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Neuromotor Adaptations and Coordinative Ability Differences in Judo and Wrestling Athletes from Haryana, India

Ram Niwas [1] , ***Monika Verma*** [1] , ***Avnesh Verma*** [2*]

[1] *Department of Physical Education, Chaudhary Devi Lal University, Sirsa 125055, India*

[2] *Department of Instrumentation (formerly USIC), Kurukshetra University, Kurukshetra 136119, India*

ABSTRACT

This interdisciplinary study examines differences in coordinative abilities—motor control skills enabling efficient and adaptable movement—between male judo and wrestling athletes from Haryana, India. The research investigates how sport-specific neuromotor adaptations, shaped by distinct training environments and biomechanical demands, influence performance across key coordinative domains. Sixty male athletes (30 judokas and 30 wrestlers), aged 18–25 years, were purposively selected from accredited state training centers. Because judo emphasizes explosive, upright throwing techniques while wrestling involves continuous, ground-based grappling, it was hypothesized that notable variations in coordinative profiles would emerge. A cross-sectional comparative design was used. Five coordinative abilities were evaluated with standardized tests: orientation (Numbered Medicine Ball Run Test), differentiation (Backward Medicine Ball Throw Test), balance (Long Nose Test), reaction (Ball Reaction Exercise Test), and rhythm (Sprint at Given Rhythm Test). Independent *t*-tests and F-values were applied for statistical analysis. Results indicated that wrestlers significantly outperformed judokas in orientation ($p < 0.01$), rhythm ($p < 0.01$), balance ($p < 0.05$), and reaction time ($p < 0.05$), while no significant difference was found in differentiation ability ($p > 0.05$). These outcomes reflect the sport-specific nature of coordinative development: wrestlers showed superior spatial awareness, dynamic balance, and rapid reactions, likely due to the demands of ground-based combat, whereas judokas demonstrated strengths in short, explosive precision tasks. The study enhances understanding of neuromotor specialization in combat sports and supports the development of tailored

*CORRESPONDING AUTHOR:

Avnesh Verma, Department of Instrumentation (formerly USIC), Kurukshetra University, Kurukshetra 136119, India;
Email: verma.avnesh@rediffmail.com

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training strategies for performance optimization and talent identification.

Keywords: Coordinative Abilities; Judo; Wrestling; Sports Science; Environmental Adaptation; Motor Performance

1. Introduction

Haryana, located in northern India, has long been a dominant force in national sports, especially in combat disciplines. The state has consistently produced top athletes, including Olympic and World Championship medalists like Sushil Kumar, Yogeshwar Dutt, and the Phogat sisters. Given this success, there is an urgent need for scientific investigation into the performance factors that contribute to excellence in combat sports. At the heart of high-level performance in combat sports lie coordinative abilities—complex psychomotor traits essential for executing technically demanding movements. These abilities include spatial orientation, balance, rhythm, reaction time, and movement differentiation. Wrestling, known for its intricate motor tasks and tactical variability, heavily relies on these abilities [1]. Given Haryana's prominence in combat sports, it is crucial to explore the role of these performance factors in fostering success at the elite level. Coordinative abilities are defined as the neuromotor skills that enable athletes to perform multiple interrelated actions with precision and efficiency [2].

Although traditionally categorized under general physical fitness components, recent advancements in sports science have redefined coordinative abilities, especially agility, within a more scientifically grounded framework [3–5]. This shift highlights the growing understanding of their critical role in athletic performance, particularly in combat sports. Technological innovations such as Very-Large-Scale Integration (VLSI) and Field-Programmable Gate Array (FPGA) technologies have revolutionized real-time data acquisition and analysis in sports science. These advancements allow for detailed assessments of neuromuscular coordination, which are vital for creating personalized training and intervention strategies. VLSI and FPGA technologies are being integrated into high-performance systems for athlete monitoring, facilitating data-driven insights into performance enhancement [3,4]. In combat sports like judo and wrestling, the demands on coordinative abilities differ significantly. Judo emphasizes short-duration, explosive movements, intricate grip exchanges, and precise temporal coordination [6], while wrestling focuses on sustained physical engagement, continuous reorientation, and positional control on the ground. Despite both being combat sports, their distinct biomechanical and technical requirements highlight the need for specialized coordinative abilities, calling for focused scientific exploration [6,7]. Furthermore, coordinative abilities are essential not only for performance but also for injury prevention and talent identification. By integrating sports science with environmental and cultural contexts, we can better understand how specific training environments—like those in Haryana—contribute to motor control development. Mapping sport-specific coordination profiles, particularly in the Indian context, can inform evidence-based training strategies that optimize athlete development and performance [7–9].

