

# Examining the Efficacy of the Wrestling-Specific Sandbag Throw Conditioning Test in Distinguishing Between Elite and Sub-Elite Wrestlers

Güreşe Özgü Kum Torbası Fırlatma Kondisyon Testinin (Sandbag Throw Conditioning Test) Elit ve Elit Altı Güreşçileri Ayırt Edebilmedeki Etkinliğinin İncelenmesi

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*Acknowledgments (The authors wish to thank to all the participants and their coaches for attending the study. Also, AI support was taken for the English writing and grammar editing.*

Geliş Tarihi/Received 18.12.2024  
Kabul Tarihi/Accepted 16.07.2025  
Yayın Tarihi/Publication Date 25.09.2025

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Cite this article: Gençoğlu, C., Özbay, S., Ulupınar, S., Asan, S., İnce, İ., & Kışhalı, N.F. (2025). Examining the efficacy of the wrestling-specific sandbag throw conditioning test in distinguishing between elite and sub-elite wrestlers. *Research in Sport Education and Sciences*, 27(3), 208-216.



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## ABSTRACT

The aim of this study is to evaluate the effectiveness of the Sandbag Throw Conditioning Test (STCT) in distinguishing between elite and sub-elite wrestlers. This test has been developed to assess performance levels specific to the sport of wrestling. A total of 30 male wrestlers voluntarily participated in the study. The participants were divided into two groups: elite and sub-elite. The STCT protocol was applied to both groups, and performance results were recorded. An independent samples t-test was conducted to determine if there were significant differences between the groups. Additionally, discriminant function analysis was performed to assess the extent to which the STCT correctly classified the groups. Statistical analyses were carried out using R software, and a significance level of  $p < .05$  was considered. The p-values obtained for all rounds and the total score ranged between 0.005 and 0.013, indicating statistically significant differences between elite and sub-elite wrestlers. The analyses demonstrate that the STCT was able to successfully differentiate between the groups and that the test effectively reflects the performance levels of wrestlers. Additionally, the discriminant function analysis revealed that 70% of the participants were correctly classified. Considering that the probability of distinguishing between groups by random guessing is 50%, the STCT does not appear to be a highly successful test for differentiating between elite and sub-elite wrestlers. This suggests that the test may not fully capture the complex, sport-specific dynamics of wrestling performance, and highlights the need for more specialized, dynamic tests that better reflect the nuances of the sport.

**Keywords:** STCT, wrestling performance, elite wrestlers, discriminant function analysis

## Öz

Bu çalışmanın amacı, güreşe özgü Kum Torbası Fırlatma Kondisyon Testi'nin (*Sandbag Throw Conditioning Test, STCT*) elit ve elit altı güreşçileri ayırt etmedeki etkinliğini değerlendirmektir. Bu test, güreş sporuna özgü performans seviyesini belirlemek amacıyla geliştirilmiştir. Çalışmaya toplam 30 erkek güreşçi gönüllü olarak katılmıştır. Katılımcılar, elit ve elit altı olmak üzere iki gruba ayrılmıştır. Her iki gruba da STCT protokolü uygulanmış ve performans sonuçları kaydedilmiştir. Gruplar arasında anlamlı bir fark olup olmadığını belirlemek için bağımsız örneklem t-testi yapılmıştır. Ayrıca STCT'nin grupları ne oranda doğru sınıflandırdığını belirlemek için diskriminant fonksiyon analizi uygulanmıştır. İstatistiksel analizler R yazılımı kullanılarak yapılmış ve anlamlılık değeri  $p < .05$  olarak değerlendirilmiştir. Tüm rauntlar ve toplam skor için elde edilen p değerleri 0,005 – 0,013 arasında olup, bu sonuçlar elit ve elit altı güreşçiler arasında istatistiksel olarak anlamlı farklılıklar olduğunu göstermektedir. Yapılan analizler, STCT'nin grupları başarılı bir şekilde ayırt edebildiğini ve testin güreşçilerin performans seviyelerini belirlemede etkili olduğunu ortaya koymuştur. Ayrıca, diskriminant fonksiyon analizi sonucunda, katılımcıların %70'inin doğru bir şekilde sınıflandırıldığı belirlenmiştir. Gruplar arasında rastgele ayırma olasılığı %50 iken, STCT'nin elit ve elit altı güreşçileri ayırt etmedeki gücü sınırlı görünmektedir. Bu durum, testin güreşe özgü performansın çok boyutlu yapısını tam olarak yansıtamadığını ve daha spesifik, dinamik testlerin geliştirilmesine ihtiyaç olduğunu göstermektedir.

