model and those following conventional training programs, thereby providing empirical evidence regarding the effectiveness of the intervention.

3.2 Research Setting and Participants

The study was conducted in Southeast Sulawesi Province, Indonesia, between January 2025 and April 2026. Small-scale field testing was carried out at Betoambari Stadium, Baubau City, whereas the large-scale field trial and effectiveness testing were conducted at Benubenua Stadium, Kendari City. The participants consisted of competitive race walking athletes aged 14–18 years who were actively registered with regional athletics organizations and clubs under the Provincial Athletics Association (PASI) of Southeast Sulawesi. Three stages of participant recruitment were implemented.

- 1) Small-scale field testing: 16 athletes representing four district PASI organizations and two athletics clubs in Baubau.
- 2) Large-scale field testing: 35 athletes representing thirteen district/city PASI organizations and three athletics clubs in Kendari.
- 3) Effectiveness testing: 32 athletes randomly assigned into an experimental group ($n = 16$) and a control group ($n = 16$).

Participants were selected because they met the inclusion criteria of actively participating in race walking training programs, belonging to the target age group, and being medically fit to participate throughout the study period.

3.3 Development of the Training Model

The development of the race walking training model followed the Borg and Gall framework. Initially, a comprehensive needs analysis was conducted through field observations, interviews with coaches, literature reviews, and analysis of existing race walking training practices. Based on these findings, an initial prototype consisting of six training modules comprising eighteen exercise variations was developed. The exercises were designed to improve both technical execution and aerobic endurance while accommodating the physiological characteristics of athletes aged 14–18 years. Exercise intensity was progressively organized into light-, moderate-, and high-intensity categories following established principles of sports training and motor learning. The prototype was subsequently evaluated by three experts representing athletics coaching, sports training, and motor learning and sports measurement. Their recommendations were incorporated into successive revisions before the model proceeded to small-scale and large-scale field testing.

Feedback collected during both field trials was used to refine exercise instructions, equipment configuration, safety procedures, exercise progression, and training objectives until the final prototype was produced.

3.4 Instruments and Data Collection

Data collection involved both qualitative and quantitative techniques throughout the development process. Qualitative data were collected through field observations, semi-structured interviews, expert validation forms, questionnaires, and documentation. These data were primarily used during the needs analysis, product validation, and product revision stages.

Quantitative data were obtained from technical performance assessments and endurance testing conducted before and after the intervention.

Race walking technique was evaluated using a structured observational assessment developed according to the official World Athletics Competition Rules. The assessment included five performance domains: starting position, supporting-leg mechanics, knee extension, arm movement, pelvic movement and finishing posture.

Each performance indicator was scored using a dichotomous scale in which correct execution received two points and incorrect execution received zero points.

Athletes' aerobic endurance was assessed using the 15-minute Balke Test, during which participants performed continuous race walking for fifteen minutes. Performance was recorded based on the total distance completed while maintaining legal race walking technique. The Balke Test has been widely used to estimate aerobic endurance and functional exercise capacity in athletic populations.

Prior to implementation, all instruments underwent validity and reliability evaluation using the test–retest method. Construct validity was examined using Pearson Product-Moment correlation analysis, whereas reliability coefficients were calculated through repeated measurements. Statistical analyses were performed using SPSS version 25, with significance established at $p < .05$.

3.5 Experimental Procedures

The effectiveness evaluation employed a pretest–posttest control group design. Participants were randomly assigned into an experimental group and a control group. Both groups completed identical pretests consisting of race walking technique assessment and the 15-minute Balke endurance test. The experimental group subsequently participated in the newly developed race walking technique and endurance training model, whereas the control group continued following conventional race walking training routinely implemented by

their coaches. After completion of the intervention period, both groups completed identical posttests using the same assessment procedures. This design enabled comparisons of performance improvements within groups as well as between groups, thereby providing evidence regarding the effectiveness of the developed training model.

