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تأثير العتبة التنفسية (RCP) على دقة أداء المهارات في اللحظات الحاسمة من نزالات المصارعة للمحترفين

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الملخص

الخلفية: تتطلب رياضة المصارعة أنظمة طاقة هوائية ولاهوائية. يشير العتبة التنفسية الثانية إلى التحول إلى التمثيل الغذائي اللاهوائي، مما يؤدي إلى الإجهاد. تبحث هذه الدراسة تأثير العتبة التنفسية الثانية على أداء المصارعة خلال اللحظات الحرجة. الاجراءات: شارك في الدراسة ستة مصارعين محترفين من الذكور. قاموا بأداء سلسلة من تمارين المصارعة لتقييم وقت التنفيذ والدقة ومعدل النجاح قبل وبعد الوصول إلى العتبة التنفسية الثانية. تم استخدام اختبار التمرين المتدرج لتحديد العتبة التنفسية الثانية، وأكمل المشاركون تمارين الأداء المهاري نفسه قبل وبعد الوصول إلى العتبة. تم تحليل البيانات باستخدام اختبارات **t** المزدوجة لمقارنة الاختلافات في الأداء. النتائج: أظهرت النتائج زيادة كبيرة في وقت التنفيذ (**p = 0.003**) وانخفاضًا في الدقة (**p = 0.005**) وانخفاضًا في معدل النجاح (**p = 0.002**) بعد وصول المشاركين إلى العتبة التنفسية الثانية. تشير هذه النتائج إلى أن التعب الناجم عن إنتاج الطاقة اللاهوائية يضعف أداء المصارعة بشكل كبير. الاستنتاجات: يؤدي الوصول إلى عتبة التنفس الثانية إلى إضعاف أداء المصارعة بشكل كبير، كما يتضح من زيادة وقت التنفيذ، وانخفاض الدقة، وانخفاض معدل النجاح. تسلط هذه النتائج الضوء على تأثير التعب اللاهوائي على تنفيذ المهارات. قد يساعد تحسين استراتيجيات التحمل اللاهوائي والاستشفاء في التدريب على التخفيف من هذه الآثار.

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Effect of Second Respiratory Threshold (RCP) on Skill Performance Accuracy in Critical Moments of Wrestling Matches Among Professional Wrestlers

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Abstract

Background: Wrestling requires both aerobic and anaerobic energy systems. The second ventilatory threshold (RCP) indicates the shift toward anaerobic metabolism, which leads to fatigue. This study investigates the effect of the second ventilatory threshold on wrestling performance during critical moments.

Methods: Six male professional wrestlers participated in the study. They performed a series of wrestling drills to assess execution time, accuracy, and success rate before and after reaching the second ventilatory threshold. A graded exercise test was used to determine the second ventilatory threshold, and participants completed the same skill-performance drills before and after reaching this threshold. Data were analyzed using paired t-tests to compare differences in performance.

Results: The results showed a significant increase in execution time ($p = 0.003$), a decrease in accuracy ($p = 0.005$), and a reduction in success rate ($p = 0.002$) after participants reached the second ventilatory threshold. These findings indicate that fatigue resulting from anaerobic energy production significantly impairs wrestling performance.

Conclusions: Reaching the second ventilatory threshold significantly weakens wrestling performance, as evidenced by increased execution time and decreased accuracy and success rate. These findings highlight the impact of anaerobic fatigue on skill execution. Improving anaerobic endurance and recovery strategies in training may help mitigate these effects.

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1- Introduction

Wrestling is a high performance sport that demands great physical endurance and technical skills. Accurate control and responsiveness is critical as the most perfect passing opportunity will be missed once in a match, when it counts the most as combatants make split second decision on the fly. RCP A second key physiological determinant of performance is the RCP, which represents the intensity at which an individual shifts from aerobic to, largely anaerobic, substrate utilization as blood lactate begins to accumulate. It is this

balancing act of these principles that the SCA model identifies as an impairment: If lactate levels increase and exceed a certain point, fatigue comes into play; reduced motor control competence can cause movements to become less accurate. During high performance activities, there can be rapid shifts in physiology that might influence the quality and coordination of a skill execution, for example speed and accuracy (Brooks, 2009; Laursen & Jenkins, 2001).