**Anahtar Kelimeler:** STCT, güreş performansı, elit güreşçiler, diskriminant fonksiyon analizi

## Introduction

Wrestling is one of the most ancient and revered combat sports in human history, with its origins dating back over 5,000 years to civilizations like the Sumerians and Egyptians. It was practiced not only as a form of combat training but also as a demonstration of physical prowess and military readiness (Park et al., 2019). Wrestling became an integral part of the ancient Greek culture, where it was one of the main events in the Olympic Games, first introduced in 708 BC (Kyle, 2014). The Greeks saw wrestling as a test of strength, endurance, and strategy, and it was often used to prepare soldiers for battle. The sport continued its prominence during the Roman era, where the Greeks' version of wrestling was adapted into what we now recognize as Greco-Roman wrestling, one of the two modern Olympic wrestling styles (Chaabene et al., 2017).

Currently, wrestling exists primarily in two forms in the Olympics: Greco-Roman and Freestyle. Greco-Roman wrestling prohibits any holds below the waist, emphasizing upper body strength and throws, which require athletes to develop significant power and technique in the upper body (Mirzaei et al., 2009). Freestyle wrestling, on the other hand, allows wrestlers to use their entire body, including leg attacks and holds, offering a broader range of techniques and strategies. This distinction makes Freestyle wrestling a more dynamic sport, with an emphasis on both strength and agility (Demirkan et al., 2014). Both styles are highly competitive and physically demanding, requiring wrestlers to possess not only strength and power but also flexibility, endurance, and tactical intelligence (Ulupinar et al., 2021; Yard & Comstock, 2008). Wrestling has remained a staple of modern Olympic competition since the early 20th century, when both Greco-Roman and Freestyle were officially included in the Olympic Games (García-Pallarés et al., 2011). The sport's long-standing tradition and its continued emphasis on physical and mental discipline have solidified its place as one of the most respected combat sports worldwide (Chaabene et al., 2018).

Performance tests play a pivotal role in the assessment, monitoring, and enhancement of athletes' capabilities, particularly in sports like wrestling where physical demands are multifaceted (Chaabene et al., 2018; Yard & Comstock, 2008). These tests provide an objective measure of various physiological parameters such as strength, power, endurance, and agility, which are critical for evaluating an athlete's readiness for competition and for identifying specific areas that may require targeted training interventions (Hickner et al., 1991). Regular performance testing enables coaches and sports scientists to establish a comprehensive profile of an athlete's current physical condition, helping to track progress over time and adjust training programs as needed. The ability to detect subtle differences in performance becomes especially important as athletes progress to higher levels of competition. As the performance gap between athletes narrows, the precision and specificity of performance tests become even more crucial in distinguishing between them (García-Pallarés et al., 2011; Ulupinar et al., 2021).

While laboratory-based performance assessments, such as maximal strength measurements, aerobic capacity evaluations, and power output tests, are essential for providing controlled and standardized data on an athlete's physical capabilities, they often lack the ecological validity necessary to fully reflect the dynamic demands of competitive sports (Chaabene et al., 2018). These tests are typically conducted in ideal, controlled environments that isolate specific physical attributes, removing the complex interplay of factors such as fatigue, psychological pressure, and opponent variability that athletes experience in actual competition (Emerson Franchini et al., 2011). As a result, while laboratory-based assessments are valuable for diagnosing specific strengths and weaknesses, they may fall short in accurately predicting an athlete's real competition performance potential (Chaabene et al., 2018).

In contrast, sport-specific performance tests offer a more holistic evaluation by replicating the actual movements, energy system demands, and tactical situations characteristic of the sport. These tests enhance the ecological validity of performance assessments, as they are designed to simulate the competitive environment more closely (Wright et al., 2015). By measuring an athlete's ability to perform under sport-specific conditions, these assessments provide more relevant data on their functional capacity and readiness for competition (Demirkan et al., 2014). This is particularly critical in high-intensity, skill-dependent sports like wrestling, where explosive strength, power, and anaerobic endurance are integral to success (Özbay et al., 2025). Sport-specific tests are thus indispensable for identifying areas of improvement and tailoring training programs to address the actual demands of the sport (Demirkan et al., 2014; Emerson Franchini et al., 2011). The STCT is designed to simulate the physical demands of wrestling by incorporating dynamic, sport-specific movements that require explosive

power, muscular endurance, and coordination—attributes that are paramount for success in the sport (Wright et al., 2015). By employing a test that reflects the real demands of wrestling, this study aims to provide a more accurate method for evaluating wrestlers' performance levels and distinguishing between athletes of different competitive calibers. Therefore, the purpose of our study is to evaluate the efficacy of the Wrestling-Specific Sandbag Throw Conditioning Test (STCT) in distinguishing between elite and sub-elite wrestlers.