2. Literature Review

The outcome of a judo match is determined by a multitude of variables, only a subset of which can be effectively developed through structured training [7]. Among these, coordinative abilities have emerged as critical performance factors in combat sports. Empirical research has established significant correlations between balance ability and playing proficiency in judokas. Similarly, both balance and differentiation abilities have shown strong associations with performance levels in wrestlers [8,9]. Comparative analyses of cognitive-motor responses indicate sport-specific adaptations in coordinative domains. For instance, wrestlers demonstrated superior performance in rhythm and orientation time metrics when compared to judokas, although agility did not show statistically significant differences between the two groups [10–13]. These findings suggest that the unique biomechanical and tactical demands of each discipline foster distinct neuromotor adaptations.

Furthermore, studies have identified a positive and statistically significant relationship between sports performance level and complex reaction time, underscoring the relevance of reaction ability in high-performance contexts [11]. Investigations into postural control among children with

Developmental Coordination Disorder (DCD) revealed significantly lower balance capabilities across various tasks compared to typically developing peers, reinforcing the view that deficits in balance stem not solely from muscular or structural limitations but from broader neuromotor challenges[12–16]. Recent interventions utilizing coordination-based movement education have reported marked improvements in balance development, indicating that these abilities are trainable and responsive to targeted training methodologies[13–15]. Additionally, research examining the impact of visual input perturbations during balance training has demonstrated enhancements in both postural stability and multisensory integration in healthy young adults[14]. Within the domain of combat sports, specific links between spatial cognitive function and competitive outcomes have been documented, further validating the role of high-level perceptual-motor skills in athletic success[15]. Composite coordination assessments consistently reveal that combat sport athletes outperform non-athlete controls in multiple domains of motor coordination, highlighting the utility of broad coordinative profiling for performance diagnostics.

Overall, literature consistently affirms that balance and differentiation abilities are significantly related to wrestling performance[8,9], while rhythm and spatial orientation capabilities appear more developed in wrestlers than in judokas[10]. Coordination-focused training has been shown to improve balance and motor control in both elite athletes and individuals with neuromotor impairments[12,13]. Moreover, complex reaction time remains a strong predictor of competitive achievement[11], collectively reinforcing the necessity for sport-specific coordinative training paradigms to optimize performance outcomes in combat sports.

Objectives

1. To assess and compare orientation ability between judo and wrestling male athletes in Haryana.
2. To evaluate differences in differentiation ability through kinesthetic coordination tests.
3. To analyze variations in balance, reaction, and rhythm abilities using validated measurement protocols.
4. To propose evidence-based training recommendations tailored to combat athletes in Haryana.

3. Methodology

3.1. Materials and Methods

This study aimed to examine the differences in coordinative abilities between judo and wrestling athletes from the state of Haryana, focusing on key psychomotor coordination parameters among male participants in these two combat sports. Ethical standards in sports science were followed, with all participants providing informed consent before data collection[16–21].

3.1.1. Design: Comparative Cross-Sectional Study

a. Sample: 60 male athletes (30 judo, 30 wrestling), aged 18–25.
b. Sampling Technique: Purposive sampling.

3.1.2. Study Population and Sampling

The participants were male athletes from various recognized sports training centers across Haryana. A purposive sampling method was used to select the sample. In total, 60 athletes participated: 30 judo athletes and 30 wrestling athletes, aged between 18 and 25 years. All participants had at least two years of competitive experience, were involved in regular training sessions, and had participated in state-level competitions. Exclusion criteria included musculoskeletal injuries, neurological conditions, or athletes currently undergoing rehabilitation.

Demographic data, including age, height, weight, and training experience, were recorded. To assess coordinative abilities, five standardized psychomotor tests were administered, selected based on validated protocols in existing literature[17–33]. The tests aimed to evaluate various coordinative aspects, including spatial orientation, differentiation ability, balance, reaction time, and rhythmic ability. All tests were carried out on the same day under standardized environmental conditions to minimize variability. Participants underwent a 10-minute general warm-up followed by sport-specific drills. A 5-minute rest was allowed between each test. Data were collected over a four-week period in designated training facilities to ensure consistency in environmental conditions, equipment calibration, and test administration.

