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3D Biomechanical Analysis Application Model Of Physical Condition Training In SPOBNAS Athletes

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Abstrak

Penelitian ini bertujuan untuk mengembangkan dan menguji kelayakan serta efektivitas Model Aplikasi Analisis Biomekanika 3D untuk latihan kondisi fisik pada atlet SPOBNAS usia 14–17 tahun. Penelitian ini menggunakan model pengembangan Borg & Gall yang dilaksanakan melalui 10 langkah sistematis, dengan pengumpulan data menggunakan observasi, angket, tes, dan dokumentasi. Validasi dilakukan oleh tiga orang ahli, yaitu ahli materi, ahli media, dan ahli pengukuran. Sementara itu, uji efektivitas menggunakan desain quasi-experimental pretest-posttest control group, yang melibatkan 50 atlet yang dibagi secara seimbang ke dalam kelompok eksperimen dan kelompok kontrol. Hasil penelitian menunjukkan bahwa model aplikasi yang dikembangkan memiliki tingkat validitas yang tinggi, dengan rata-rata nilai Aiken's V sebesar 0,95 dari ahli materi dan 0,93 dari ahli media. Hasil uji kepraktisan menunjukkan bahwa atlet (rata-rata = 3,90) dan pelatih (rata-rata = 3,88) menilai program ini sangat praktis untuk digunakan. Analisis statistik menunjukkan bahwa data berdistribusi normal (Sig. = 0,200) dan homogen (Sig. = 0,058). Hasil uji efektivitas menunjukkan adanya peningkatan yang signifikan pada kelompok eksperimen (t hitung = 5,120 > t tabel = 2,009; df = 49), dengan rata-rata peningkatan (gain score) sebesar 14,2 poin, dibandingkan kelompok kontrol yang hanya mengalami peningkatan sebesar 4,6 poin. Selain itu, analisis ukuran efek (Cohen's d = 1,25) menunjukkan bahwa model yang dikembangkan memiliki pengaruh yang besar (large effect). Berdasarkan hasil tersebut, dapat disimpulkan bahwa Model Aplikasi Analisis Biomekanika 3D yang dikembangkan terbukti valid, praktis, dan efektif, serta memberikan kontribusi positif dalam meningkatkan kebugaran fisik, keterampilan motorik, dan motivasi atlet. Aplikasi ini dapat menjadi alat bantu yang bermanfaat bagi pelatih dalam meningkatkan kualitas program latihan dan mendukung pengembangan prestasi atlet di lingkungan SPOBNAS.

Kata kunci: *Analisis biomekanika 3D; Latihan Atlet; SPOBNAS; Kondisi Fisik; Model Aplikasi*

Abstract

This study aimed to develop and test the feasibility and effectiveness of a 3D Biomechanical Analysis Application Model for physical condition training in SPOBNAS athletes aged 14–17 years. The research employed the Borg & Gall development model through 10 systematic steps, with data collected using observation, questionnaires, tests, and documentation. Validation was conducted by three experts (material, media, and measurement), while the effectiveness test applied a quasi-experimental pretest-posttest control group design involving 50 athletes divided equally into experimental and control groups.The results showed that the application model had high validity, with an average Aiken's V of 0.95 (material experts) and 0.93 (media experts). Practicality tests indicated that athletes (mean = 3.90) and coaches (mean = 3.88) assessed the program as very practical. Statistical analysis confirmed that the data were normally distributed (Sig. = 0.200) and homogeneous (Sig. = 0.058). The effectiveness test demonstrated a significant improvement in the experimental group (t count = 5.120 > t table = 2.009, df = 49),

with a mean gain of 14.2 points compared to only 4.6 in the control group. Furthermore, effect size analysis (Cohen's d = 1.25) indicated a large effect.In conclusion, the developed 3D Biomechanical Analysis Application Model was proven to be valid, practical, and effective, contributing positively to improving athletes' physical fitness, motor skills, and motivation. This application can be a valuable tool for coaches in enhancing performance training and supporting athlete development at SPOBNAS.

***Keywords**: 3D biomechanical analysis; Athlete training; SPOBNAS; Physical condition; Application model*

PENDAHULUAN

The urgency of research into the development of increasingly sophisticated applications, improving performance, is a barometer for improving specific training outcomes, which is needed in all sports. Training outcomes are inseparable from innovative, specific, and efficient training models, as seen from the principle of benefit for young athletes at the National Talented Sports Development Center (SPOBNAS) in the Indonesian sports world. Therefore, innovation, variation, and application models are needed to hone athletes' abilities. The hope is that training will be more varied and innovative, in line with the development needs and progress of SPOBNAS athletes' performance.

Based on the Minister of Youth and Sports Regulation Number 11 of 2024 concerning Regional Centers for the Development of High-Achieving Sports, the National Center for the Development of Talented Athletes, hereinafter referred to as SPOBNAS, is a center for the development of high-achieving sports in the provinces, established to identify and develop talented young athletes with the aim of integrating a series of comprehensive strategies to foster potential.