## Methods

### Study Design

This study was designed to evaluate the anaerobic performance of wrestlers using a sport-specific test, the Wrestling-Specific Sandbag Throw Conditioning Test (STCT). The primary aim was to assess the effectiveness of the STCT in distinguishing between elite and sub-elite wrestlers. The study involved two groups of wrestlers: elite and sub-elite, with the protocol applied uniformly across both groups. The STCT protocol includes multiple sets of dynamic, explosive throws using sandbags, designed to replicate the physical demands experienced during wrestling matches.

The study was conducted indoors under controlled environmental conditions (22-24°C temperature and 55-60% humidity) to ensure consistency in performance results. All tests were randomized and balanced to prevent interaction effects between participants. Before each testing session, participants were provided with a designated rest period to ensure optimal preparation. Additionally, the tests were administered at the same time of day, aligned with the athletes' routine training hours (16:00-18:00), to minimize the impact of circadian rhythm variations on performance.

Participants were informed about the study's aims, procedures, and potential risks, and written informed consent was obtained from all participants. The study was conducted in full accordance with the Declaration of Helsinki (2013 revision) and was approved by the Ataturk University Ethics Committee (3.7.2023; 2023/6). Any wrestler who did not wish to continue or who felt unwell during the tests was excluded from the study. Confidentiality of the participants' personal information was strictly maintained, and all collected data were anonymized and utilized solely for scientific purposes.

### Participants

A total of 30 male wrestlers voluntarily participated in the study. The participants were divided into two groups: elite (n=15) and sub-elite (n=15). The elite group consisted of wrestlers with a minimum of five years of regular training experience and at least one medal won at a national or international level competition in the last two years (age:  $26.13 \pm 4.21$  years; height:  $163.67 \pm 6.29$  cm; body weight:  $69.37 \pm 8.48$  kg; BMI:  $25.83 \pm 1.82$ ). The sub-elite group, on the other hand, included wrestlers with 1-5 years of training experience and no national or international success within the last two years (age:  $25.47 \pm 3.87$  years; height:  $161.53 \pm 5.45$  cm; body weight:  $68.15 \pm 4.77$  kg; BMI:  $26.14 \pm 1.31$ ). All participants were actively engaged in regular wrestling training sessions and were free of any injuries or health issues.

### Test Protocol

The testing sessions were conducted under the supervision of experienced coaches to ensure that all participants performed at their maximum capacity. Continuous verbal encouragement was provided to each wrestler to help maintain optimal effort throughout the test. During the execution of the Wrestling-Specific Sandbag Throw Conditioning Test (STCT), the coaches closely monitored the participants to ensure proper technique. In cases where a wrestler executed the technique incorrectly, a rest period of 10 minutes was provided before they were required to repeat the test.

The primary objective of the STCT was to have the wrestlers complete a series of dynamic movements involving sandbag throws in the shortest time possible with accurate technique (Wright et al., 2015). The test consisted of multiple sets, each incorporating sport-specific movements designed to simulate the physiological demands of a wrestling match. Participants were required to complete seven rounds of sandbag throws, with each round lasting one minute. The sandbag weighed 50% of each wrestler's body weight to ensure a consistent relative load across all participants (Wright et al., 2015).

Performance during the STCT was assessed using video recordings, which were later analyzed using Adobe Premier Pro software (Adobe Inc., USA) to determine set durations and technique accuracy with millisecond precision. The coaches aimed to replicate match-like conditions by using wrestling-specific warm-up protocols before each test session to prepare the participants for peak performance (Sterkowicz et al., 1999). The test protocol was structured to enhance ecological validity, ensuring that the STCT effectively replicated the physical and technical demands of competitive wrestling.