3.6 Data Analysis

Qualitative data obtained from observations, interviews, and expert evaluations were analyzed descriptively to identify weaknesses of the prototype and generate recommendations for product revision throughout the R&D process. Quantitative data were analyzed using IBM SPSS Statistics version 25. Instrument validity was assessed using Pearson Product–Moment correlation, whereas instrument reliability was examined using the test–retest reliability coefficient. Descriptive statistics, including means and standard deviations, were calculated for all outcome variables. Prior to hypothesis testing, the assumptions of normality and homogeneity of variance were examined. The effectiveness of the developed training model was evaluated using:

- 1) Paired-samples t-tests to compare pretest and posttest scores within each group,
- 2) Independent-samples t-tests to compare posttest outcomes between the experimental and control groups and
- 3) Normalized Gain (N-Gain) analysis to determine the magnitude of improvement achieved following implementation of the developed training model.

Statistical significance was established at $\alpha = 0.05$. N-Gain values were interpreted according to the categories proposed by Delipinar and Kocaoglu (2016), where values greater than 0.70 indicate high effectiveness, values between 0.30 and 0.70 indicate moderate effectiveness, and values below 0.30 indicate low effectiveness.

4.1 FINDINGS

4.1 Development of the Preliminary Product

(Research Question 1: How was the race walking technique and endurance training model for athletes aged 14–18 years developed?)

Following the preliminary study, which included a comprehensive literature review, needs assessment, field observations, and research planning, the researchers designed the initial prototype of a race walking technique and endurance training model beginning in early 2025. The development process was guided by the principles of systematic instructional design and sport-specific training methodology to ensure that every exercise addressed the biomechanical and physiological characteristics of race walking.

The preliminary product was developed to improve both race walking technique and aerobic endurance among athletes aged 14–18 years. Each exercise model was systematically organized according to its objectives, movement characteristics, equipment requirements, implementation procedures, level of difficulty, and safety considerations. Furthermore, the sequence of activities progressed from simple technical movements toward more complex coordination and endurance tasks, enabling athletes to master fundamental skills before performing more demanding movement combinations.

The product development process was based on three major sources of information: (1) Findings from the preliminary needs analysis, (2) Recommendations obtained from literature related to race walking biomechanics and endurance training, and (3) Practical considerations gathered from coaches and athletes during the preliminary investigation. These stages resulted in 33 preliminary exercise models consisting of various combinations of race walking technical drills and endurance-oriented exercises. After further evaluation during the product development process, overlapping movement patterns and exercises with similar training objectives were merged, refined, and simplified. Consequently, the preliminary prototype was finalized into 25 representative training models, which were considered capable of representing all essential technical and endurance components required for adolescent race walkers.

Overall, the developed training package emphasizes five major performance components: improvement of race walking technique, enhancement of hip mobility and stride efficiency, improvement of postural stability and body alignment, development of lower-limb muscular endurance and enhancement of aerobic endurance and movement efficiency. The final preliminary product consisted of six categories of training models with a total of 25 structured exercise variations, each designed according to progressive training principles.

Table 1. Preliminary Design of the Race Walking Technique and Endurance Training Models

Category	Exercise Models	Number of Variations	Primary Objective
S-Series Racewalk	Racewalk S1; S1–S2–S3; S3–S1–S2; S2; S2–S1–S3; S3; S3–S2–S1	7	Improve arm-leg coordination, hip mobility, balance, posture, and stride efficiency
U-Series Racewalk	Racewalk U-1; Racewalk U-2	2	Develop cardiovascular endurance and lower-limb muscular endurance
M-Series Racewalk	Racewalk M-1; M-2; M-3; M-4	4	Improve body posture, heel strike, center of gravity control, and upper-body coordination
Pyramid Racewalk	Position 1; Position 2; Position 3	3	Improve endurance, stride length, and progressive race walking performance
E-Series Racewalk	Racewalk e-1; Racewalk e-2	2	Enhance aerobic endurance through continuous walking exercises
N-Series Racewalk	N1–N2–N3; N2–N3–N1; N3–N1–N2	3	Improve posture, balance, and arm positioning during race walking
I-Series Racewalk	I1–I2–I3; I2–I3–I1; I3–I1–I2	3	Improve stride accuracy, center of gravity, and movement efficiency
Hexagonal Racewalk	Hexagonal Racewalk	1	Integrate technical skills and endurance through multidirectional movement
Total	25 Training Models	25	Integrated development of race walking technique and endurance

The developed product consists of 25 structured training models, each designed to target specific technical and physiological aspects of race walking.

