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INTERRELATIONSHIP BETWEEN CARDINAL ABILITIES AND PHYSICAL QUALITIES IN THE PROCESS OF TRAINING OF HIGHLY QUALIFIED JUDO PLAYERS

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Abstract: This study examines the relationship between cardiac performance and physical performance in highly skilled judo athletes during training. A sample of 20 elite male judo athletes was administered cardiovascular measures, including resting heart rate, maximum heart rate, and VO_2 max, as well as physical performance tests measuring grip strength, vertical jump height, agility, and endurance. The results showed a strong correlation between VO_2 max and several physical attributes, including endurance ($r = 0.82$), agility ($r = -0.58$), and explosive power ($r = 0.55$). A decrease in resting heart rate was also associated with better strength and power performance. No significant correlation was found between maximum heart rate and physical performance. These findings highlight the central role of aerobic capacity in overall athletic performance and suggest that improving cardiovascular fitness can improve judo-specific physical abilities. The study provides valuable insights into optimizing training protocols for elite judo athletes.

Keywords: Judo, VO_2 max, resting heart rate, physical performance, endurance, agility, grip strength, elite athletes, cardiovascular fitness, training optimization

Introduction

Judo, a dynamic combat sport based on precision, power, and strategy, requires a finely tuned synergy between the athlete's cardiovascular system and physical capabilities. As training intensity and levels of competition increase, especially among highly skilled judokas, understanding the physiological factors that contribute to peak performance is becoming increasingly important. One important area of interest in sports science is the relationship between cardiac capabilities such as heart rate variability, stroke volume, and oxygen consumption, and key physical attributes such as strength, endurance, agility, and flexibility.

Recent research suggests that elite judo athletes undergo significant cardiovascular adaptations due to high-volume anaerobic and aerobic training. These adaptations are believed to affect not only recovery time and energy efficiency, but also explosive power and decision-making under physical stress. For example, a well-equipped cardiovascular system allows athletes to maintain high performance during the intense, short-term movements typical of judo matches, while also helping them recover more quickly between rest periods.

Despite the existing literature on the general physiology of combat athletes, there is limited empirical data directly linking specific cardiac parameters during training to measured physical characteristics among elite judo athletes. This study seeks to fill this gap by examining how

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cardiac performance, as assessed by measures such as resting heart rate, maximum heart rate, and VO_2 max, is related to physical parameters including grip strength, vertical jump height, and agility test performance.

By systematically analyzing highly skilled judo athletes during regular training, this study aims to determine how changes in cardiac activity reflect or predict differences in physical performance. The findings may provide practical insights for coaches and exercise physiologists in developing individualized training protocols that optimize cardiovascular health and athletic performance in judo.

Literature review

The relationship between cardiovascular function and physical fitness in combat sports, particularly judo, has attracted the attention of researchers seeking to optimize athlete performance. Judo requires both anaerobic and aerobic energy systems, making cardiac efficiency an important component of an athlete's physical development. Several studies have suggested that elite-level judo athletes undergo specific physiological adaptations that enhance their cardiovascular function and overall physical performance (Franchini et al., 2011).

As Franchini et al. (2007) have noted, judo athletes often operate near their anaerobic threshold during high-intensity training and competition. As a result, well-developed cardiovascular fitness, as reflected by high VO_2 max levels and rapid heart rate recovery, plays a central role in maintaining performance and reducing fatigue. These cardiac parameters not only indicate physical fitness, but also help predict competitive success (Franchini & Takito, 2014). In addition, recovery heart rate has been used as a non-invasive marker to assess cardiovascular adaptation during training.

In a study by Artioli et al. (2010), judokas with higher heart rates also demonstrated improved performance in strength and power tests, including isometric grip strength and vertical jump. This suggests a direct relationship between cardiovascular conditioning and neuromuscular function. Similarly, Sterkowicz-Przybycień et al. (2011) found that elite judokas with better heart rate variability (HRV) had better agility and reaction times, highlighting the importance of autonomic nervous system balance in skill performance.

Furthermore, specific physical attributes such as explosive strength, grip strength, and agility in judo have been shown to influence an athlete's cardiovascular and metabolic efficiency (Boguszewska et al., 2010). These findings support the concept that aerobic fitness not only aids in recovery between matches, but also increases endurance for overall training load.

Although several studies have examined the relationship between physical attributes and performance, few have focused on the synchronous development of cardiovascular and physical attributes during training. This calls for a comprehensive assessment that demonstrates how cardiac-related functions influence or correlate with athletic performance in real time.

Thus, the current study builds on previous findings by analyzing empirical data from highly skilled judo athletes during training and provides a more detailed picture of how heart rates

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correlate with specific physical abilities. Such studies may provide more insight into training frequency, injury prevention, and individual conditioning strategies for elite judo.

Methodology

This study was designed to investigate the relationship between cardiovascular fitness and physical performance during regular training periods in highly skilled judo athletes. A quantitative, correlational research design was used to assess how cardiovascular performance correlates with physical performance.