### Statistical Analysis

All statistical analyses were conducted using R (version 4.2.0, R Core Team, 2023), an open-source statistical computing software extensively used in academic research for advanced statistical modeling and visualization. Prior to conducting parametric tests, the assumption of normality was assessed using the Shapiro-Wilk test, implemented via the “stats” package in R. Independent samples t-tests were performed to compare the STCT performance of elite and sub-elite wrestlers across all rounds, as well as for total and average scores, using the stats package (version 4.2.0) in R, with statistical significance set at  $p < 0.05$ . Effect sizes were calculated using Cohen’s  $d$  via the “effsize” package (Cohen, 1988) and were classified following Hopkins’ scale as trivial ( $< 0.2$ ), small ( $0.2–0.6$ ), moderate ( $0.6–1.2$ ), large ( $1.2–2.0$ ), very large ( $2.0–4.0$ ), and nearly perfect ( $> 4.0$ ), ensuring nuanced interpretation of the magnitude of differences (Hopkins et al., 1999). Discriminant function analysis (DFA) was conducted using the “MASS” package to determine the STCT’s ability to classify participants into elite and sub-elite groups. The classification accuracy, expressed as the percentage of correctly classified wrestlers, was further validated using cross-validation techniques to enhance reliability.

Visualizations were created using the “ggplot2” package, including boxplots to illustrate the distribution of individual round performances, total scores, and average scores across groups, as well as a linear discriminant analysis plot to depict the separation between elite and sub-elite wrestlers based on the discriminant function. These methods ensured a rigorous, reproducible, and methodologically sound analysis, highlighting the test’s discriminative ability and areas for refinement.

### Results

**Table 1.**

***Comparison of anthropometric characteristics of the top elite and elite level wrestlers***

|                               | Elite Group   | Sub-Elite Grup | t          | p   | ES (d)      |
|-------------------------------|---------------|----------------|------------|-----|-------------|
| <b>Age (years)</b>            | 26.13 ± 4.21  | 25.47 ± 3.87   | 0.452      | .65 | 0.16 (TES)  |
| <b>Body Mass (kg)</b>         | 69.37 ± 8.48  | 68.15 ± 4.77   | 0.488      | .63 | 0.18 (TES)  |
| <b>Height (cm)</b>            | 163.67 ± 6.29 | 161.53 ± 5.45  | 0.993      | .33 | 0.36 (SES)  |
| <b>BMI (kg/m<sup>2</sup>)</b> | 25.83 ± 1.82  | 26.14 ± 1.31   | -<br>0.543 | .59 | -0.19 (TES) |
| <b>Body Fat (%)</b>           | 12.45 ± 2.20  | 11.80 ± 2.10   | 0.828      | .41 | 0.30 (SES)  |
| <b>Muscle Mass (kg)</b>       | 60.61 ± 6.26  | 60.04 ± 3.48   | 0.309      | .76 | 0.11 (TES)  |

Notes: Data are presented as mean ± standard deviation. BMI: Body Mass Index; ES: Effect size according to Cohen’s  $d$ , TES: Trivial effect size; SES; Small effect size.

The comparison between Elite and Sub-Elite wrestlers did not reveal statistically significant differences in age ( $t = 0.452$ ,  $p = .655$ ,  $d = 0.16$ , trivial effect size), body mass ( $t = 0.488$ ,  $p = .629$ ,  $d = 0.18$ , trivial effect size), height ( $t = 0.993$ ,  $p = .329$ ,  $d = 0.36$ , small effect size), body mass index (BMI) ( $t = -0.543$ ,  $p = .592$ ,  $d = -0.19$ , trivial effect size), body fat percentage ( $t = 0.828$ ,  $p = .415$ ,  $d = 0.30$ , small effect size), and muscle mass ( $t = 0.309$ ,  $p = .760$ ,  $d = 0.11$ , trivial effect size) as described in Table 1.

These results indicate that the anthropometric characteristics of the two groups are not significantly different, suggesting no meaningful variability in these features between Elite and Sub-Elite wrestlers. The effect sizes, as determined by Cohen’s  $d$  values, predominantly fall within the trivial to small range, indicating limited practical significance of these differences.