Table 2. Description of the 25 Preliminary Training Models

No.	Training Model	Main Training Objective	Main Activity
1	Racewalk S1	Coordination and hip mobility	Walking through an S-shaped course with relaxed arm swing
2	Racewalk S1–S2–S3	Coordination with shoulder rotation	S-course combined with forward and backward shoulder rotation
3	Racewalk S3–S1–S2	Movement sequencing	Combination of S-pattern walking at varying movement tempos
4	Racewalk S2	Hip rotation and posture	S-course with forward shoulder rotation
5	Racewalk S2–S1–S3	Coordination progression	Combination of relaxed arm swing and shoulder rotation
6	Racewalk S3	Hip flexibility	S-course with backward shoulder rotation

7	Racewalk S3–S2–S1	Maximum coordination	Progressive S-pattern at moderate to maximal speed
8	Racewalk U-1	Aerobic endurance	Continuous U-pattern walking for 30 minutes with speed variation
9	Racewalk U-2	Muscular endurance	Long-stride walking inside the U-pattern
10	Racewalk M-1	Postural control	Walking through M-pattern while coordinating opposite arm movement
11	Racewalk M-2	Heel-strike technique	M-pattern emphasizing heel contact and forward arm movement
12	Racewalk M-3	Straight-line foot placement	M-pattern emphasizing propulsion efficiency
13	Racewalk M-4	Upper-body coordination	M-pattern combining opposite arm actions and pelvic rotation
14	Pyramid Racewalk Position 1	Endurance foundation	Walking from the first pyramid station using proper heel contact
15	Pyramid Racewalk Position 2	Stride length	Long-stride walking between stations
16	Pyramid Racewalk Position 3	Speed endurance	Maximum-speed walking across pyramid stations
17	Racewalk e-1	Aerobic endurance	Continuous walking around the "e" course for three-minute intervals
18	Racewalk e-2	Interval endurance	Alternating long strides with continuous walking
19	Racewalk N1–N2–N3	Postural stability	Walking while changing arm positions (side, waist, head)
20	Racewalk N2–N3–N1	Technical coordination	Straight-line walking with sequential arm-position changes
21	Racewalk N3–N1–N2	Balance control	Walking while combining head, side, and waist arm positions
22	Racewalk I1–I2–I3	Propulsive force	Heel-strike, crossover steps, and long-stride walking
23	Racewalk I2–I3–I1	Center of gravity	Crossover steps combined with long-stride walking
24	Racewalk I3–I1–I2	Stride efficiency	Long-stride walking followed by heel-strike and crossover movement
25	Hexagonal Racewalk	Integrated technique and endurance	Sequential walking through six stations using different walking techniques

The findings indicate that the developed training package possesses several important characteristics. First, the exercises were arranged progressively from simple to complex movements, allowing athletes to gradually master race walking skills while minimizing injury risk.

Second, each model combines technical correction with endurance development rather than treating them as separate training components. Consequently, athletes simultaneously improve movement quality and physiological capacity. Third, the training variations emphasize biomechanical efficiency by incorporating exercises that improve hip rotation, heel-strike mechanics, knee extension, arm swing coordination, stride length, and postural alignment. These movement components represent the fundamental technical requirements established in competitive race walking. Finally, the inclusion of multiple movement patterns (S-, U-, M-, Pyramid-, e-, N-, I-, and Hexagonal configurations) provides greater training variability, thereby reducing monotony while increasing athletes' motivation and engagement during practice sessions.

These findings demonstrate that the preliminary product successfully transformed the results of the needs assessment into a structured and progressive training package comprising 25 validated race walking technique and endurance exercise models, which subsequently proceeded to expert validation and field testing in the next stage of the research.

4.2 Expert Validation and Revision of the Preliminary Training Model

(Research Question 2: Is the developed race walking technique and endurance training model feasible for implementation according to expert judgment?)

Following the completion of the preliminary prototype, the developed race walking technique and endurance training model underwent a systematic expert validation process to determine its content validity, feasibility, practicality, and applicability before field implementation. The validation stage represented a crucial phase of the Research and Development (R&D) procedure because it ensured that every exercise variation was scientifically appropriate, technically correct, and practically applicable for athletes aged 14–18 years.

