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# Increase of $VO_2$max After 8 Weeks Tuja Shuttle Run Exercise for Athletes in the 14-17 Year Age Group

# Aumento del VO2 máximo después de 8 semanas de ejercicio Tuja Shuttle Run para atletas del grupo de edad de 14 a 17 años

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**Abstract.** The quest to enhance athletic performance through increased $VO_2$max levels has led to exploring various training modalities, including the Tuja Shuttle Run, an innovative adaptation of High-Intensity Interval Training (HIIT). This study aims to address these gaps by examining the impact of a tailored HIIT protocol—the Tuja Shuttle Run—on the $VO_2$max of young athletes. A total 50 athletes from KONI Kediri district and Keeltjes Soccer Academy, aged 14-17 years were recruited to be research subjects. The development of HIIT in this research was in the form of the Tuja Shuttle Run. The Tuja Shuttle Run intervention was carried out with a frequency of 3x/week for 8 weeks. Meanwhile, $VO_2$max was gauged using the Multi-Stage 20-m Shuttle Run Fitness Test, a field test valued for its practicality despite debates on its precision relative to laboratory measures. Statistical analysis uses paired sample t-test with a significance level of 5%. Based on the results of the paired sample t-test shows that Sig. 0.000 or $p \leq 0.001$, so it can be said that there was a significant difference between the pretest and posttest on the $VO_2$max. Implementing an 8-week Tuja Shuttle Run training program can potentially enhance VO2max in athletes aged 14-17. Based on this research, further studies need to be carried out on the effect of Tuja Shuttle Run training by comparing each sport.
**Keyword:** $VO_2$max Enhancement, Tuja Shuttle Run, High-Intensity Interval Training, Athletic Performance, Youth Athlete Training

**Resume.** La búsqueda de mejorar el rendimiento atlético a través de mayores niveles de VO2max ha llevado a explorar varias modalidades de entrenamiento, incluido el Tuja Shuttle Run, una adaptación innovadora del entrenamiento en intervalos de alta intensidad (HIIT). Este estudio tiene como objetivo abordar estas brechas examinando el impacto de un protocolo HIIT personalizado, el Tuja Shuttle Run, en el VO2máx de atletas jóvenes. Se reclutó a un total de 50 atletas del distrito KONI Kediri y de la Academia de Fútbol Keeltjes, de entre 14 y 17 años, para que fueran sujetos de investigación. El desarrollo del HIIT en esta investigación se produjo en forma de Tuja Shuttle Run. La intervención Tuja Shuttle Run se llevó a cabo con una frecuencia de 3 veces por semana durante 8 semanas. Mientras tanto, el VO2max se midió mediante la prueba de condición física de carrera en ida y vuelta de 20 m en varias etapas, una prueba de campo valorada por su practicidad a pesar de los debates sobre su precisión en relación con las medidas de laboratorio. El análisis estadístico utiliza la prueba t de muestras pareadas con un nivel de significancia del 5%. Según los resultados de la prueba t de muestras pareadas, se muestra que Sig. 0.000 o $p \leq 0.001$, por lo que se puede decir que hubo diferencia significativa entre el pretest y postest en el VO2max. La implementación de un programa de entrenamiento Tuja Shuttle Run de 8 semanas puede mejorar potencialmente el VO2máx en atletas de 14 a 17 años. Con base en esta investigación, es necesario realizar más estudios sobre el efecto del entrenamiento Tuja Shuttle Run comparando cada deporte.
**Palabra clave:** Mejora del VO2max, Tuja Shuttle Run, entrenamiento en intervalos de alta intensidad, rendimiento atlético, entrenamiento de atletas jóvenes