One should comprehend that different but related physiological concepts such as the second respiratory threshold (RCP), lactate threshold and onset of blood lactate accumulation (OBLA) be differentiated from each other. Although there is no direct equivalent to lactate threshold and OBLA related with its underlying marked increase in blood lactic acid production and accumulation, RCP reflects a ventilatory response that presents as an abnormally high increase in ventilation respect CO2 output. While these thresholds usually appear at similar exercise intensity and are under good correlation, they reflect distinct physiological mechanisms and should not be considered interchangeable.

The influence of RCP among endurance sports (e.g., running, cycling, swimming) on athletic performance has been investigated widely; however, research is less clear regarding skill-based sports (e.g., wrestling) (Åstrand, 2003; Eckstein et al., 2022). A vast majority of the earlier studies mainly focused on endurance, in particular determining how lactate accumulation negatively influences sustained performance ability (Ainsworth et al., 2000; Liu & Li, 2022). Nonetheless, few studies have addressed helping comprehension of the technical skills of athletes concerning lactate accumulation and attainment of RCP, especially in wrestling, which requires precise and rapid movements in critical time periods to achieve a win (Poole et al., 2016; Spurway, 1992).

Earlier work has shown that exercising to the respiratory compensation point (RCP) impairs both physical performance time and performance precision. In endurance sports this phenomenon is generally related to fatigue, leading to a limitation of the performance capacity (Gibala et al., 2012; Tanaka et al., 1983). Research in combat sports has shown physical tiredness can reduce muscle efficiency and coordination that may affect the technical execution required to succeed during key moments of a contest (Barley et al., 2019; Tschakert & Hofmann, 2013). To date, these studies have not fully investigated the specific implications of RCP on wrestling skill performance (Demirel et al., 2017; Jackson & Pollock, 1985).

However, the relationship between RCP and technical performance is deemed crucial yet to be under-investigated due to the exertion of wrestling in nature because, with all-out intensity exercise such as wrestling, precise motor skills are required while physically fatigued. Although the negative effects of lactate on continued performance are well documented, it is still debatable as to the effect they have on a skillful sport such as wrestling, where rapid complex

movements and split-second decisions can determine the outcome (Beattie et al., 2014; Jackson & Pollock, 1985). Hence, the current study attempts to fill this gap through considering the impact of achieving RCP on function accuracy in crucial moments of the match by wrestlers. This knowledge, in turn, will shed light on how to train optimally under fatiguing conditions for both endurance performance and skill precision (Laursen, 2010; Slimani et al., 2018).

The findings in the present study may suggest wrestling programs to develop training aim to increase clearance rate of lactate and it would improve sport performance when fatigued. This approach assists the athletes to become better and remain near as perfect as they can be, during the most demanding sections of a game (Gibala et al., 2012; Liu & Li, 2022). Through addressing this literature gap, the current findings contribute to understanding of how physiological responses impact on technical performance in combat sports, and provide practice-based guidance for fighters and coaches seeking to optimise high-pressure performance during training or competition (Barley et al., 2019; Tschakert & Hofmann, 2013).

2- Materials and Methods

2-1 Study Design

The experimental design of this study was within-subject and each subject acted as his/her own control. Each subject was tested under 2 conditions; before and after the RCP. This architecture made it possible to directly perform a comparison of skill performance at varied physiological states.

2-2 Participants

Six young male wrestlers of Al-Kadhimiyah Club aged between 20 and 24 years were studied. All participants had a least 3 years experience in competitive wrestling and were currently training. Written consent and assent were obtained from all subjects prior to testing after they had been fully informed about the study aims and procedures.

