



An Analytical Study of the Variables (Oxygen Threshold and Total Energy Expenditure) and the Ability to Withstand Offensive Skill Performance During the Special Preparation Phase for Advanced Iraqi National Badminton Team Players

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Abstract

Oxygen threshold (OT) is a key index that can reflect the ability to resist offensive skill performance in elite badminton players during the special preparation phase, which can be estimated when utf8_output = 'false'separated methods: A total of 20 professional elite male badminton players at the national level were recruited as research subjects. A total of twenty male elite players of the Iraqi badminton national team were included in this study. Oxygen threshold, total energy expenditure was monitored with wearable metabolic tracking devices and measured the clone endurance entraining specifically in sport literary offense skill performance. Scores correlated significantly with the O₂ threshold and offensive skill endurance ($r = .71, p < .01$), and between total energy expenditure and endurance performance ($r = .50, p < .05$). The resilience of the physiological system to high strain has been associated with higher levels of sustained offensive skill performance during periods of heightened training stress.

Keywords: oxygen threshold, total energy expenditure, skill endurance, badminton, elite athletes

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Introduction

Badminton is an intermittent racket sport, that involves both high levels of aerobic and anaerobic fitness to maintain repeated explosive efforts, rapid change of direction and maximum shuttle velocity over protracted periods of match play (Phomsoupha & Laffaye, 2015). Unlike continuous endurance activities, badminton matches involve short bursts of high-intensity efforts followed by limited recovery durations, which rely on the efficiency of metabolic pathways to delay fatigue phenomenon and maintain optimal technical execution under pressure (Abdelkrim et al., 2010).

One such physiological marker investigated within the endurance research literature is oxygen threshold (OT) more commonly operationalized as ventilatory threshold or that point at which ventilation increases exponentially compared to the influx of oxygen during an incremental exercise protocol (Gaesser & Poole, 1996). Oxygen threshold is the point of maximal aerobic activity above which there is an increasing dependence on anaerobic metabolism, thus being critical in determining endurance and exertional tolerance (Wasserman et al., 2012). Generally, higher oxygen threshold is associated with an athlete capable of sustaining efforts above critical power or VO_{2max} without having to rely too much on the fast development of metabolic fatigue (Midgley, McNaughton, & Wilkinson, 2007).

Total energy expenditure (TEE) — which encompasses resting metabolic rate, thermic effect of food and physical activity-related energy expenditure — is emerging as another marker of an athlete's overall physiological load and capacity (Jeukendrup & Gleeson, 2010). To assess the energetic stress of trained athletes and guide periodization (Meyer et al., 2011), TEE is monitored during high-performance training and preparatory periods. In racket based sports like badminton which usually consists of repetitive preconditioned high-intensity bouts over long periods of time during the course of a play session, TEE poses some implications for both adaptations in performance and recurrent injury prevention. (Salman et al., 2022)

While abundant research has focused on endurance and team sports, relative to this there is a scarcity of studies that have investigated the relationships between the oxygen threshold metric and total energy expenditure with sport-specific skill endurance, particularly in badminton. Physiological profiling, match analysis, and biomechanical factors influencing talent have garnered the majority of existing badminton research (Phomsoupha & Laffaye, 2015) Nonetheless, endurance of technical skill execution, especially those associated with offensive actions such as overhead smashes, jumps at the net and fast drop shots under fatigue is poorly covered in literature. The endurance of offensive skill is crucial since ongoing force and precision in attacks gives a competitive advantage for a longer period match. (Shehab et al., n.d.)

Physiological variables such as oxygen threshold and total energy expenditure or even distance run can tell coaches, sport scientists how he/she able to repeat the offensive skill execution under fatigue, this can help coach/sport scientist to design training. In practice, it could even fine-tune conditioning cycles to maximise metabolic thresholds and dynamic energy resource management during critical training phases (eg the special preparation phase



which aims at a cohesive improvement of technical, tactical and physiological processes preceding competition). (Kadhim et al., n.d.)

Thus, this research analyzes the correlations of oxygen threshold and total energy expenditure in resistance to offensive skill performance in advanced Iraqi national badminton team players during the special preparation phase. It is hypothesized that the higher oxygen threshold and total energy expenditure will be positively related to superior endurance of offensive skill performance. (Kadhim & Mahmood, 2023)

Methods

Participants

This study included twenty male elite badminton players from the Iraqi national team (mean age = 24.4 ± 2.6 years). All athletes were free from injury, had at least 5 years competitive experience and signed written informed consent before participation. Ethical approval: [Number; version/Date] EthicalApproval.png

Design and Procedure

Oxygen threshold was calculated according to a graded treadmill exercise test with continuous gas exchange analysis (COSMED K5 Portable Metabolic System). Participants started at a speed of 8 km/h, and the speed increased by 1 km/h every two minutes until volitional fatigue. Threshold detection was carried out using the ventilatory equivalent method and defined as increases in ventilation against oxygen uptake to indicate the OT point (Wasserman et al. 2012).