Participants

The sample included 20 male judo athletes aged 18 to 28 years, qualified at least at the national level, and with at least five years of professional training experience. All participants were free of injury at the time of the study and provided informed consent prior to testing. The study was approved by the Ethics Committee of the relevant sports science institution.

Data collection procedures

Data collection was conducted over a four-week mesocycle during the athletes' training preparation phase. Measurements were conducted in a controlled indoor environment to ensure consistency.

Cardiac capacity assessment

Three main cardiac parameters were measured:

1. **Resting heart rate (RHR)**- Measured using a Polar H10 heart rate monitor after 10 minutes of sitting.
2. **Maximum heart rate (HRmax)**- determined by progressive treadmill test for voluntary fatigue.
3. **VO_2 Max**- Assessed using a metabolic cart (COSMED Quark CPET) during a treadmill test.

Assessment of physical qualities

Four physical qualities were tested:

1. **Grip strength**- measured using a grip dynamometer, the best of three tests recorded.
2. **Explosive force**- is assessed by vertical jump height using a power plate.
3. **Agility**- Measured using the Illinois Agility Test.
4. **Endurance**- Assessed using the Yo-Yo Intermittent Recovery Test Level 1.

A standardized warm-up session was performed before all tests. To avoid bias due to fatigue, physical tests were performed on separate days from the cardiac examination.

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Data analysis

Descriptive statistics (mean, standard deviation) were calculated for all variables. Pearson correlation coefficients were used to examine the relationships between cardiac and physical variables. The significance level was set at $p < 0.05$. Statistical analysis was performed using SPSS version 26.

This methodology provides accurate and objective data collection on cardiovascular and physical performance, allowing for detailed analysis of their correlations among elite judo athletes during training.

Results

This section presents the results of an assessment of cardiac capacity and physical qualities among 20 highly skilled judo athletes. The data collected included resting heart rate (RHR), maximum heart rate (HRmax), and VO_2 max as cardiac parameters, and grip strength, vertical jump height, agility, and endurance as physical performance parameters. The aim was to analyze the relationships between these two sets of variables using Pearson correlation analysis.

Descriptive statistics

Table 1 summarizes descriptive statistics (mean ± standard deviation) for all measured variables.

Table 1. Descriptive statistics of measured variables (n = 20)

Variable	Mean ± SD
Resting heart rate (bpm)	57.8 ± 5.2
Maximum heart rate (bpm)	188.2 ± 6.7
VO_2 max (ml/kg/min)	55.4 ± 4.8
Grip strength (kg)	52.7 ± 5.4
Vertical jump height (cm)	52.1 ± 6.2
Agility (seconds)	15.3 ± 0.7
Yo-Yo IR1 distance (m)	1620 ± 210

The results show that the athletes generally demonstrated above-average cardiovascular fitness and physical performance, consistent with their elite status. VO_2 max values above 50 ml/kg/min are typical of highly endurance-trained athletes. Grip strength and vertical jump height values also fell within the expected range for judo athletes.

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Correlation analysis

Pearson correlation coefficients were calculated to examine the relationship between cardiac abilities and physical attributes. Significant correlations ($p < 0.05$) are discussed below.

1. **VO_2 Max and Yo-Yo IR1 performance.**There was a strong positive correlation between VO_2 max and endurance test scores ($r = 0.82$, $p < 0.001$). Athletes with higher VO_2 max scores tended to cover greater distances on the Yo-Yo Intermittent Recovery Test, suggesting that aerobic capacity is a key factor in endurance performance in judo-specific training.
2. **VO_2 Max and Agility VO_2 max and agility test time (r = -0.58,**p= 0.007), indicating that athletes with higher aerobic capacity performed faster on the Illinois Agility Test. This suggests that improving oxygen uptake efficiency may help improve performance and recovery during high-speed directional changes.
3. **Resting heart rate and physical performance Resting heart rate was significantly associated with grip strength (r = -0.48,**p= 0.03) and showed a moderate negative correlation with vertical jump height (r = -0.51, p= 0.02). This means that athletes with lower resting heart rates, often showing better cardiovascular fitness, had greater strength and explosive power.
4. **Maximum heart rate and physical performance**There was no significant association between maximum heart rate and any of the physical performance variables (all $p > 0.05$), suggesting that HRmax itself may not be a sensitive indicator of physical performance in trained athletes.
5. **VO_2 Max and Vertical Jump Height VO_2 max and vertical jump performance (r = 0.55,**p= 0.01), suggesting that athletes with better aerobic conditioning may also exhibit neuromuscular strength. This may be due to improved oxygen delivery to fast-twitch muscle fibers during explosive movements.
6. **Grip strength and durability.**Interestingly, grip strength was moderately correlated with Yo-Yo IR1 distance ($r = 0.46$, $p = 0.04$), which may reflect the importance of grip endurance in prolonged bouts and repeated game simulations in judo training.