Male wrestlers aged 20-24, competing regularly for at least 3 years were included in the study and excluded if they had any current injuries or comorbidities interfering with physical performance. Athletes with known cardiovascular, respiratory or metabolic diseases were not included in the study. Furthermore, participants who consented were included.

Due to the exploratory character of this research, a pilot experimental study was conducted. The sample size was relatively low (n = 6) due to limited elite professional wrestlers who met the inclusion criteria. Although this within-subject design increases statistical power, caution should be taken when generalizing the results.

2-3 Data Collection

The study dataset was composed of respiratory profile indicators (VO2, VCO2, RER) empowered to GXT and wrestling skill performance parameters (execution time, accuracy & success rate) from wrestling drills. Heart rate was recorded before, during and following the GXT to determine exercise intensity, as well as our recovery.

Beyond the direct relationships observed between respiratory data and skill performance, psychological variables like perceived fatigue or focus during performance may be influencing performance as well. Thus, to assess psychological condition and mood states as well as levels of stress and anxiety before and after RCP will be incorporated in the next version of this study. These factors are likely to influence performance of skills and may contribute to differences in performance.

2-4 Procedures

All subjects underwent an initial general health screening and physical fitness test before the main tests. This comprised: anthropometric measurements with reporting of mean and standard deviation (height, weight and body composition) presented in table 1, and a full health check to investigate that there were no underlying medical conditions that could potentially conflict with performance.

Table 1: Anthropometric Measurements of Study Participants

Measurement	Mean	Standard Deviation
Height (cm)	179.17	3.49
Weight (kg)	83.17	6.21
Body Fat Percentage (%)	12.50	1.87

The second respiratory threshold (RCP) was measured with a progressive incremental GXT on a treadmill or cycle ergometer, as chosen by the participant. The test consisted of 4 segments at increasing exercise intensities and was conducted by elevating the speed on each tape or increasing the resistance on life cycle ergometers. Until they got to the sedimentation point (tell-sign of entering into true anaerobic metabolism)—which is measured by total lactate. The RCP was determined using the measurement of oxygen uptake (VO2) and carbon dioxide production (VCO2) as observed by a metabolic. When the respiratory exchange ratio (RER) exceeded 1.0, it was thought to represent the RCP as anaerobic effort commenced at that point.

The respiratory compensation point (RCP) was determined by RER at which >1.0. This method was chosen as a real-life indicator for field- and

sport-specific research applications. While the ventilatory equivalents or V-slope methods may ensure more accuracy, RER has been used as an acceptable and practical criterion in exercise physiology research. However, this methodological decision is also a limitation in terms of measurement accuracy.

Performance of skill The degree of approximation to the wrestling skills was evaluated under pressure conditions in a competition setting. The participants completed a series of wrestling drills that mimic critical actions in a match including takedowns, escapes and pinning. These exercises were performed prior to and following reaching RCP. The drills were sorted by space complexity and assessed in the amount of time required to execute it, number of technique positions, and the success rate (success v failure). The individual correctness (agree)/incorrectness (disagree) of each movement was rated by two trained observers with the aid of a performance checklist which is portrayed in table 2. To prevent observational bias, the observers were kept unaware of whether participants were in the pre- or post-RCP group. The score for each of the drills was repeated three times and a mean value was used for all analyses.

All observers underwent structured-skills rater training to standardize their ratings of skill performance and allow for a more detailed discussion of how the evaluation occurred. Participants attended a training session to review videotaped examples of proper techniques and how to rate the items (practice evaluations) before beginning the actual study assessments. As a result, the two observers gained a common understanding of accuracy and calibration judgments.