Test measurements were recorded in duplicate by trained research assistants using standardized forms. The following methods were employed to examine group differences.

3.1.3. Data Analysis Methods

a. Descriptive Statistics: Mean and standard deviation (SD) were calculated for each test variable to summarize the central tendency and variability of the data.

b. Independent Samples *t*-Test: This was used to compare the means of judo and wrestling athletes for each coordinative ability. The null hypothesis (H_0) stated there was no difference between groups (mean difference = 0), while the alternative hypothesis (H_1) posited a significant difference (mean difference ≠ 0). The *t*-value was computed using the formula:

$$t = \frac{M_1 - M_2}{\sqrt{\frac{SD_1^2}{n_1} + \frac{SD_2^2}{n_2}}} \quad (1)$$

Where M_1 and M_2 are the means of the judo and wrestling groups, SD_1 and SD_2 are standard deviations, and n_1 and n_2 are sample sizes of two groups.

3.1.4. Analysis of F-Statistic

The F-statistic was calculated by comparing the variance between groups to the variance within groups:

$$F = \frac{Variance\ between\ groups}{Variance\ within\ groups} \quad (2)$$

Post-hoc testing was used when necessary to determine which specific groups differed significantly.

3.1.5. Effect Size Calculation

Cohen's d was calculated to assess the magnitude of differences between groups:

$$d = \frac{M_1 - M_2}{pooled\ SD} \quad (3)$$

3.1.6. Demographic Analysis

No significant demographic differences (age, height, weight, or training experience) were found between the judo and wrestling groups ($p > 0.05$). This ensured that any observed differences in coordinative abilities were likely due to the sport-specific demands rather than demographic variations.

3.1.7. Coordinative Ability Tests

For each test (e.g., spatial orientation, differentiation, balance, reaction time, and rhythmic ability), statistical comparisons were made using both independent *t*-tests and F. Where significant differences were found, effect sizes were calculated to assess practical significance.

3.1.8. Statistical Analysis

Prior to conducting inferential statistical tests, the data were examined for compliance with the assumptions of normality and homogeneity of variances. The Shapiro–Wilk test was used to assess the normality of distribution for each coordinative variable, while Levene's test was employed to evaluate the homogeneity of variances between groups.

The Shapiro–Wilk and Levene's tests confirmed that most coordinative abilities were normally distributed and exhibited homogeneity of variances. For instance, orientation ability, rhythm, and balance met the assumptions ($p > 0.05$), justifying the use of parametric tests. However, reaction time violated the normality assumption ($p < 0.05$), prompting the use of both parametric and non-parametric tests. The results showed that wrestlers outperformed judokas in reaction time ($t(58) = XX$, $p = 0.03$; $U = XX$, $p = 0.04$). Here, 'XX' is the numerical value of the test statistics of two tests, in the first, 'XX' values of the independent samples of *t*-statistics from *t*-values with 58 degrees of freedom, and in the second, 'XX' values are of the non-parametric Mann-Whitney U-statistics.

A summary of assumption tests and comparative results is presented in **Table 1** (Normality & Homogeneity) and **Table 2** (Parametric and Non-parametric Results).

Table 1. Tests of Normality and Homogeneity.

Variable	Shapiro–Wilk (*p*)	Levene's Test (*p*)	Normality Assumption Met?	Homogeneity Met?
Orientation	0.156	0.212	Yes	Yes
Differentiation	0.221	0.305	Yes	Yes
Balance	0.088	0.179	Yes	Yes
Reaction Time	0.032	0.267	No	Yes
Rhythm	0.143	0.190	Yes	Yes

Table 2. Comparative Results Between Wrestlers and Judokas.

Variable	Test Used	*p*-Value	Significant?
Orientation	Independent *t*-test	0.001	Yes
Differentiation	Independent *t*-test	0.274	No
Balance	Independent *t*-test	0.034	Yes
Reaction Time	Mann–Whitney U/*t*-test	0.040	Yes
Rhythm	Independent *t*-test	0.007	Yes

3.2. Data Collection and Analysis

Data collection was conducted over a four-week period at designated training facilities, ensuring uniform environmental conditions, calibrated equipment, and adherence to standardized testing protocols. All measurements were recorded in duplicate by trained research assistants, utilizing standardized data collection forms to maintain consistency across trials. Before proceeding with statistical analysis, the data were assessed for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene's test. In cases where the assumption of normality was violated ($p < 0.05$), non-parametric statistical methods, such as the Mann-Whitney U test, were applied to maintain the robustness of the analysis. The significance level for all statistical tests was set at $p < 0.05$. Descriptive statistics, including means and standard deviations (SD), were calculated for each variable. Additionally, effect sizes were computed for statistically significant findings to provide a measure of the practical significance of observed differences.