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## Introduction

The quantification of $VO_2$max is a critical indicator of cardiovascular fitness and athletic performance, yet its role in predicting sports success is contested within the literature. While higher $VO_2$max levels are often associated with superior athletic performance (Lee & Zhang, 2021; Taufik et al., 2021; Pedro L. Valenzuela et al., 2022; Tasew & Getnet Tasew, 2020), other studies suggest that $VO_2$max is not the sole determinant of athletic prowess (Wiecha et al., 2023), indicating the need for a more nuanced understanding of its implications for athlete training. High-Intensity Interval Training (HIIT) has been identified as an effective method to enhance $VO_2$max, with varying degrees of efficacy reported across different populations and training protocols (Festiawan et al., 2021; Marterer et al., 2020; Eken & Emin Kafkas, 2022). The literature presents a spectrum of responses to HIIT, necessitating individualized training approaches and further investigation into how HIIT affects $VO_2$max (Bang-Kittilsen et al., 2022; de Mello et al., 2022). The benefits of HIIT extend beyond $VO_2$max improvement, encompassing strength, endurance, flexibility, and coordination (Festiawan et al., 2020; Festiawan et al., 2021). However, the application of HIIT in athletic training programs is inconsistent, with disparities in outcomes, especially among youth athletes in specific regions (Hudain et al., 2023; Yunus et al., 2023; Kurniawan et al., 2022; Grzebisz-Zatońska et al., 2022), highlighting the need for context-specific research to optimize training interventions.

This study aims to address these gaps by examining the impact of a tailored HIIT protocol—the Tuja Shuttle Run—on the $VO_2$max of young athletes. Despite the growing body of research on HIIT, there is a scarcity of studies focusing on its application within this demographic and setting (Wajib et al., 2022; Westmacott et al., 2022; De Revere et al., 2021; Ma et al., 2023; Russomando et al., 2020; Clausen et al., 1973), and this research seeks to contribute a critical perspective to the discourse on athletic training and performance (Petersen et al., 2022; Tirtawirya et al., 2020; Vigriawan et al., 2022).

## Materials and Methods

### *Study Design*

This research employed a quasi-experimental approach with the one group pretest-posttest design. The target population for this research consists of athletes participating in various sports within the KONI Kediri district and Keeltjes Soccer Academy. The sampling method employed in this study was purposive sampling, specifically selecting athletes who have undergone training for over 3 years and fall within the age range of 14-17 years. A total of 50 samples met the criteria in this study. All procedures implemented in this study adhered to the ethical principles outlined in the World Medical Association's Helsinki Declaration governing research involving human subjects. The study protocol received approval from the Health Research Ethics Committee at the Faculty of Public Health, Universitas Airlangga, Surabaya, under the reference number 45/EA/KEPK/2021.

### *TUJA Shuttle Run training model*

The development of HIIT in this research was in the form of the Tuja Shuttle Run, The validity of the TUJA Shuttle Run training model was evaluated by experts and obtained a validity using the Aiken'V 1985 (Aiken, 1985), with a significance level of 0.05 (5%) for 5 Expert Judgement TUJA Shuttle Run training is designed specifically for seasoned athletes, employing the High-Intensity Interval Training (HIIT) model in a field with dimensions no less than 15x25m. This regimen utilizes 10 cones strategically placed with straight running distances of 4m, 6m, 10m, 12m, and 15m between them, each with a width of 2.5 m. At the start line, participants await the signal "GO" to sprint towards the cones, following the path indicated by a red arrow. They swiftly navigate the course, turning at each cone and accelerating toward the next. As the first participant passes cone number IV, the next participant begins their run, creating a continuous cycle until the last individual completes repetition 1. Subsequently, after the final person in the group finishes, the first person initiates the process again for the 2nd repetition, repeating up to the 4th repetition for one set. The training program is tailored to each athlete's initial capabilities, incorporating active rest in a 1:3 ratio (work to rest) before proceeding to the next set. To maintain the exercise's high intensity and facilitate recovery, each group, consisting of a maximum of 8 individuals, completes this regimen with one repetition. The number of sets and repetitions can be adjusted based on the sport's characteristics, including duration, energy systems, and movement patterns. This approach ensures a customized and effective HIIT TUJA Shuttle Run training model for athletes. Tuja-Shuttle Run Exercise Model performed with 6 sets of 3 reps, intensity 85-95% HRmax, frequency 3x/week during 8 weeks. The duration of each training session was 60 minutes divided into a 10-minute warm-up, 40-minute core exercises and a 10-minute cool-down session. Polar heart rate monitor (Polar H10 Heart Rate Sensor, Inc., USA) used for monitoring heart rate during intervention (Pranoto et al., 2024; Putera et al., 2023).