**Table 2.**  
**Comparison of sandbag throw conditioning test results of the elite and sub-elite wrestlers**

|                                | Elite Group  | Sub-Elite Group | $t_{(28)}$ | $p$  | ES (d)                 |
|--------------------------------|--------------|-----------------|------------|------|------------------------|
| <b>STCT</b> 1. Round           | 4.63 ± 0.36  | 5.15 ± 0.46     | -3.49      | .002 | -1.27 <sub>(LES)</sub> |
| <b>STCT</b> 2. Round           | 5.96 ± 0.42  | 6.58 ± 0.58     | -3.29      | .003 | -1.20 <sub>(LES)</sub> |
| <b>STCT</b> 3. Round           | 6.22 ± 0.44  | 6.85 ± 0.61     | -3.26      | .003 | -1.19 <sub>(MES)</sub> |
| <b>STCT</b> 4. Round           | 6.54 ± 0.45  | 7.19 ± 0.64     | -3.22      | .003 | -1.17 <sub>(MES)</sub> |
| <b>STCT</b> 5. Round           | 6.88 ± 0.47  | 7.55 ± 0.67     | -3.17      | .004 | -1.16 <sub>(MES)</sub> |
| <b>STCT</b> 6. Round           | 7.23 ± 0.50  | 7.93 ± 0.70     | -3.13      | .004 | -1.14 <sub>(MES)</sub> |
| <b>STCT</b> 7. Round           | 7.61 ± 0.52  | 8.33 ± 0.74     | -3.09      | .004 | -1.13 <sub>(MES)</sub> |
| <b>STCT</b> <sub>Total</sub>   | 45.09 ± 3.14 | 49.61 ± 4.41    | -3.23      | .003 | -1.18 <sub>(MES)</sub> |
| <b>STCT</b> <sub>Average</sub> | 6.44 ± 0.45  | 7.09 ± 0.63     | -3.24      | .003 | -1.19 <sub>(MES)</sub> |

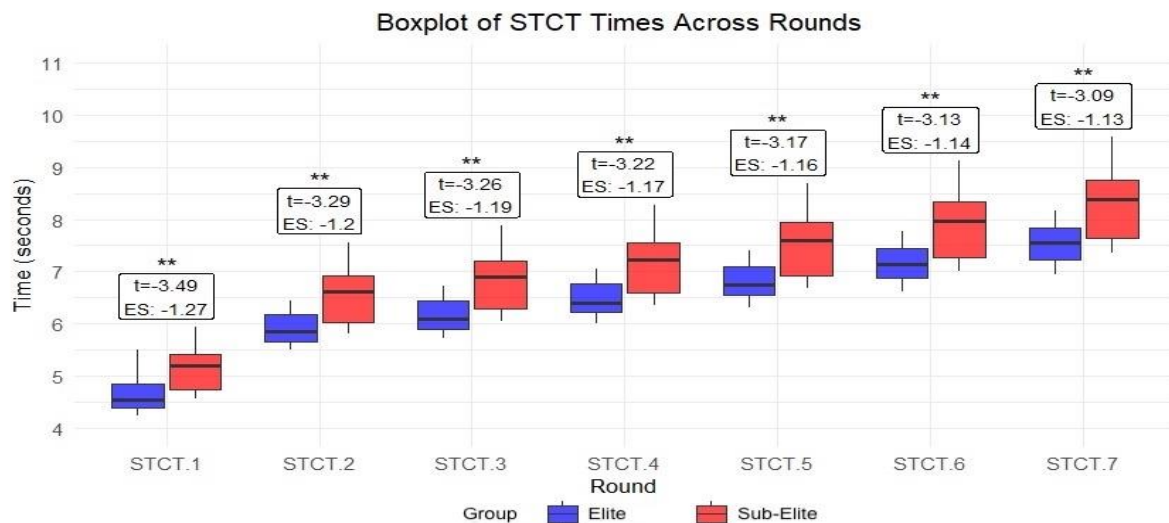
Note: Data are presented as mean ± standard deviation; STCT; Sandback throw conditioning test ES: Effect size according to Cohen's d, LES: Large effect size; MES: Moderate effect size.

According to the independent sample t-test statistical analysis in Table 2 and Figure 1, significant differences were observed between the Elite and Elite wrestlers in the Sandbag Throw Conditioning Test (STCT) across all rounds. From the first to the seventh round, the STCT performance durations of the Elite wrestlers were consistently better than those of the Sub-Elite wrestlers (Round 1:  $t_{(28)} = -3.49$ ,  $p = .002$ , ES = -1.27, large effect size; Round 2:  $t_{(28)} = -3.29$ ,  $p = .003$ , ES = -1.20, large effect size; Round 3:  $t_{(28)} = -3.26$ ,  $p = .003$ , ES = -1.19, moderate effect size; Round 4:  $t_{(28)} = -3.22$ ,  $p = .003$ , ES = -1.17, moderate effect size; Round 5:  $t_{(28)} = -3.17$ ,  $p = .004$ , ES = -1.16, moderate effect size; Round 6:  $t_{(28)} = -3.13$ ,  $p = .004$ , ES = -1.14, moderate effect size; Round 7:  $t_{(28)} = -3.09$ ,  $p = .004$ , ES = -1.13, moderate effect size).