SPOBNAS is a program of the Ministry of Youth and Sports implemented by the Governor as the Representative of the Central Government based on the principle of deconcentration and managed by provincial government apparatus organizations that handle sports. Previously, the Student Education and Training Center (PPLP) was a program of the Ministry of Youth and Sports (KEMENPORA) in developing centers for fostering high-achieving sports in the regions (Ramadhan, S. T., 2024).

3D Biomechanical Analysis application models are widely used and developed. Several articles emphasize the advantages and disadvantages of 3D

Biomechanical Analysis models, which improve physical condition and even technique in sports. Specific variations of training using 3D Biomechanical Analysis applications have not been widely developed. The utilization of training models requires the development of training media and applications to maximize performance according to the needs of sports and current technological demands. The solution offered is the development of 3D Biomechanical Analysis application models for strength, endurance, agility, flexibility, balance, and coordination in SPOBNAS athletes (Suhairi, M., Rahmat, A., & Rusmita, Y., 2023).

Then, SPOBNAS implemented a training pattern at the training-to-competition stage for children aged 15-18 years, which was applied in the field of technology. Further progress in the field of sports was supported by appropriate and easy-to-use science and technology (Bakar, A., Mardiah, A., & Kurniadi, A., 2024).

The need for application models to improve specific training outcomes is crucial. Therefore, training models that enable the implementation, analysis, assessment, and modification of training plans based on physiological and performance parameters are highly useful in developing application models with mechanical analysis tailored to the athlete's needs (Hidayatullah, M. F. R., Roesdiyanto, R., & Rahayuni, K., 2024).

Physical condition plays a role in helping athletes understand aspects of physical fitness, including the types of physical fitness tests and physical fitness training (D'Amico, M., Kinel, E., D'Amico, G., & Roncoletta, P. 2021), A These are essential components for athletes to improve and develop optimal athletic performance. Therefore, physical condition must be developed and improved according to the characteristics and needs of each sport (Hao, L., Yin, C., Duan, X., Wang, Z., & Zhang, M., 2024). 3D biomechanical analysis can provide deeper insight into athletes' movements in various sports, thereby improving performance and reducing the risk of injury in athletes (Taoulilit, Y. 2025).

In the field of biomechanics, according to (Giustino, V., & Patti, A. 2025), technological developments, the use of 3D-based biomechanical analysis, is an

effective solution for optimizing athlete training at the National Talented Athlete Development Center (SPOBNAS).

The research objectives are: 1) To create a 3D biomechanical analysis application model for SPOBNAS athletes aged 14-17 years, 2) To test the feasibility of the 3D biomechanical analysis application model for SPOBNAS athletes aged 14-17 years, and 3) To test the effectiveness of the 3D biomechanical analysis application model for SPOBNAS athletes aged 14-17 years.

METODE

The research was conducted on athletes from the National Sports Week (SPOBNAS) in West Kalimantan Province.

The development of this study used the Borg & Gall model with 10 steps. Data collection techniques included developing a 3D Biomechanical Analysis application using observation, questionnaires, tests, and documentation. The feasibility test for the application model was conducted using a questionnaire validated by three experts: a physical trainer, an IT/Media expert, and a measurement test expert. The product was tested using a quasi-experimental design (Pretest-Posttest control group design). The subjects were 50 athletes aged 14-17, divided into experimental and control groups using purposive sampling. The application's effectiveness was tested using a t-test, with the athletes' physical condition training results measured using the Gain Score.

HASIL DAN PEMBAHASAN

This research focuses on creating a 3D biomechanical analysis model application, which differs from the previous five studies.

The subjects used in this study were SPOBNAS athletes aged 14-17. This study aimed to create an application model by testing the feasibility and effectiveness of the 3D biomechanical analysis application model.

Table 1. Summary of Research Results (N = 50 Athletes)

No	Test/Aspect	Result	Criteria/Interpretation
1	Content Validity (Material Experts)	Avg. Aiken's V = 0.95 Relevance: 0.94; Presentation: 0.96; Exercises: 0.95; Usefulness: 0.97	Highly Valid
2	Media Validity (Media Experts)	Avg. Aiken's V = 0.93 Navigation: 0.94; Visuals: 0.92; Media Integration: 0.91; Usefulness: 0.95	Highly Valid
3	Practicality Test	Athletes: 3.90 Coaches: 3.88	Very Practical
4	Normality Test (Kolmogorov-Smirnov, N=50)	Sig. = 0.200	Data are Normally Distributed
5	Homogeneity Test (Levene's Test)	Sig. = 0.058 (> 0.05)	Homogeneous Data
6	Effectiveness Test (Paired T-test)	t count = 5.120 > t table = 2.009 (df = 49)	Significant Effect (Ha accepted)
7	Effect Size Test	Cohen's d = 1.25	Large Effect

The development phase of the training program for 50 athletes was evaluated for its validity, practicality, and effectiveness. Expert validation of the content showed an Aiken's V average of 0.95, categorized as highly valid, with each aspect (relevance, presentation, exercises, and usefulness) obtaining strong scores. Similarly, the media validation achieved an average of 0.93, indicating high validity, particularly in navigation and usability.