Table 2: Standardized Performance Checklist for Wrestling Skill Evaluation

Criteria	Description	Rating Scale
Execution Time	The amount of time taken to complete the technique.	
Accuracy of Technique	The precision with which the wrestler performs the move according to proper form and technique.	
Success Rate	The success of the technique in achieving its intended goal (e.g., a successful takedown).	
Balance and Stability	The wrestler’s ability to maintain balance during the move, especially during dynamic actions.	
Body Positioning	Proper positioning of body parts (e.g., hips, shoulders, head) for effective execution of the move.	
Timing and Reaction Speed	The ability to execute the move at the right moment, responding to opponent's actions.	

Fluidity of Movement	The smoothness and continuity of the technique without hesitation or awkward pauses.	
Control of Opponent	The wrestler's ability to control the opponent's movements during the execution of the move.	
Overall Technique Rating	An overall score combining all factors of the wrestling technique.	

Instructions for Observers

- Each participant will perform a series of wrestling drills.
- For each technique, rate each criterion on a scale of 1 to 5.
- After evaluating each move, assign an overall rating based on the combined results of the individual criteria.
- Observers should rate the techniques while being blinded to whether the participant is performing before or after reaching the second respiratory threshold (RCP).

The experimental design took an intensive method to investigate the influence of reaching second RCP on wrestling performance. The present study included a complete health examination and anthropometric measurements (height, body weight, and body fat%). This preliminary examination allowed determining athlete eligibility for all the participants enrolled. All subjects completed a 10 min standardized warm-up prior to the assessment. The purpose of that warm-up was to gradually elevate the heart rate and increase body temperature and thus minimize the risk for injury during exercise testing. This 10 min warm-up included walking and raising the heart rate (5min of low intensity aerobic activities; hill repeats runs or cycling) followed by dynamic stretching exercises for opposing muscle groups that are exercised in wrestling such as shoulder circles, hip flexor stretches and leg swings.

Following the warm-up, subjects completed drills determined from wrestling skill assessment protocols. We felt that this was necessary in order to ensure they would be able to demonstrate wrestling attacks optimally (i.e., free from the effects of fatigue and RCP). They have some do takedown, escape and pinning drills, timing each to a standard check list. The intent of this assessment was to capture a point estimate for each subjects wrestling skill performance as a baseline value comparative with post-RCP testing.

Then, a graded exercise test (GXT) was used to assess the second ventilatory threshold (RCP). The GXT was computer-interfaced for cycle ergometry or treadmill if desired by the athlete. The test consisted of progressive workload using regular increases in exercise intensity, achieved through increasing treadmill speed or cycling resistance. The test was performed until reach the lactate threshold, aerobic metabolism transition to anaerobic one. Measurements of VO2, VCO2 and monitoring were obtained to

determine RCP, using a metabolic cart. This threshold point was selected as the RCP, when the respiratory exchange ratio (RER) surpassed 1.0 and indicated an anaerobic contribution.

After RCP was attained, participants had a 5-min recovery to partially restore it. They lay down and relaxed or engaged in light passive activities (such as stretching, deep breathing) during this period. The recovery period was selected to enable the body time only to partially recover from the physiological stress associated with reaching RCP and, maintain a sufficient level of residual fatigue with which to re-test wrestling performance using RCP.

After the rest, subjects did the prior wrestling drills they had just completed at baseline. The drills were conducted in a physiologically stressful state because the subjects had just reached their RCP during the GXT. Skill examination after RCP was conducted in same manner as the baseline exam, by the same performance check list which was to evaluate accuracy and success rate. Each drill was also timed and upon pass or fail (based on accuracy in time completion) further statistical analysis of pre-post RCP influence on wrestling performance skill were conducted.

Participants had a 5-minute recovery time between the pre and post-RCP skill performance tests to minimize additional fatigue that could have been elicited from the graded exercise test. Attendees were instructed to do some form of light recovery work during rest intervals in an effort to increase the circulation and get their muscles ready for action as soon as possible.