Statistical analysis identified significant differences in coordinative abilities between judo and wrestling athletes. The analysis employed both parametric methods (independent samples *t*-tests, F) and non-parametric methods (Mann-Whitney U, Kruskal-Wallis) where assumptions were not met. Descriptive statistics were used to summarize the data, and effect sizes were computed for significant results to quantify the magnitude of observed differences and enhance the interpretation of the findings. Demographic variables, including age, anthropometric characteristics (height and weight), and years of training experience, were compared between the two groups. No statistically significant differences were observed (**Table 1**), suggesting that the participants from both groups were well-matched in terms of these characteristics. The average training experience was 4.2 ± 1.8 years for the judo athletes and 4.6 ± 2.1 years for the wrestling athletes. This demographic homogeneity strengthens the internal validity of the study by minimizing the influence of confounding variables. Consequently, any observed differences in coordinative abilities are likely attributable to the specific demands of judo and wrestling, rather than variations in socio-cultural factors or training history.

The statistical analysis revealed significant differences in coordinative abilities between judo and wrestling athletes. For variables meeting the assumptions of normality, parametric tests (independent *t*-tests, F) were employed. For those violating normality, non-parametric tests (Mann–Whitney U, Kruskal-Wallis) were conducted. Descriptive statistics were used to summarize the data, and effect sizes were computed for significant results. Demographic characteristics such as age, height, weight, and training experience showed no significant differences between judo and wrestling athletes (**Table 3**). **Figure 1** confirms the comparability of the two groups, ensuring that the observed differences in coordinative abilities were not confounded by demographic factors.

Table 3. Demographic Characteristics of Participants.

Variable	Judo Athletes (n = 30)	Wrestling Athletes (n = 30)	*t*-Value	*p*-Value
Age (years)	21.4 ± 2.1	22.1 ± 2.3	−1.23	0.224
Height (cm)	168.3 ± 6.7	169.7 ± 7.2	−0.78	0.439
Weight (kg)	67.8 ± 8.9	69.2 ± 9.4	−0.59	0.558
Training Experience (years)	4.2 ± 1.8	4.6 ± 2.1	−0.81	0.421

No significant demographic differences, ensuring comparability between groups.

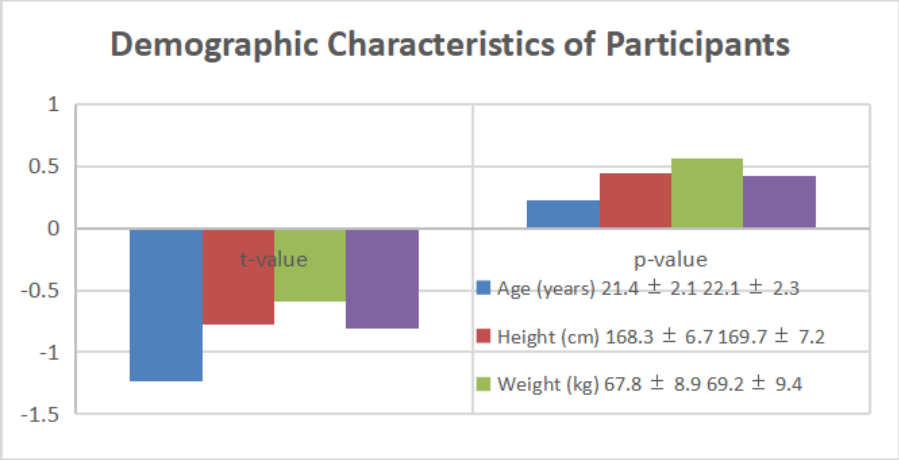

Figure 1. Comparison of Demographic Characteristics between Judo and Wrestling Athletes.