The total and average STCT performance times also showed significant differences (Total:  $t_{(28)} = -3.23$ ,  $p = .003$ , ES = -1.18, moderate effect size; Average:  $t_{(28)} = -3.24$ ,  $p = .003$ , ES = -1.19, moderate effect size). All effect sizes were classified as moderate or large according to Cohen's d using Hopkins' classification.

**Figure 1.**

Boxplot graphs of the elite and sub-elite wrestlers' STCT performance scores



Significance levels: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ ; ES: Effect Size (Cohen's d); STCT: Sandback Throw Conditioning Test

**Table 3.**  
**Discriminant function analysis table (n=30)**

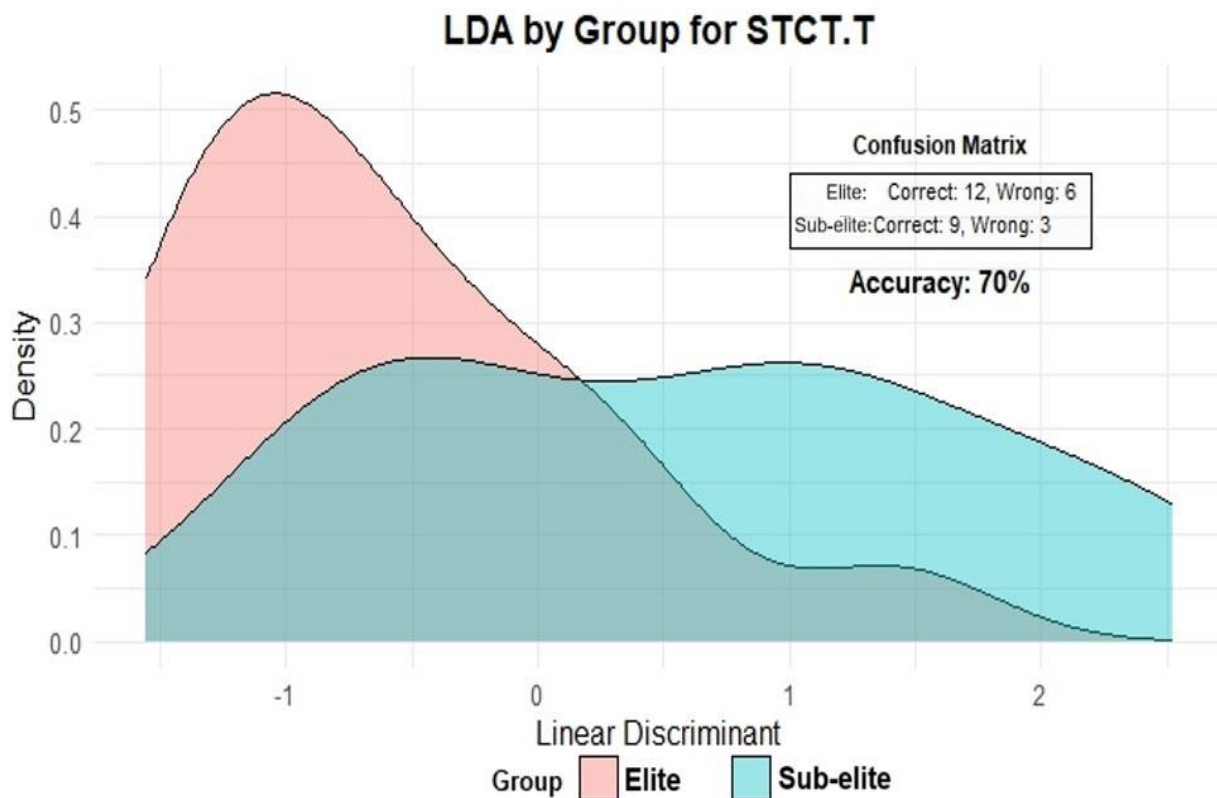
|                | Predicted Group Membership   |                              | Total  |
|----------------|------------------------------|------------------------------|--------|
|                | Elite Wrestlers              | Sub-Elite Wrestlers          |        |
| Original Count | Elite Wrestlers<br>12        | Sub-Elite Wrestlers<br>3     | 15     |
|                | Sub-Elite Wrestlers<br>6     | Elite Wrestlers<br>9         | 15     |
| Original %     | Elite Wrestlers<br>80.0%     | Sub-Elite Wrestlers<br>20.0% | 100.0% |
|                | Sub-Elite Wrestlers<br>40.0% | Elite Wrestlers<br>60.0%     | 100.0% |