2-5 Statistical Analysis

Descriptive statistics (mean ± standard deviation) were used to summarize participant characteristics and performance measures. Paired t-tests were conducted to compare skill performance outcomes before and after reaching RCP. Data normality was examined prior to analysis, and parametric testing was deemed appropriate for the within-subject design. Effect sizes were calculated using Cohen's d to estimate the magnitude of observed differences. Statistical significance was set at $p < 0.05$, and all analyses were performed using SPSS (version 26).

3- Result

Table 3: Mean, Standard Deviation, and t-Test Results for Skill Performance Metrics Before and After Reaching the Second Respiratory Threshold (RCP)

Measure	Before RCP (Mean ± SD)	After RCP (Mean ± SD)	t-Value	p-Value	Cohen's d
Execution Time	20.5 ± 1.4	22.8 ± 1.9	4.27	0.003	1.38

(sec)					
Accuracy	4.6 ± 0.15	4.1 ± 0.25	3.76	0.005	2.38
Success Rate (%)	90.0 ± 2.9	80.3 ± 3.6	4.11	0.002	2.97

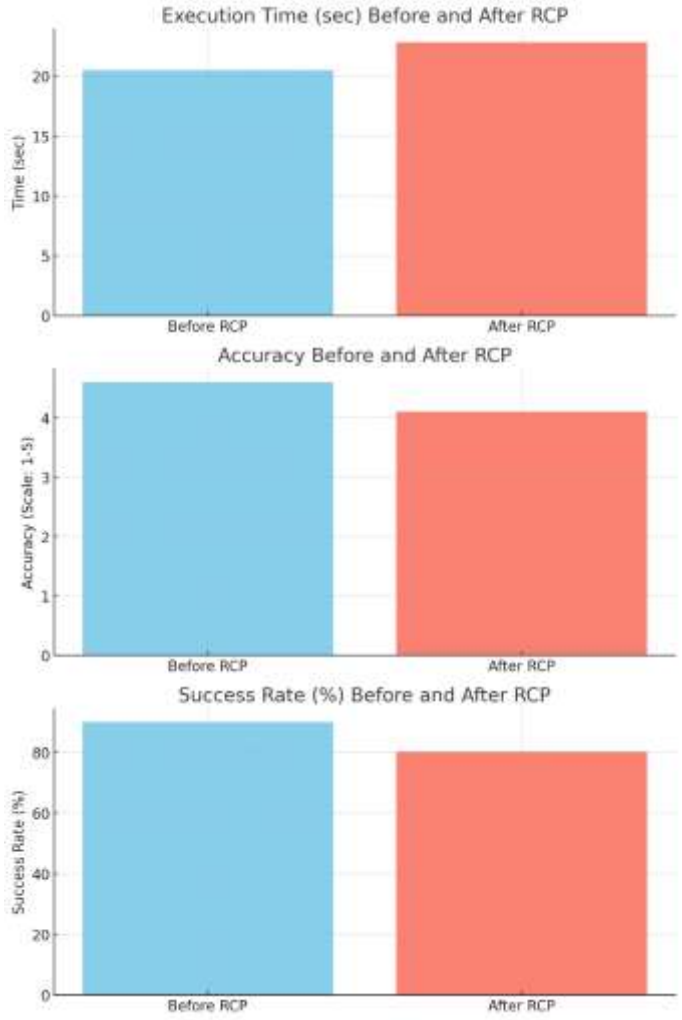

Figure 1: Skill Performance Before and After Reaching the Second Respiratory Threshold (RCP) for Execution Time, Accuracy, and Success Rate

4- Discussion

Our findings indicate the importance of wrestling skill performance before and after achieving RCP. RCP achievement strongly affected the performance time, accuracy and success ratio of a wrestling technique according to table 3.