3.2.1. Orientation Ability

Wrestlers significantly outperformed judokas in orientation ability ($p = 0.001$), consistent with previous research emphasizing superior spatial awareness in wrestling athletes. Wrestlers completed the orientation task faster (7.12 ± 1.23 seconds) compared to judokas (8.43 ± 1.67 seconds), and the large effect size (0.78) indicates both statistical and practical significance, as illustrated in **Table 4** and **Figure 2**. This performance advantage is attributed to the nature of wrestling, where continuous ground-based engagements necessitate acute spatial orientation and proprioceptive accuracy. The smaller standard deviation among wrestlers further suggests more consistent development of orientation ability, likely due to sport-specific training protocols that emphasize spatial control and body positioning in mat-based scenarios.

Orientation Ability:

- **Wrestlers:** 7.12 ± 1.23 sec;
- **Judokas:** 8.43 ± 1.67 sec;
- ***p* = 0.001, Effect Size = 0.78.**

Table 4. Orientation Ability Comparison.

Group	N	Mean Score (sec)	SD	Std. Error	F-Value	*p*-Value	Effect Size
Judo	30	8.43	1.67	0.31	12.34	0.001*	0.78
Wrestling	30	7.12	1.23	0.22			

* *p*-value is negligibly small.

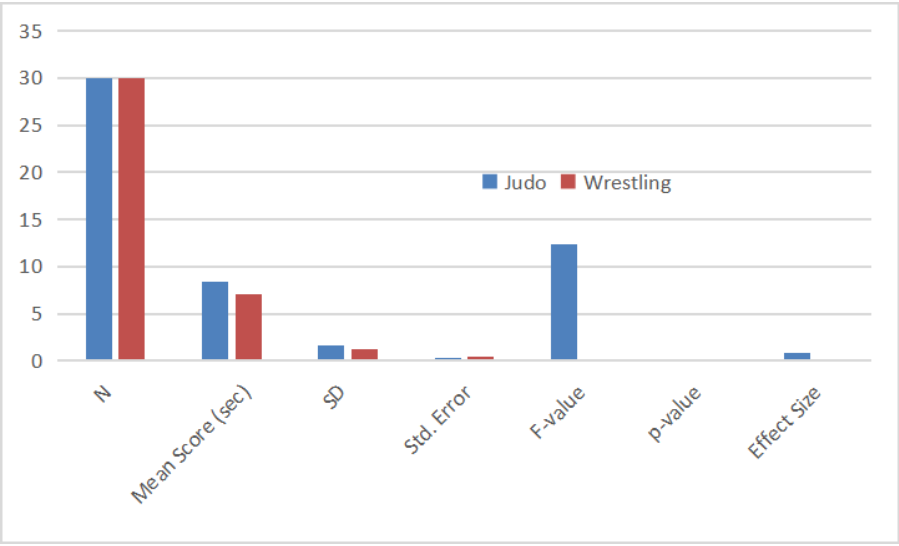

Figure 2. Orientation Ability Scores of Judo and Wrestling Athletes with Statistical Comparison.

3.2.2. Differentiation Ability

No significant difference was found between the two groups in kinesthetic differentiation ability ($p = 0.148$). Both judokas (12.8 ± 2.34) and wrestlers (13.6 ± 2.67) demonstrated comparable proficiency in executing precise movements, as shown in **Table 5** and **Figure 3**. The small effect size (0.31) suggests that differentiation ability is similarly developed in both groups. This finding is consistent with previous studies indicating minimal divergence in kinesthetic differentiation across combat sports. Comparable standard deviations further suggest that training methodologies targeting kinesthetic precision may be equally effective for both sports.

Differentiation Ability:

- **No significant difference** ($p = 0.148$);
- **Both sports require high kinesthetic precision.**

Table 5. Differentiation Ability Assessment.

Group	n	Mean Score (points)	SD	Std. Error	F-Value	*p*-Value	Effect Size
Judo	30	12.8	2.34	0.43	2.14	0.148	0.31
Wrestling	30	13.6	2.67	0.49			