**70.0% of original grouped cases correctly classified**

According to the discriminant function analysis, the STCT (both total and average scores) correctly classified the Elite and Sub-Elite wrestlers with an accuracy of 70% (see Table 3 and Figure 2).

**Figure 2.**

*Linear discriminant analysis graph of the STCT total scores*



LDA: Linear Discriminant Analysis, STCT.T: Sandback Throw Conditioning Test - Total Scores

## Discussion

This study evaluates the effectiveness of the Wrestling-Specific Sandbag Throw Conditioning Test (STCT) in differentiating between elite and sub-elite wrestlers. Designed to reflect the physical and technical demands of wrestling, the STCT incorporates sport-specific movements that require explosive power and anaerobic endurance, offering a more ecologically valid alternative to traditional laboratory tests. By including both elite and sub-elite athletes with verified national and international achievements, the study addresses a critical gap in understanding performance distinctions within high-level wrestling. Such research is essential for refining training interventions and developing benchmarks tailored to the advanced capabilities of top-tier athletes.

The findings demonstrated significant differences in STCT performance between the groups across all rounds and total scores, with elite wrestlers consistently outperforming sub-elite wrestlers despite the absence of notable differences in anthropometric characteristics. However, the STCT correctly classified 70% of elite and sub-elite wrestlers, which, while exceeding the minimum threshold of 50%, suggests it may have limited discriminatory power. This indicates that other factors, such as technical or tactical features, might also contribute to differentiating performance levels between elite level wrestlers (Özbay & Ulupinar, 2022). Further exploration of these variables and refinement of sport-specific tests are necessary to enhance their effectiveness in evaluating elite-level athletes. Compared to the study by Wright et al. (2015), which validated the sandbag test for collegiate wrestlers, our findings similarly confirm its ecological validity in replicating wrestling's physiological demands (Wright et al., 2015). While they demonstrated the test's reliability and its ability to assess fatigue across weight classes, our study extends its application by examining elite and sub-elite wrestlers. The moderate classification accuracy observed (70%) highlights the need for refining the test to better address the performance distinctions at higher competitive levels, as also suggested by Wright et al. (2015).

The STCT's relevance to wrestling-specific performance aligns with earlier studies emphasizing the importance of anaerobic and ecologically valid testing in wrestling (Hickner et al., 1991; Wright et al., 2015). While Wright et al. demonstrated the sandbag test's reliability and sensitivity to weight-class differences, their findings focused on collegiate wrestlers, suggesting room for further refinement when applied to higher competitive levels. Similarly, Hickner et al.'s arm crank protocol provided insights into anaerobic capacity but was limited in replicating the full-body demands of wrestling. Horswill (1992) and Callan et al. (2000) reinforced the importance of anaerobic endurance and strength in wrestling (Callan et al., 2000; Horswill, 1992), attributes central to the STCT, while Kraemer et al. (2001) and Nilsson et al. (2002) detailed physiological responses during matches, including lactate production (Kraemer et al., 2001; Nilsson et al., 2002), which align conceptually with the STCT's focus on repeated high-intensity efforts. However, these earlier studies, conducted decades ago, may not fully address contemporary competitive standards, and their findings require cautious interpretation when compared to newer testing approaches like the STCT. Utter et al. (1997) emphasized the practicality of wrestling-specific tests, but the simplicity of their design limits their applicability to current high-performance settings (Utter et al., 1997). While the STCT addresses some of these limitations, concerns remain about its moderate discriminatory power, indicating that further refinements and validation may still be necessary.