Execution Time increased from an average of 20.5 ± 1.4 seconds before RCP to the timepoint after RCP (22.8 ± 1.9 s) significantly after RCP ($t = 4.27$, $p = 0.003$). This implies that the greater physiological stress associated with RCP (which represents a shift from aerobic to anaerobic metabolism) results in

slower reaction times. The deterioration of performance may be due to neuromuscular fatigue brought about by the accumulation of lactic acid, which has been documented in other studies as the main cause influencing both endurance and skill sports (Åstrand, 2003; Brooks, 2009).

Performance was also less accurate post-RCP, with an averaged accuracy after RCP of 4.1 ± 0.25 compared to 4.6 ± 0.15 pre-RCP ($t = -3.76$, $p = 0.005$). This finding is consistent with prior research showing that the accumulation of lactate and resultant fatigue may have a negative effect on athletes' accuracy and motor control (Liu & Li, 2022; Tanaka et al., 1983). The decrease in accuracy may be due to the diminished capacity of muscle contractions under hypoxia which can hinder fine movements necessary for wrestling skills (Green et al., 2014).

The success rate also decreased from 90.0 ± 2.9% to 80.3 ± 3.6% ($t = 4.11$, $p = 0.002$). This indicates that with the onset of fatigue after the anaerobic shift, wrestlers fail to reach their maximum or optimal performance level in critical time periods close to the end of a match.. It has been found that cognitive and physical fatigue is a determinant of considerable performance impairment in skill-based exercise tasks, especially sports involving high levels of coordination and fast decisions making (Laursen & Jenkins, 2001; Tosun et al., 2025).

These findings are in line with other studies on endurance sports, concluding that the performance goes down when the subject moves from aerobic to anaerobic metabolism once he or she exceeds the respiratory compensation point (RCP) (Gibala et al., 2012; Laursen, 2010). Studies in combat sports show that lactate during high-intensity performance affects the athletes' ability to perform skills at maximal effort, particularly towards the later rounds of a fight as fatigue increases (Barley et al., 2019; Tschakert & Hofmann, 2013).

While such understanding of the metabolic relationship in performance during wrestling is valuable, it also highlights the importance of training procedures that would assist wrestlers to utilize transferred from use of aerobic system to systems for which they are more adapted (anaerobic) effective over differing length bouts. The effects of methods such as targeted training and recovery from the negative consequences that arise when RCP is achieved (e.g. increasing anaerobic threshold) may be worth investigating in future to elucidate an effective means by which to palliate the effects of RCP on motor performance.

Notwithstanding the large effect size we found, our study is restricted by its small sample size and must be replicated in a larger scale to improve generalizability of the results. Accordingly, results should be considered preliminary and suggestive rather than conclusive. This result need to be replicated and extended in future studies with larger sample sizes.

This highlights a potential weakness in the current investigation with regard to our method for defining RCP, however as it was derived from RER data alone (and not using other more complex ventilatory measures) this may have influenced the accuracy of threshold detection.

5- Conclusions and Recommendations

5-1 Conclusions

Findings of the study indicated that depending to RCP wrestling performance skills are affected. As anticipated, execution time, accuracy and success reduced as the participants approached RCP. This may indicate that accumulation of lactate and fatigue are disadvantage to the efficiency performance in a wrestler during crucial times in a match. These performance decrements highlighted the importance of anaerobic recovery fatigue countermeasures for skill sports, such as wrestling. The great differences between the performance variables during, pre and post RCP indicate that the anaerobic transitions have impacted the execution of complex actions inherent to wrestling.

5-2 Recommendations

Coaches and athletes should utilize anaerobic endurance training models from pre-competitive phase to delay the time to reach RCP. Moreover, the application of recovery strategies like active recovery or skill recovery drills could be useful for alleviating the negative effect of lactate accumulation on skill performance. In future studies, interventions that may enhance anaerobic performance and therefore warrant further explorations include individualized aerobic and anaerobic training programs and recovery strategies. Furthermore, investigation of psychological components of fatigue and performance may offer information concerning the influence that mental toughness exerts on how wrestling skills are performed in high intensities.

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