The validation process was conducted through expert judgment, involving specialists with extensive academic qualifications and professional experience in athletics coaching, sport science, motor learning, and sport measurement. Their combined expertise provided comprehensive evaluations covering biomechanical accuracy, coaching practicality, movement progression, training safety, and athlete suitability. The three experts involved in the validation process were:

- 1) Prof. RL (Athletics Expert)
- 2) Dr. EDM (Coaching Science Expert)
- 3) Prof. W (Motor Learning and Sport Measurement Expert)

Each expert independently reviewed the complete training package, including the objectives, movement sequence, technical execution, training progression, safety aspects, equipment requirements, and implementation procedures of every exercise model. The experts then provided qualitative comments and recommendations for improving the product before it proceeded to field testing.

Table 3. Expert Validation Results of the Preliminary Race Walking Technique and Endurance Training Models

No.	Training Model	Expert Judgment
1	Racewalk S1	Feasible
2	Racewalk S1–S2–S3	Feasible
3	Racewalk S3–S2–S1	Feasible
4	Racewalk S2	Feasible
5	Racewalk S2–S1–S3	Feasible
6	Racewalk S3	Feasible
7	Racewalk S3–S2–S1	Feasible
8	Racewalk U1	Feasible
9	Racewalk U2	Feasible
10	Racewalk M1	Feasible
11	Racewalk M2	Feasible
12	Racewalk M3	Feasible
13	Racewalk M4	Feasible
14	Pyramid Racewalk Position 1	Feasible
15	Pyramid Racewalk Position 2	Feasible
16	Pyramid Racewalk Position 3	Feasible
17	Racewalk e1	Feasible
18	Racewalk e2	Feasible
19	Racewalk N1–N2–N3	Feasible
20	Racewalk N2–N3–N1	Feasible
21	Racewalk N3–N1–N2	Feasible
22	Racewalk I1–I2–I3	Feasible
23	Racewalk I2–I3–I1	Feasible
24	Racewalk I3–I1–I2	Feasible
25	Hexagonal Racewalk	Feasible

The expert validation demonstrated that all 25 developed training models were classified as feasible for implementation. None of the proposed exercise variations were rejected or considered unsuitable for adolescent race walkers. This finding indicates that the developed product successfully met the essential criteria concerning technical correctness, scientific rationale, coaching applicability, safety, and training progression.

Overall, the experts agreed that the developed training package adequately represented the fundamental components of race walking technique and endurance development. The exercise sequence was considered

systematic, progressing from basic movement patterns to more complex coordination and endurance tasks, thereby supporting long-term athlete development.

The validation also confirmed that the movement variations reflected the biomechanical characteristics of legal race walking, particularly with respect to heel contact, knee extension, pelvic rotation, postural alignment, arm coordination, and stride efficiency. Furthermore, the integration of endurance-oriented drills within the technical exercises was considered appropriate for improving both movement quality and physiological performance simultaneously.

4.3 Effectiveness of the Developed Racewalking Technique and Endurance Training Model

(Research Question 3: Is the developed race walking technique and endurance training model effective in improving race walking technique and endurance among athletes aged 14–18 years?).

The third research question examined whether the developed racewalking technique and endurance training model effectively improved racewalking performance and endurance among athletes aged 14–18 years. To evaluate the effectiveness of the developed model, an operational field test was conducted using a pretest–posttest control group design involving 32 racewalking athletes from athletics clubs in Kendari, Southeast Sulawesi. Sixteen athletes were assigned to the experimental group, which received the newly developed training model, while sixteen athletes in the control group continued their conventional training programs under their respective coaches.

Prior to the intervention, all participants completed baseline assessments using validated instruments measuring racewalking technique and endurance. The experimental group then participated in 14 structured training sessions based on the developed model, whereas the control group followed routine coaching practices. Following the intervention, identical posttests were administered to evaluate changes in performance.

4.3.1 Descriptive Statistics

Table 4 presents the descriptive statistics of racewalking technique performance before and after the intervention.

Table 4. Descriptive Statistics of Racewalking Technique Performance

Variable	N	Minimum	Maximum	Mean	SD
Experimental Pretest	16	2100	3100	2631.63	265.05
Experimental Posttest	16	3350	3985	3716.06	164.35
Control Pretest	16	2100	3100	2631.63	265.05
Control Posttest	16	2350	3300	2754.81	243.54

The experimental group demonstrated a substantial increase in racewalking performance, with the mean score improving from 2631.63 to 3716.06. In contrast, the control group showed only a modest improvement from 2631.63 to 2754.81. The descriptive statistics for endurance performance are presented in Table 5.