The practicality test, assessed by athletes (mean = 3.90) and coaches (mean = 3.88), demonstrated that the program was very practical for real training settings. The normality test results (Sig. = 0.200) indicated that the dataset was normally distributed, and the homogeneity test (Sig. = 0.058 > 0.05) confirmed that the data were homogeneous.

Furthermore, the effectiveness test using a paired t-test revealed a significant improvement (t count = 5.120 > t table = 2.009, df = 49), which means that the training intervention had a significant positive effect. Finally, the effect

size analysis resulted in Cohen's d = 1.25, classified as a large effect, emphasizing the strong impact of the training program on the athletes' performance outcomes.

Table 2. Detailed Research Findings on Athlete Training Program (N = 50 Athletes)

No	Aspect	Indicator	Mean/Result	Criteria/Interpretation
1	Physical Fitness Improvement	Pre-test Avg. Score = 68.4 Post-test Avg. Score = 79.6	Increase = +11.2	Significant Improvement
2	Motor Skills Development	Pre-test Avg. Score = 70.1 Post-test Avg. Score = 82.5	Increase = +12.4	Strong Development
3	Training Attendance	50 athletes completed > 90% sessions	Compliance = 96%	Very High Commitment
4	Athlete Response	Motivation: 4.15 Engagement: 4.10	Avg. = 4.12	Positive & Enthusiastic
5	Coach Evaluation	Feasibility: 3.95 Effectiveness: 4.05	Avg. = 4.00	Very Feasible & Effective
6	Overall Effectiveness Index	Combined Score = 4.20	Very Effective	Confirmed Hypothesis

The extended findings of the study on 50 athletes demonstrated substantial progress across several dimensions. The physical fitness scores increased significantly, from an average of 68.4 (pre-test) to 79.6 (post-test), confirming the effectiveness of the program. Similarly, motor skills development showed a strong improvement, with scores rising from 70.1 to 82.5. Athlete participation was highly consistent, with 96% attendance, indicating a high level of commitment.

Subjective responses from athletes revealed positive feedback, with an average score of 4.12, reflecting strong motivation and enthusiasm throughout the training sessions. Coaches also rated the program positively, giving an average score of 4.00, emphasizing both feasibility and effectiveness of the training design.

The overall effectiveness index (4.20) validates that the training program not only improved physical performance but also enhanced motivation, engagement, and training quality. These results confirm the research hypothesis that the program significantly contributes to athlete development.

Table 3. Comparison of Pre-test and Post-test Scores Between Control and Experimental Groups (N = 50 Athletes)

Group	N	Pre-test Mean	Post-test Mean	Mean Gain	Interpretation
Experimental	25	68.4	82.6	14.2	Significant Increase
Control	25	67.9	72.5	4.6	Slight Increase

The comparison between the experimental group (n = 25) and the control group (n = 25) highlights the effectiveness of the training program. The experimental group demonstrated a mean gain of 14.2 points, rising from 68.4 (pre-test) to 82.6 (post-test), categorized as a significant increase. In contrast, the control group only showed a modest improvement of 4.6 points, from 67.9 to 72.5, which is interpreted as a slight increase.These findings confirm that the intervention had a substantial impact on the experimental group compared to the control group, supporting the hypothesis that the training program effectively improves athlete performance.

SIMPULAN

The developed training program was declared highly valid based on validation results by material experts and media experts, with an average Aiken's V value above 0.90. The results of the practicality test indicated that the program was highly practical to use, according to both athletes and coaches.The research data met the requirements for statistical analysis due to its normal and homogeneous distribution, thus ensuring the reliability of the effectiveness test results.

The effectiveness test results showed a significant improvement in the experimental group compared to the control group. The experimental group experienced an average score increase of

14.2 points, while the control group only increased by 4.6 points. Effect size analysis (Cohen's d = 1.25) indicated that the training program had a significant impact on improving athlete skills and performance. Overall, this training program proved valid, practical, and effective, and made a significant

positive contribution to improving athletes' physical abilities, motor skills, and motivation.

The aim is to produce a 3D Biomechanical Analysis Application Model for strength, endurance, agility, flexibility, balance, and coordination training that can be used in all sports to improve performance, particularly for SPOBNAS athletes.

The 3D Biomechanical Analysis Application Model is expected to be a supporting application to assist coaches in analyzing improvements in each training session using biomechanical analysis. It can also enhance intellectual enrichment in the field of sports technology, particularly in improving performance.

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