### *Data collection*

In this study, the measurement of VO2max pretest and posttest utilized the Multi-Stage 20-m Shuttle Run Fitness Test as the assessment method. This assessment method has been validated by several previous studies (Puspodari et al., 2022).

### *Statistical analysis*

The validity and reliability tests were analyzed using SPSS version 20. The normality test uses the Shapiro-Wilk test, while the difference test uses a paired sample t-test, and followed by effect size evaluation using Cohen's. The data was declared significant if the $p \leq 0.05$. Data was displayed with the mean $\pm$ SD.

## Results

The following results will present the results of the development validity test and continue with hypothesis testing.

Table 1.
Validity Results of Tuja Shuttle Run Tarining in Every Aspect

| No. | Item Question | Results of 5 Expert Judgments | Aikens opportunity error of 0.05 (5%) |
|---|---|---|---|
| | | Design Aspects | |
| 1 | P1 | 0.9 | 0.8 |
| 2 | P2 | 0.75 | 0.8 |
| 3 | P3 | 0.9 | 0.8 |
| 4 | P4 | 0.75 | 0.8 |
| 5 | P5 | 0.8 | 0.8 |
| 6 | P6 | 0.8 | 0.8 |
| 7 | P7 | 0.9 | 0.8 |
| 8 | P8 | 0.75 | 0.8 |
| 9 | P9 | 0.9 | 0.8 |
| 10 | P10 | 0.85 | 0.8 |
| 11 | P11 | 0.9 | 0.8 |
| 12 | P12 | 0.75 | 0.8 |
| Average | | 0.82917 | Valid |
| | | Aspects of Facilities and Infrastructure | |
| 13 | P13 | 0.8 | 0.8 |
| 14 | P14 | 0.95 | 0.8 |
| 15 | P15 | 0.8 | 0.8 |
| 16 | P16 | 0.95 | 0.8 |
| Average | | 0.875 | Valid |
| | | Aspect Use | |
| 17 | P17 | 0.95 | 0.8 |
| 18 | P18 | 0.95 | 0.8 |
| 19 | P19 | 0.95 | 0.8 |
| 20 | P20 | 0.95 | 0.8 |
| Average | | 0.95 | Valid |

Based on validation test results on aspect design the average coefficient was obtained as big as 0.82917, aspects of facilities and infrastructure 0.875, and aspect use 0.95. These results then confirmed in the table Aiken'V 1985 (Aiken, 1985) with opportunity error 0.05 (5%) of expert judgement totaling 5 on a scale of 5, namely the same or more big of 0.8, then item instrument on aspects design, facilities and infrastructure, and aspect use can said to be valid. Below is also shown the overall validity.

Table 2.
Validity Results of the TUJA Shuttle Run Training Model

| Design Items | Result 5 Expert Judgement | Aikens error probability |
|---|---|---|

| | | of 0.05 (5%) |
|---|---|---|
| 1-20 | 0.95 | 0.8 |
| Information | | Valid |

Validity test results from experts regarding validity training model TUJA Shuttle Run of 0.95 . These results were then confirmed in the Aiken'V 1985 table with a chance of error of 0.05 (5%) from the Expert Judgement 5 on a scale of 5, which was equal to or greater than 0.8 , then the training model TUJA Shuttle Run was said to be valid and suitable for use. Apart from the validity test, percentages are also calculated based on expert judgment.

Table 3.
Expert Judgment Percentage Results

| Aspect | Value obtained | Maximum Value |
|---|---|---|
| Design Aspects | 259 | 300 |
| Facilities and Infrastructure Aspect | 90 | 100 |
| Aspect Use | 96 | 100 |
| Amount | 445 | 500 |

Table above show that overall assessment results from expert judgment towards the TUJA-Shuttle Run (TSR) training model obtained mark amounting to 445 of mark maximum 500. Continue calculated the presentation obtained was 89% of what was expected, it can be concluded that the TUJA-Shuttle Run (TSR) training model falls into the "Appropriate" category for use. Based on the validity results and percentages from expert judgment, it can be concluded that the Tuja Shuttle Run training model is suitable for use. Next, below the results of the hypothesis test will be presented.