Table 5. Descriptive Statistics of Endurance Performance

Variable	N	Minimum	Maximum	Mean	SD
Experimental Pretest	16	34.50	45.97	40.60	3.04
Experimental Posttest	16	48.84	56.12	53.04	1.89
Control Pretest	16	34.50	45.97	40.60	3.04
Control Posttest	16	37.98	48.26	42.14	2.76

Similarly, endurance performance increased considerably in the experimental group, with the mean score rising from 40.60 to 53.04, whereas only a slight improvement was observed in the control group (40.60 to 42.14). These descriptive findings suggest that athletes who participated in the developed training model experienced substantially greater improvements in both racewalking technique and endurance than those receiving conventional training.

4.3.2 Normality Test

Before hypothesis testing, data normality was examined using the Shapiro–Wilk test. The results are summarized in Table 6.

Table 6. Shapiro–Wilk Normality Test

Variable	Group	Sig.
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Racewalking Technique	Experimental Pretest	0.837
	Experimental Posttest	0.092
	Control Pretest	0.837
	Control Posttest	0.737
Endurance	Experimental Pretest	0.839
	Experimental Posttest	0.091
	Control Pretest	0.839
	Control Posttest	0.505

All significance values exceeded 0.05, indicating that the data followed a normal distribution. Consequently, parametric statistical analyses were considered appropriate for subsequent hypothesis testing.

4.3.3 Within-Group Improvement (Paired Sample t-Test)

To determine whether significant improvements occurred within each group, paired sample t-tests were performed. The results are presented in Table 7.

Table 7. Paired Sample t-Test Results

Variable	Comparison	t	df	p
Racewalking Technique	Experimental	-18.125	15	<0.001
	Control	-3.274	15	0.005
Endurance	Experimental	-18.129	15	<0.001

Significant improvements were observed in both groups ($p < 0.05$). However, the magnitude of improvement was substantially greater in the experimental group, indicating that the developed training model produced stronger performance gains than conventional practice.

4.3.4 Homogeneity Test

Levene's test confirmed the assumption of homogeneity of variance (Table 8).

Table 8. Homogeneity Test

Variable	Levene Statistic	Sig.
Ricewalking Technique	1.622	0.213
Endurance	1.844	0.185

Since all significance values exceeded 0.05, equal variance between groups could be assumed, allowing the use of the independent sample t-test.

4.3.5 Between-Group Comparison

Independent sample t-tests were conducted to compare posttest performance between the experimental and control groups.

Table 9. Independent Sample t-Test

Variable	t	df	p	Mean Difference
Racewalking Technique	13.087	30	<0.001	961.25
Endurance	13.032	30	<0.001	10.89

The experimental group significantly outperformed the control group in both racewalking technique and endurance ($p < 0.001$). These findings demonstrate that the developed training model produced significantly greater improvements than conventional training. The posttest group statistics are summarized in Table 10.

Table 10. Posttest Group Statistics

Variable	Group	Mean	SD
Racewalking Technique	Experimental	3716.06	164.35
	Control	2754.81	243.54

Endurance	Experimental	53.04	1.89
	Control	42.14	2.76

The differences in posttest means further confirm the superiority of the developed model over conventional training methods.

4.3.6 N-Gain Analysis

To determine the practical effectiveness of the developed model, normalized gain (N-Gain) analysis was conducted.

Table 11. N-Gain Analysis

Group	N-Gain	N-Gain (%)	Interpretation
Experimental (Technique)	0.798	79.77	Effective
Control (Technique)	0.086	8.58	Not Effective
Experimental (Endurance)	0.640	64.04	Moderately Effective
Control (Endurance)	0.077	7.65	Not Effective

The experimental group achieved an N-Gain score of 79.77% for racewalking technique, indicating that the developed model was effective in improving technical performance. For endurance, the model achieved an N-Gain score of 64.04%, categorized as moderately effective. In contrast, both control-group scores fell below 10%, indicating that conventional training was not effective in producing meaningful performance improvements. Overall, these findings provide strong empirical evidence that the developed racewalking technique and endurance training model substantially enhances athletes' technical execution and physiological endurance compared with traditional coaching approaches.