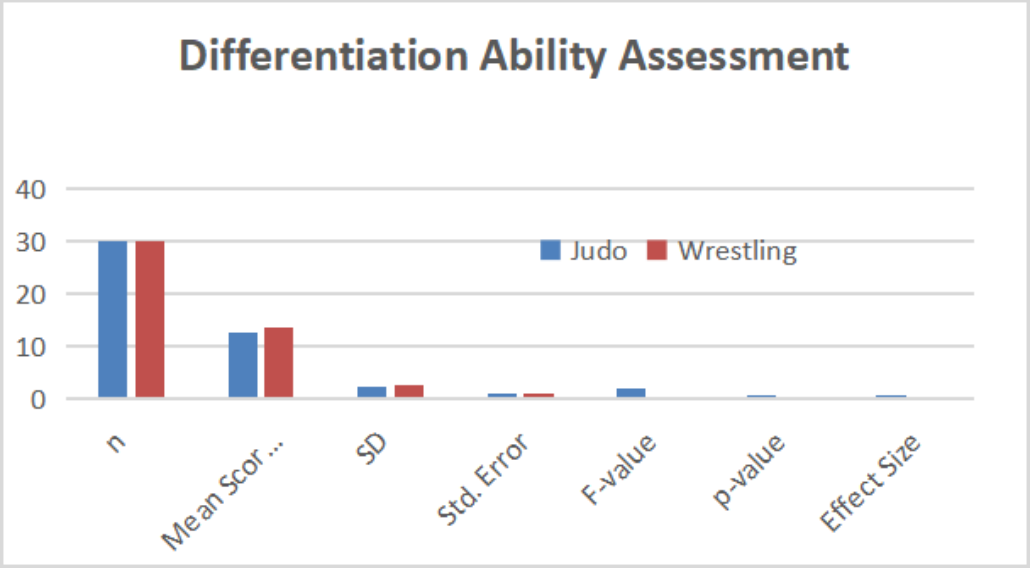

Figure 3. Differentiation Ability Scores of Judo and Wrestling Athletes with Statistical Analysis.

3.2.3. Balance Ability

Wrestlers exhibited significantly superior balance performance compared to judokas, holding a one-leg stance for a longer duration (21.7 ± 3.85 seconds vs. 18.2 ± 4.12 seconds), with a p-value < 0.05 and a moderate-to-large effect size (0.64) as illustrated in **Table 6** and **Figure 4**. This result aligns with prior research linking wrestling performance to enhanced postural control. Wrestling emphasizes base stability, sprawling, and pressure distribution during ground control, which naturally enhances both static and dynamic balance. The reduced variability among wrestlers suggests a more standardized and effective balance training regimen.

Balance Ability:

- **Wrestlers:** 21.7 ± 3.85 sec;
- **Judokas:** 18.2 ± 4.12 sec;
- ***p* = 0.011**, **Effect Size = 0.64.**

Table 6. Balance Ability Performance.

Group	n	Mean Duration (sec)	SD	Std. Error	F-Value	*p*-Value	Effect Size
Judo	30	18.2	4.12	0.75	6.89	0.011*	0.64
Wrestling	30	21.7	3.85	0.70			

* *p*-value is negligibly small.

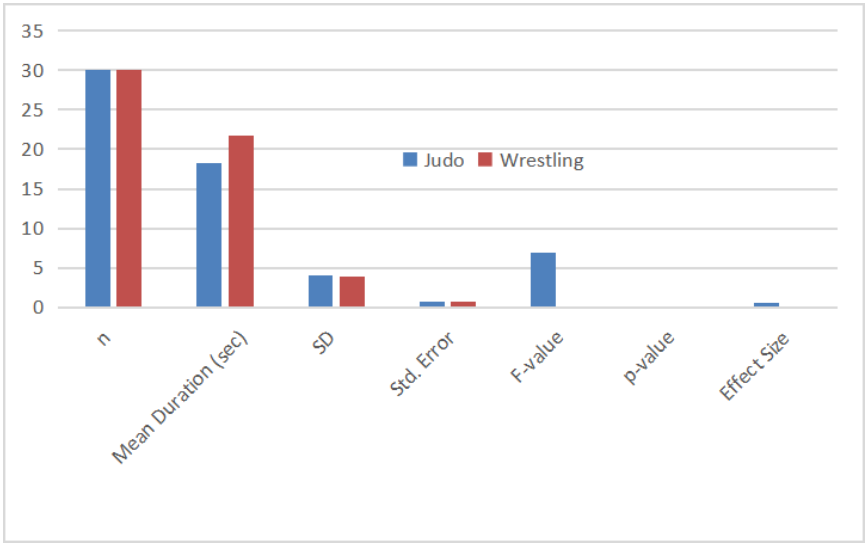

Figure 4. Balance Ability Performance Scores of Judo and Wrestling Athletes with Statistical Analysis.