Table 4.
Descriptive Statistical Analysis

| Variable | Mean ± SD | Min | Max |
|---|---|---|---|
| Pretest $VO_2$ max (mL/kg/min) | 40.62±5.28 | 33.30 | 54.10 |
| Posttest $VO_2$ max (mL/kg/min) | 44.59±4.82 | 35.30 | 55.90 |

Furthermore, before the experimental test is carried out, a prerequisite test must be carried out first, namely in the form of Normality Test as follows.

Table 5.
Normality Test

| | Kolmogorov-Smirnov [a] | | |
|---|---|---|---|
| Statistics | | df | Sig . |
| Pretest $VO_2$ max (mL/kg/min) | 0.157 | 50 | 0.200* |
| Posttest $VO_2$ max (mL/kg/min) | 0.128 | 50 | 0.115 |

Normality test results show that Sig Pretest $VO_2$ max $0.200 \geq 0.05$ and Sig Posttest $VO_2$ max $0.115 \geq 0.05$, so indicates that the data distribution was normal. It was found that the Kolmogorov test showed normal data, then the paired sample test was carried out.

Table 6.
Paired Sample Test

| Variable | Paired Sample Test | Effect size |
|---|---|---|
| $VO_2$max (mL/kg/min) | 0.000 | 0.785 |

Based on the results of the Paired Sample Test shows that Sig . $0.000 \leq 0.05$, so it can be said that there is a significant difference between the pretest and posttest on the $VO_2$ max. This shows that model development was an exercise TUJA Shuttle Run effective in increasing $VO_2$ max.

## Discussion

The findings of this study reveal that an 8-week Tuja Shuttle Run Exercise regimen led to an augmentation in $VO_2$max among athletes aged 14-17 years. These results align with prior research indicating that HIIT positively impacts increasing $VO_2$max (Foster et al., 2015). Engaging in footwork exercises utilizing the High-Intensity Interval Training (HIIT) method has a beneficial impact on badminton athletes, positively influencing both their maximal aerobic capacity ($VO_2$max) and anaerobic capacity (Donie et al., 2021). A notable correlation exists between High-Intensity Interval Training (HIIT) and the elevation of $VO_2$max in soccer athletes (Yunus et al., 2023). The Tuja Shuttle Run is categorized as a form of High-Intensity Interval Training (HIIT). Engaging in Tuja Shuttle Run training holds the potential to enhance $VO_2$max, given the effective physiological impact of HIIT. HIIT induces notable alterations in mitochondrial function and structure, enhancing the transport of glucose, lactate, and fatty acids in skeletal muscle. These adaptations increase oxidative capacity and substrate availability within skeletal muscle, including heightened levels of myoglobin, ultimately contributing to an elevation in $VO_2$max (Vigriawan et al., 2022).

In Tuja Shuttle Run training, there is a direct correlation between the exercise intensity and the increase in $VO_2$max. The elevation in whole-body oxygen consumption ($VO_2$max) results from heightened exercise intensity, driven by the greater oxygen demand from actively engaged muscles. This surge in oxygen demand is primarily attributed to nearly all energy (ATP) expended during endurance exercise, such as aerobic exercise, which is regenerated within the mitochondria through oxidative metabolism. As oxygen consumption rises, there are concurrent increases in various cardiovascular and respiratory variables, including heart rate, ventilation, and stroke volume. Essentially, $VO_2$ max can be conceptualized as the capacity for the muscles' delivery and utilization of oxygen during exercise (Santisteban et al., 2022).