5. DISCUSSION

The present study resulted in the development of a Racewalking Technique and Endurance Training Model for Athletes Aged 14–18 Years, which was systematically designed and validated through the ten stages of the Research and Development (R&D) model proposed by Borg and Gall. These stages included preliminary research, planning, product development, expert validation, small-scale field testing, large-scale field testing, operational field testing, product revision, final product development, and dissemination. The systematic implementation of these stages ensured that the developed training model was theoretically grounded, empirically validated, and practically applicable for coaches and athletes. The findings demonstrated that the developed model was effective in improving both racewalking technique and endurance among adolescent athletes, as evidenced by the significant improvement achieved by the experimental group compared with the control group following the intervention.

Racewalking is a technically demanding athletic event that requires athletes to maintain continuous contact with the ground while keeping the supporting leg straight from the moment of initial ground contact until the body passes over the vertical upright position. These requirements are explicitly stated in World Athletics (formerly IAAF) Competition Rule 230.2, making technical mastery the most fundamental aspect determining competitive performance. Failure to execute the correct movement pattern often results in warnings from judges, entry into the penalty zone, or even disqualification during competition. Consequently, developing an effective and systematic technical training program during adolescence is essential because athletes aged 14–18 years are undergoing rapid neuromuscular development and are highly responsive to motor skill acquisition.

The development of the training model was based on Motor Learning Theory, which emphasizes that complex motor skills are acquired most effectively through structured, repetitive, progressive, and varied practice. According to Schmidt and Lee (2019), motor learning occurs through continuous interactions between cognitive processing, motor execution, and feedback mechanisms, enabling athletes to gradually refine movement efficiency and coordination. In the present model, athletes first develop cognitive understanding of correct racewalking mechanics before progressing to repeated movement execution under increasingly varied practice conditions. Such an approach facilitates the formation of stable motor programs, improves movement consistency, and enhances technical accuracy during competition.

The developed model integrates various movement patterns represented by the S, U, M, N, I, Pyramid, and Hexagonal Racewalk drills. Each drill was specifically designed to improve different components of racewalking performance. The S-pattern exercises emphasize pelvic rotation, arm swing coordination, stride rhythm, and body balance. The U-pattern focuses on stride control during directional changes while maintaining continuous ground contact. The M-pattern develops trunk stability and center-of-gravity control through coordinated upper-limb movements. The N- and I-pattern drills improve postural stability, stride variation, foot placement, and movement coordination. Meanwhile, the Pyramid and Hexagonal Racewalk drills integrate technical execution with aerobic endurance development by combining changes in stride length, walking speed, movement direction, and prolonged exercise duration. Collectively, these variations provide athletes with diverse movement experiences that enhance motor adaptability while preventing monotony during training sessions.

The effectiveness of the model was confirmed through operational field testing using a pretest–posttest control group design. Statistical analysis demonstrated significant improvements in both racewalking technique and endurance among athletes who received the developed training model. The paired-sample t-test revealed statistically significant differences between pretest and posttest scores in the experimental group ($p < .001$), whereas improvements in the control group were substantially smaller. Independent-sample t-test analysis further confirmed significant differences between the experimental and control groups after treatment ($p < .001$). Furthermore, the N-Gain analysis indicated that the developed model was effective in improving racewalking technique (79.77%) and moderately effective in improving endurance (64.04%), whereas conventional training produced only minimal improvement. These findings indicate that the structured integration of technical drills and endurance exercises provides greater training benefits than traditional coaching methods.

The improvement observed in technical performance can be explained through biomechanical principles of racewalking. The developed drills encourage proper pelvic rotation, efficient arm swing, optimal stride mechanics, and maintenance of vertical posture throughout the gait cycle. These movement characteristics contribute to reduced unnecessary body oscillation, improved movement economy, and enhanced walking efficiency while maintaining compliance with official racewalking regulations. Simultaneously, endurance-oriented drills such as the Hexagonal and Pyramid Racewalk improve cardiovascular efficiency and muscular endurance by increasing aerobic workload in a progressive manner. This integrated approach enables athletes to maintain proper racewalking technique even under conditions of prolonged physical exertion, thereby reducing technical deterioration caused by fatigue.