Summary of key findings

- VO_2 max was the most consistently correlated cardiac variable across multiple physical attributes.
- A lower resting heart rate was associated with higher strength and power output.
- Maximum heart rate did not show a statistically significant correlation with any physical quality.
- Aerobic capacity was significantly correlated with agility and endurance, both of which are crucial for the repetitive high-intensity movements in judo competitions.

These results highlight the correlation between cardiorespiratory and physical fitness variables in elite judo athletes. The strongest correlations were observed between VO_2 max and physical attributes, suggesting that training programs aimed at improving aerobic capacity can lead to improvements in endurance, agility, and even explosive power.

Visual representation

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To further illustrate the results, scatter plots were created to show the relationship between VO_2 max and key physical performance measures. The scatter plots showed a clear upward trend between VO_2 max and endurance and vertical jump height, and a downward trend with agility time, which strengthened the strength of the observed correlation.

Group comparison

When athletes were divided into two subgroups based on their VO_2 max values (high: >56 ml/kg/min; low: ≤56 ml/kg/min), the high VO_2 max group consistently outperformed the low group on all physical tests. The average Yo-Yo IR1 distance was 1740 m vs. 1490 m, vertical jump height was 56.2 cm vs. 48.3 cm, and grip strength was 55.1 kg vs. 49.3 kg, respectively.

Overall, the data support a significant relationship between cardiovascular fitness, particularly VO_2 max and resting heart rate, and physical performance in highly skilled judo athletes. These findings suggest that monitoring and improving cardiovascular fitness can improve multiple aspects of athletic performance in elite judo training.

Discussion

The results of this study reveal an important relationship between the cardiovascular capabilities of highly skilled judokas, specifically VO_2 max and resting heart rate, and key physical attributes. VO_2 max showed the strongest and most consistent correlation with endurance, agility, and even explosive power, suggesting that aerobic capacity is not only important for long-term performance, but also contributes to the short-term, high-intensity efforts that are specific to judo. This is consistent with previous studies by Franchini et al. (2011) and Artioli et al. (2010), who highlighted the dual reliance on aerobic and anaerobic systems in judo.

The negative correlation between resting heart rate and performance measures such as grip strength and vertical jump height suggests that good cardiovascular conditioning is associated with increased neuromuscular efficiency. Athletes with a lower resting heart rate have improved blood flow, oxygen delivery, and metabolic efficiency, which enhances endurance and recovery, especially during interval training and competition.

Interestingly, maximum heart rate was not significantly associated with any physical variables. This finding is consistent with previous literature that HRmax is more genetically determined and less responsive to training than VO_2 max or heart rate recovery measures (Midgley et al., 2007). Therefore, it may have limited practical value in predicting physical performance among elite athletes.

Overall, the results reinforce the importance of integrated training strategies that simultaneously address cardiovascular health and sport-specific physical attributes. Coaches and trainers should prioritize increasing VO_2 max through targeted aerobic and interval training, as improvements in this area can impact broader aspects of judo performance, including agility, grip strength, and explosiveness.

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These findings contribute valuable insight into judo-specific conditioning and highlight the need for individualized training plans based on cardiac profiles. Future research could expand this analysis to include hormonal, psychological, and recovery markers to create a more holistic model of performance optimization.

Conclusion

This study examined the relationship between cardiac performance and physical attributes during training in highly skilled judo athletes. The analysis showed that key cardiac parameters, specifically VO_2 max and resting heart rate, were significantly correlated with important physical performance factors such as endurance, agility, grip strength, and explosive power.

VO_2 max emerged as the most influential cardiac variable, showing strong positive correlations with Yo-Yo interval recovery test and vertical jump height, and negative correlations with agility test times. This suggests that athletes with higher aerobic capacity perform better not only in endurance-based tasks, but also in activities requiring speed and explosive power. Similarly, the negative correlation between resting heart rate and physical fitness suggests that a well-conditioned cardiovascular system supports the neuromuscular function and faster recovery required for high-level judo performance.

In contrast, maximum heart rate did not show a significant relationship with any of the measured physical attributes, confirming previous findings that HRmax has limited value in predicting performance and is less responsive to training adaptations.

The findings highlight the importance of incorporating cardiovascular conditioning into judo-specific training regimens. By focusing on improving VO_2 max and lowering resting heart rate through targeted aerobic and high-intensity interval training, athletes can improve their overall performance in multiple physical domains.

This study contributes to a growing body of literature highlighting the interrelationship of physiological systems in elite athletic performance. The information obtained may assist coaches, sports scientists, and conditioning coaches in developing more effective, individualized training protocols for judo athletes.

Future studies should examine longitudinal changes in cardiac and physical performance across different phases of training and competition. In addition, incorporating other physiological and psychological variables would provide a more complete understanding of the determinants of performance in elite judo.

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