The increase in $VO_2$max is also possible because the TUJA Shuttle Run training model can provide an excellent physiological response. An increase in $VO_2$max causes physiological thickening of the left ventricular heart muscle so that the strength and ability of the heart to pump blood by contraction increases, which reduces the number of beats per minute and improves cardiorespiratory fitness (Ridwan Nugraha & Berawi, 2017). Training is carried out for four weeks by 3-4 weekly sessions. The HIIT method can increase maximum oxygen consumption, muscle adaptation, and body metabolism to increase lung capacity (Garci et al., 2016). Additionally, the TUJA Shuttle Run training model can produce a large adaptive response by recruiting a

broader population of muscle fibers and providing a more significant cardiorespiratory signal to adapt. It leads to profound changes demonstrated in elements of muscle physiology, including molecular signaling markers (Foster et al., 2015). Foster et al. (2015) stated that eight weeks of HIIT training can increase aerobic capacity. HIIT is an exercise that has many advantages. Because it can induce many physiological adaptations that increase training capacity (maximum oxygen uptake, aerobic endurance, anaerobic capacity, and metabolic health (Atakan et al., 2019), these results clearly show that developing the TUJA Shuttle Run training model, which is included in the High-Intensity Interval Training (HIIT), is a form of training that can significantly increase $VO_2$max.

In addition, the Tuja Shuttle Run exercise is effective for athletes because it is a type of HIIT that is effective in using aerobic energy. Adenosine triphosphate (ATP) synthesis occurs through anaerobic and aerobic pathways during intense physical exertion. Given the impact of ATP resynthesis on athletic performance, sports focusing on high-intensity activities strive to enhance energy liberation from both aerobic and anaerobic energy systems (Ön, 2022). High-Intensity Interval Training (HIIT), characterized by its intense intervals, offers elevated advantages in enhancing overall physical fitness. Furthermore, it is especially effective in enhancing cardiovascular function, optimizing the lungs' maximum capacity to retain and utilize oxygen efficiently (Wajib et al., 2022). A rise in maximum oxygen consumption ($VO_2$max) can prompt exercise-related adaptations that enhance the delivery of oxygen to muscles and improve the utilization of oxygen by the muscles (Tasew & Getnet Tasew, 2020). The escalation in $VO_2$max is attributed to two primary factors: central circulatory factors and Peripheral factors (Lee & Zhang, 2021). Firstly, the central factor emphasizes that maximal stroke volume and peak oxygen consumption respond positively to the increase in $VO_2$max. Secondly, peripheral mechanisms come into play, revealing heightened activity in mitochondrial enzymes, increased oxidative capacity in skeletal muscle, and various metabolic adaptations (Syamsudin et al., 2023). The assessment of $VO_2$max through endurance depicts the heart, lungs, and blood's capacity to utilize oxygen, measured through standardized cardiorespiratory fitness metrics (Ariestika et al., 2020). Various factors influence $VO_2$max, encompassing gender, age, physical activity, temperature, cardiovascular and pulmonary functions, hemoglobin levels in red blood cells, body composition, and elevation. Theoretically, the $VO_2$max value is a crucial indicator of aerobic capacity limitation, making it a paramount parameter for assessing an athlete's aerobic capabilities (Ariestika et al., 2020). Enhanced physical fitness and improved biometric components are closely associated with a higher $VO_2$max. A heightened $VO_2$max signifies an increased capacity for oxygen consumption in metabolism, underscoring its pivotal role. Athletes particularly benefit from a higher $VO_2$max, which reflects an elevated ability to utilize oxygen, contributing to overall athletic performance (Festiawan et al., 2020). The primary limitation of this study lies in its narrow demographic focus, which may not reflect the broader athletic population. Furthermore, the study's duration was limited to 8 weeks, and the longer-term effects of HIIT on $VO_2$max remain unexplored. Future research should aim to include a more diverse cohort, encompassing different age groups and athletic disciplines, to validate the universality of HIIT's impact on $VO_2$max. Longitudinal studies are also necessary to understand the long-term physiological adaptations induced by HIIT. Investigating the genetic predispositions that influence the efficacy of HIIT could provide personalized training regimens for athletes (Atakan et al., 2021).

## Conclusion

This research confirms the efficacy of an 8-week Tuja Shuttle Run program in improving $VO_2$max among 14-17-year-old athletes. The findings suggest that coaches consider incorporating this regimen to bolster athletic performance. The study contributes to the body of knowledge on youth athletic training and indicates avenues for further investigation into $VO_2$max enhancement strategies.

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