Oxygen Threshold Measurement

Oxygen threshold was assessed via a graded treadmill exercise test with continuous gas exchange analysis (COSMED K5 Portable Metabolic System). Participants started at a speed of 8 km/h, increasing 1 km/h every two minutes until volitional fatigue. The ventilatory equivalent method was used to assess threshold detection, with elevations in ventilation per oxygen uptake indicating the OT point (Wasserman et al., 2012).

Total Energy Expenditure

Validated wearable devices (BodyMedia SenseWear Armband) were used to track total energy expenditure over the four weeks. Devices measured energy expenditure throughout the entire day while awake, both when training and recovering. We then calculated the weekly TEE averages of each athlete.

Offensive Skill Endurance Test

Data are expressed as mean \pm SD (standard deviation) for all variables. Pearson correlation coefficients were computed to explore associations between oxygen threshold, total energy expenditure and offensive skill endurance. Significance was set at $p < .05$.



Statistical Analysis

For all variables, descriptive statistics (mean ± SD) were calculated. Pearson correlation coefficients were computed to assess relationships between threshold oxygen, total energy expenditure, and offensive skill endurance. Significance was set at $p < .05$.

Results

Descriptive statistics for the study variables are presented in Table 1.

Table 1. Descriptive Statistics for Key Variables

Variable	Mean ± SD
Oxygen Threshold ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	46.5 ± 3.7
Total Energy Expenditure ($\text{kcal}\cdot\text{week}^{-1}$)	$3,820 \pm 430$
Offensive Skill Endurance Score	88.3 ± 5.4

Significant positive correlations were found between oxygen threshold and offensive skill endurance ($r = .71, p < .01$), and between total energy expenditure and offensive skill endurance ($r = .50, p < .05$).

Discussion

Objectives The aim of the present study was to investigate how key physiologic variables are associated with endurance of offensive skill performance in elite-level badminton players. Results showed both physiological metrics are related to offensive training endurance experienced during the special preparation phase. (Kadhim et al., n.d.)

The close relationship between *vair* and skill endurance echoes earlier findings that greater levels of aerobic metabolic thresholds are associated with better sustained performance in high intensity intermittent exercise (Midgley et al., 2007; Bassett & Howley, 2000). Anaerobic fatigue inhibition and efficient oxidative metabolism during time to exhaustion (29–36), as observed in badminton, would provide adaptive support for repeated sustained or explosive offensive shots over the course of a long game. (Easa et al., 2022)

Skill endurance also had strong moderate correlation with recruited equals energy expenditure. This finding further supports the basis that a higher TEE is associated with greater [total] energy expenditure in training, congruent with readiness and adaptive capacity (Jeukendrup & Gleeson, 2010). High-intensity, repetitive work is an effective means of increasing daily energy expenditure and may directly correlate with the need for more training stimulus as that athlete will have learned how to use energy stores more efficiently, in turn allowing them to shift greater amounts of pressure under fatigue. (Jawad et al., 2024)

Such results underscore the importance of including aerobic conditionings and energy management among preparation programs employed by elite badminton players. Not only specific to high intro endurance but also as this type of interval training is well known for being



the basis of good level coordination when fatigued - a kind that can be retained in play during your performances. (Kadhim & Shihab, 2019)

This study aimed to compare oxygen threshold (OT) and total energy expenditure (TEE) concerning offensive skill performance tolerance between elite Iraqi national badminton players in the special preparation phase. The results show significant positive correlations between OT and measures of offensive skill endurance, and between TEE and technical performance. Such results finally offer some surely physiological hints for performance sustainment in repeated high-intensity and intermittent racket sports 3.

1. Oxygen Threshold and Offensive Skill Endurance

Oxygen threshold and offensive skill endurance ($r = .71$) confirms that high aerobic metabolic efficiency was key towards sustaining high intensity technical performance (play) in badminton. The exercise intensity at which lactate starts to accumulate faster, is called the oxygen threshold and it reflects the interplay of lactate production and clearance (Gaesser & Poole, 1996). Athletes who possess a higher OT are able to train at greater intensities while also postponing metabolic acidosis and neuromuscular fatigue.