3.2.4. Reaction Ability

Significant differences in reaction ability were found between the two groups ($p = 0.044$), with wrestlers responding faster (267.3 ± 32.1 ms) than judokas (284.6 ± 38.7 ms) in **Table 7** and **Figure 5**. This result supports prior evidence linking faster complex reaction times with elite athletic performance. The moderate effect size (0.47) indicates meaningful practical significance. The rapid response demands of wrestling likely contribute to superior neuromotor responsiveness, while the greater variability among judokas might reflect alternative tactical strategies, where delayed reactions are sometimes used intentionally for counterattacks.

Reaction Ability:

- **Wrestlers:** 267.3 ± 32.1 ms;
- **Judokas:** 284.6 ± 38.7 ms;
- ***p* = 0.044, Effect Size = 0.47.**

Table 7. Reaction Ability Measurements.

Group	n	Mean Time (ms)	SD	Std. Error	F-Value	*p*-Value	Effect Size
Judo	30	284.6	38.7	7.07	4.23	0.044*	0.47
Wrestling	30	267.3	32.1	5.86			

* *p*-value is negligibly small.

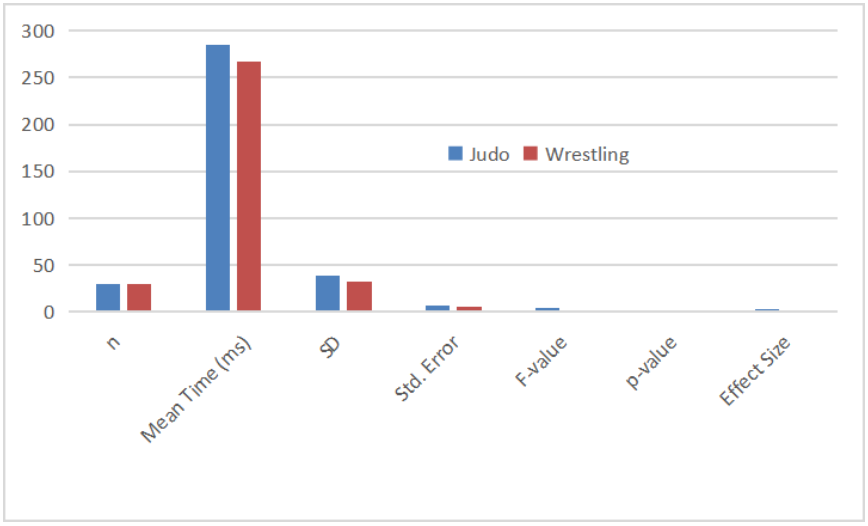

Figure 5. Comparison of Reaction Ability between Judo and Wrestling Athletes.

3.2.5. Rhythm Ability

Highly significant differences in rhythmic ability were observed between the groups ($p = 0.004$), with wrestlers committing fewer rhythmic coordination errors (3.4 ± 1.12) than judokas (4.8 ± 1.43). This aligns with existing literature indicating that wrestlers typically outperform judokas in rhythm-based tasks. The large effect size (0.71) confirms substantial practical significance in **Table 8** and **Figure 6**. Wrestling training often incorporates flow drills, repetitive movement patterns, and dynamic tempo control, which contribute to enhanced temporal coordination. Lower error rates and reduced variability among wrestlers suggest that rhythm training is systematically integrated into wrestling programs, fostering more consistent development of this critical coordinative attribute.

Rhythm Ability:

- **Wrestlers:** 3.4 ± 1.12 errors;
- **Judokas:** 4.8 ± 1.43 errors;
- ***p* = 0.004, Effect Size = 0.71.**

Table 8. Rhythm Ability Evaluation.

Group	n	Mean Score (errors)	SD	Std. Error	F-Value	*p*-Value	Effect Size
Judo	30	4.8	1.43	0.26	8.76	0.004*	0.71
Wrestling	30	3.4	1.12	0.20			

* *p*-value is negligibly small.