Another important contribution of this study lies in the incorporation of training periodization principles proposed by Tudor O. Bompá. The developed model follows the principles of progressive overload, specificity, variation, and systematic progression, ensuring that training loads increase gradually according to athletes' developmental characteristics. Such progression allows physiological adaptation without imposing excessive fatigue or injury risk. Moreover, the variation embedded within the training model increases athlete motivation and engagement while preventing repetitive training boredom that frequently occurs during conventional racewalking practice.

The quality of the developed model was further strengthened through expert judgment, involving specialists in athletics, coaching science, motor learning, and sports measurement. Expert validation concluded that all components of the model—including training objectives, exercise organization, implementation procedures, progression, and evaluation—were appropriate for athletes aged 14–18 years and consistent with contemporary coaching principles. Subsequent small-scale and large-scale field testing also demonstrated that coaches and athletes perceived the model as practical, understandable, systematic, and easy to implement within regular training programs. Suggestions obtained during each evaluation stage were incorporated through iterative revisions, resulting in a final product with improved instructional clarity and technical precision.

From both theoretical and empirical perspectives, the developed training model demonstrates strong scientific validity. Theoretically, it integrates principles from Motor Learning Theory, biomechanics, exercise physiology, and periodization into a comprehensive training framework specifically designed for adolescent racewalkers. Empirically, its effectiveness is supported by expert validation, successive field testing, and statistical evidence showing significant improvements in technical performance and endurance. Therefore, the model satisfies both conceptual and practical requirements expected of an evidence-based sports training program.

Overall, this study provides a practical contribution to athletics coaching by introducing an innovative, structured, and scientifically validated racewalking training model for athletes aged 14–18 years. The model not only enhances technical execution and aerobic endurance but also helps athletes minimize technical violations that may lead to judges' warnings or disqualification during competition. Consequently, this training model may

serve as a comprehensive coaching guideline for athletics coaches, sports academies, schools, and regional athletics associations seeking to improve racewalking performance among youth athletes. Future studies are encouraged to evaluate the long-term effectiveness of the model across different age categories, competitive levels, and training environments while integrating biomechanical motion analysis and wearable technology to further optimize racewalking performance.

6. CONCLUSION

Based on the findings and discussion presented in the previous chapters, several conclusions can be drawn in accordance with the research objectives and research questions of this study.

- 1) The racewalking technique and endurance training model was successfully developed using the Research and Development (R&D) approach proposed by Borg and Gall. The development process was grounded in Motor Learning Theory, racewalking biomechanics, and endurance training principles, while also incorporating the technical requirements of racewalking established by World Athletics. The systematic development procedure, consisting of expert validation, limited field testing, large-scale trials, and operational field testing, produced a structured, progressive, and scientifically based training model. The findings demonstrate that the developed model effectively improves racewalking technique and endurance among athletes aged 14–18 years.
- 2) The developed training model was confirmed to be feasible and appropriate for practical implementation through expert validation and successive field testing. The model underwent evaluation by experts in athletics, coaching science, motor learning, and sports measurement, followed by small-scale and large-scale field trials involving coaches and athletes. The validation process indicated that the five categories of racewalking technique and endurance training models met the required standards of content validity, practicality, systematic organization, and training progression. Therefore, the model is considered suitable for implementation by athletics coaches as a structured training guideline to improve racewalking performance among youth athletes.
- 3) The developed racewalking technique and endurance training model demonstrated significant effectiveness in improving athletes' performance. Athletes in the experimental group who participated in the developed training program achieved significantly greater improvements in racewalking technique and endurance than those in the control group after completing sixteen training sessions. Statistical analyses, including paired-sample t-tests, independent-sample t-tests, and N-Gain analysis, confirmed that the developed model produced significant improvements in both technical performance and endurance capacity. These findings indicate that the training model provides a more effective approach than conventional training methods for developing racewalking performance in athletes aged 14–18 years.

In conclusion, the Racewalking Technique and Endurance Training Model for Athletes Aged 14–18 Years developed in this study represents a scientifically validated and practically applicable training program. The model integrates principles of motor learning, biomechanics, periodization, and endurance training into a comprehensive coaching framework that effectively enhances racewalking technique and physiological endurance. It is expected that this model will contribute to improving the quality of athletics coaching in Indonesia, particularly in the racewalking event, while serving as a practical reference for coaches, sports practitioners, and athletics development programs in preparing young athletes to achieve higher levels of competitive performance at regional, national, and international competitions.

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