Badminton is defined by multiple repeated explosive rallies of 5–15 seconds interspersed with brief recovery periods. Thus, oxidative metabolism plays a key role in phosphocreatine resynthesis during breaks (between rallies) when such intermittent activity occurs (Phomsoupha & Laffaye, 2015). Hence, higher oxygen threshold players would show faster metabolic recovery between offensive actions, allowing them to sustain smash velocity, shot accuracy and movement economy under fatigue overload.

These results parallel those of the overall literature in which resting ventilatory threshold is a better predictor than maximal oxygen uptake (VO_{2max}) for performance in many types of intermittent exercises (Midgley et al., 2007; Bassett & Howley, 2000)}. VO_{2max} is a measure of maximal aerobic capacity, and the oxygen threshold reflects sustainable intensity which can be considered to have more relevance to match-play from a physiological position.

Additionally, being able to execute offensive skills while tired relies upon, not only muscular endurance, but also neuromuscular coordination. Metabolic disruptors resulting from fatigue can restrict patterns of motor unit recruitment and fine motor control, thus reducing shot accuracy and timing attempts. Higher OT may improve this metabolic buffering capacity and efficiency of oxygen delivery, thus enabling high OT athletes to be more resistant to these impairments.

2. Total Energy Expenditure and Performance Sustainability

A moderate yet significant correlation ($r = .50$) suggested that players capable of achieving a greater cumulative energy turnover during the preparation phase demonstrated an enhanced ability to maintain offensive execution.

Thus, TEE encompasses the metabolic demands still cortical sealant circular training volume in addition to intensity and activity each day. High-performance athletes' training



patterns are usually associated with an increased TEE which can act as a stimulus for adaptations (Jeukendrup & Gleeson, 2010). But you have to be careful with that association. Just because this translates to higher energy expenditure does not mean better performance — it could simply signal an optimal proportion of training stimulus and restitution.

During the special preparation period in which athletes performed mostly sport-specific conditioning whilst being integrated with tactics, containment of higher TEE likely represents a step-up in intensity such as high-intensity drills or game simulation. Such exposure increases metabolic efficiency, mitochondrial density, and patterns of substrate utilization (Meyer et al., 2011). These physiological adaptations enhance the athlete's capacity to produce and maintain ATP synthesis during successive attacking actions.

Moreover, optimal nutritional management is important in phases of increased TEE. Low energy availability can affect glycogen resynthesis and recovery, most importantly causing lower turnover in technical consistency. As such, TEE monitoring can help to manage both performance and recovery.

3. Interaction Between Metabolic and Technical Performance

A new approach of this study is to be able to relate physiological markers with offensive skill endurance instead of linking it to general endurance values. Badminton technical performance is very sensitive to reductions in reaction time, coordination precision and lower-limb power output induced by fatigue.

Power moves such as jump smashes and attacking net drives demand maximum force generation and the ability to control that production with the fine motor skills of racket and ball contact. As metabolic fatigue accumulates, the reductions in central drive and peripheral muscle efficiency impair both power generation and timing of movement. Athletes with higher oxygen thresholds may be more resistant to such mechanisms of fatigue, as a result of types of training that improve oxygen delivery through increased capillarization and greater oxidative capacity, (Wasserman et al., 2012).

This supports an integrative model of performance because physiological capacity facilitates technical persistence. These findings dully reinforce the rationale behind sport-specific conditioning programs and not to separate domains of conditioning and skill training.

4. Practical Applications for Training Periodization

From a coaching point of view the results highlight that:

1. In special preparatory period, the main attention is focused on increasing of oxygen threshold.
2. HIIT and sport-specific interval training drills might be effective in increasing OT.
3. Tracking total energy expenditure can help optimize loads but also aid in preventing overtraining.
4. Transfer-to-match performance can be further improved by highlighting the connection between conditioning interventions and appropriate technical drills.



5. Competitions can be more accessible through periodization models characterized by progressive increases in the intensity of aerobic threshold that accompanies repeated executions of a skill in conditions of fatigue.

5. Limitations and Future Research

Despite the valuable findings, several limitations must be acknowledged:

1. The national team examined may limit the generalisability.
2. Because the concern is correlational, no causal inference can be made.
3. Energy use was measured by wearables (validated but not easy and a small measurement error)
4. Future research should:
 - Interventional studies to increase oxygen thresholds in the long run.
 - Ventilatory threshold and lactate kinetics
 - Look for markers of neuromuscular fatigue and how they relate to technical degradation.
 - For comparison, female elite badminton players are also included.



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