Performance testing in combat sports has increasingly shifted towards the development of sport-specific assessments that accurately reflect the unique physiological, technical, and tactical demands of each discipline (Chaabene et al., 2018). In taekwondo, the Taekwondo Anaerobic Intermittent Kick Test (TAIKT) (Taati et al., 2022; Tayech et al., 2020) or Frequency Speed of Kick Test (FSKT) (da Silva Santos & Franchini, 2018; Ulupinar et al., 2021) has been widely adopted to evaluate anaerobic power and capacity, focusing on the explosive kicking techniques central to the sport, demonstrating strong validity and reliability in both laboratory and field settings. In judo, the Special Judo Fitness Test (SJFT) has been extensively validated, offering valuable metrics such as grip strength, aerobic and anaerobic capacity, and recovery efficiency during simulated match conditions, thereby aligning closely with the intermittent nature of judo matches (E. Franchini et al., 2011; Sterkowicz-Przybycien & Fukuda, 2014; Sterkowicz et al., 1999). In boxing, the development of sport-specific dynamometers, such as the triaxial force measurement system combined with a boxing manikin interface, provides a reliable means to evaluate punching force and its multidirectional components. These tools effectively distinguish performance levels among elite, intermediate, and novice boxers, with elite athletes demonstrating significantly higher maximal punching forces in both rear and lead hand punches compared to their less experienced counterparts (Smith et al., 2000). These sport-specific performance tests have become indispensable for combat sports as they enhance ecological validity, providing coaches with actionable data to

evaluate the effectiveness of training interventions, monitor athlete progress, and identify areas for improvement. Furthermore, the integration of advanced physiological and biomechanical testing methods into these assessments continues to refine their application, ensuring they remain essential tools for optimizing performance in the distinct and multifaceted demands of combat sports.

### Limitations

This study is limited by its small sample size, cross-sectional design, and inclusion of only male wrestlers, which may reduce the generalizability of the findings. Although the STCT incorporates sport-specific elements, it may not fully reflect the technical-tactical demands of wrestling. Future studies should include larger and more diverse samples, including female athletes, and adopt longitudinal designs to assess performance adaptations over time.

### Conclusion and Recommendation

The Wrestling-Specific Sandbag Throw Conditioning Test (STCT) provides a valuable method for evaluating the unique demands of wrestling by incorporating sport-specific movements that mirror the dynamic and anaerobic requirements of the sport. However, its ability to classify only 70% of elite and sub-elite wrestlers highlights the need for further improvement in its discriminatory power. Earlier approaches to performance evaluation, such as arm crank protocols or studies on anaerobic endurance and physiological parameters during matches, have significantly contributed to understanding the metabolic and strength demands of wrestling. However, many of these assessments are based on older studies, which may not fully align with the evolving physical and tactical demands observed in modern elite-level competition. This indicates that future approaches should aim the development of more comprehensive and ecologically valid tests that integrate endurance, strength, and technical-tactical parameters, enabling a more accurate evaluation of the multifaceted nature of elite level performance wrestling.

**Etik Komite Onayı:** Bu çalışma için etik komite onayı Atatürk Üniversitesi'nden (Tarih: 03/07/2023, Karar No: 22) alınmıştır.

**Hasta Onamı:** Çalışmaya katılan tüm katılımcılardan yazılı onam alınmıştır.

**Hakem Değerlendirmesi:** Dış bağımsız.

**Yazar Katkıları:** Fikir-; CG, SU, SÖ, İİ; Tasarım-; SG, NFK, SA, İİ; Denetleme-; SU, SÖ, NFK; Kaynaklar-; İİ, SA, SU, CG; Veri Toplanması ve/veya İşlenmesi; CG, SG, SO, SU, NFK; Analiz ve/ veya Yorum-; CG, NFK, SU; Literatür Taraması-; İİ, SA, CG, SÖ; Yazıyı Yazan-; CG, SÖ, SU; Eleştirel İnceleme-; SU, SÖ, NFK

**Çıkar Çatışması:** Yazarlar, çıkar çatışması olmadığını beyan etmiştir.

**Finansal Destek:** Yazarlar, bu çalışma için finansal destek almadığını beyan etmiştir.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Ataturk University (Date: July 3, 2023, Decision Number: 22,).

**Informed Consent:** Written consent was obtained from all participants..

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept -; CG, SU, SÖ, İİ; Design-; SG, NFK, SA, İİ; Supervision-; SU, SÖ, NFK; Resources-; İİ, SA, SU, CG; Data Collection and/or Processing-; CG, SG, SO, SU, NFK Analysis and/or Interpretation-; CG, NFK, SU; Literature Search-; İİ, SA, CG, SÖ; Writing Manuscript-; CG, SÖ, SU; Critical Review-; SU, SÖ, NFK

**Conflict of Interest:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

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