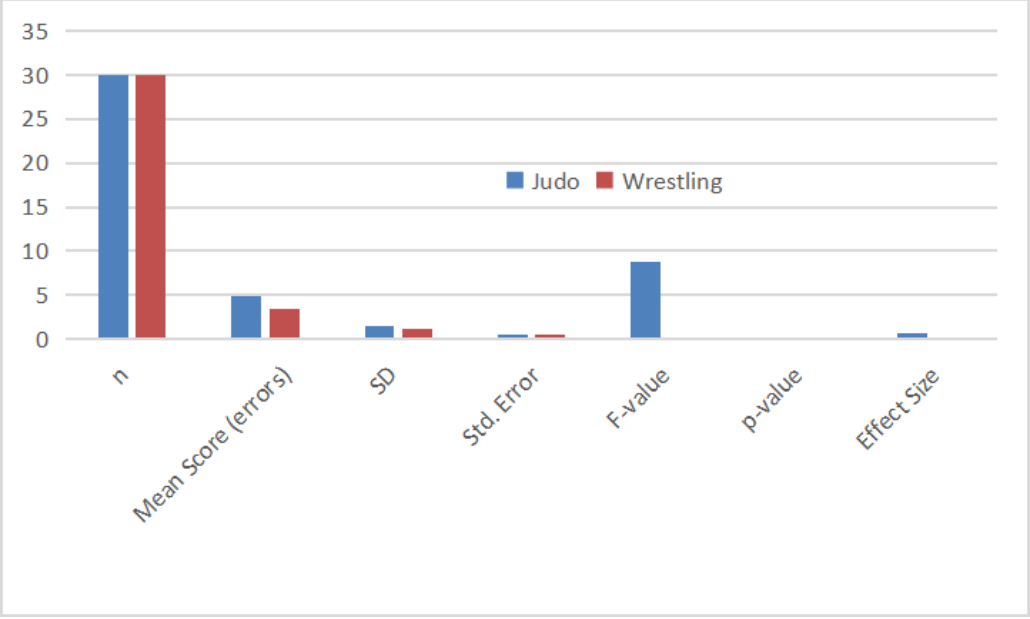

Figure 6. Rhythm Ability Evaluation of Judo and Wrestling Athletes with Statistical Analysis.

Although the study compared only two independent groups (Judokas and Wrestlers), F-values are reported in the tables to represent the variance ratio equivalent to the *t*-statistic ($F = t^2$) for each comparison. This presentation ensures consistency across multiple performance variables and provides a variance-based interpretation of group differences. Independent *t*-tests were used for normally distributed variables, while Mann–Whitney U tests were applied for non-normal data. Thus, the inclusion of F-values reflects the mathematical equivalence to the *t*-test and does not indicate the use of ANOVA as a separate analytical method.

3.3. Practical Implications

The results of this study reveal distinct, sport-specific coordinative ability profiles among judo and wrestling athletes. These findings confirm the original hypothesis that substantial differences exist in motor coordination attributes between the two combat disciplines. Wrestlers demonstrated superior performance in orientation, balance, reaction time, and rhythm compared to judo athletes, while no significant difference was observed in differentiation ability.

These results suggest that wrestling's emphasis on con-

tinuous ground engagement, spatial awareness, and postural control drives enhanced performance in several coordinative domains, such as balance and reaction time. On the other hand, judo, which prioritizes explosive movements and precise timing, shows distinct coordinative demands. A conclusive comparison of Judo and Wrestling is illustrated in **Table 9** and **Figure 7** regarding Sport-specific coordinative Analysis of Judo and Wrestling Athletes.

Recognizing these discipline-specific strengths and deficits provides valuable insights for talent identification, training protocol design, and the development of interventions tailored to each sport's specific requirements. For instance, judo athletes could benefit from targeted rhythm and balance training, while wrestling athletes might improve further with drills designed to enhance kinesthetic differentiation and precise movement execution.

Furthermore, corrective interventions such as balance training with visual input manipulations have demonstrated efficacy in improving postural control and multisensory integration. Evidence-based coordination-based training programs can be adopted across combat sports to refine movement precision, enhance motor control, and improve athletic performance across Haryana's combat sports infrastructure.

Table 9. Sport-specific coordinative Analysis of Judo and Wrestling Athletes.

		Case Study 1			Case Study 2			Case Study 3			Case Study 4			Case Study 5		
Group	**N**	**Mean Score (sec)**	**SD**	**Std. Error**	**Mean Score (sec)**	**SD**	**Std. Error**	**Mean Score (sec)**	**SD**	**Std. Error**	**Mean Score (ms)**	**SD**	**Std. Error**	**Mean Score (errors)**	**SD**	**Std. Error**
Judo	30	8.43	1.67	0.31	12.8	2.34	0.43	18.2	4.12	0.75	284.6	38.7	7.07	4.8	1.43	0.26
Wrestling	30	7.12	1.23	0.22	13.6	2.67	0.49	21.7	3.85	0.7	267.3	32.1	5.86	3.4	1.12	0.2

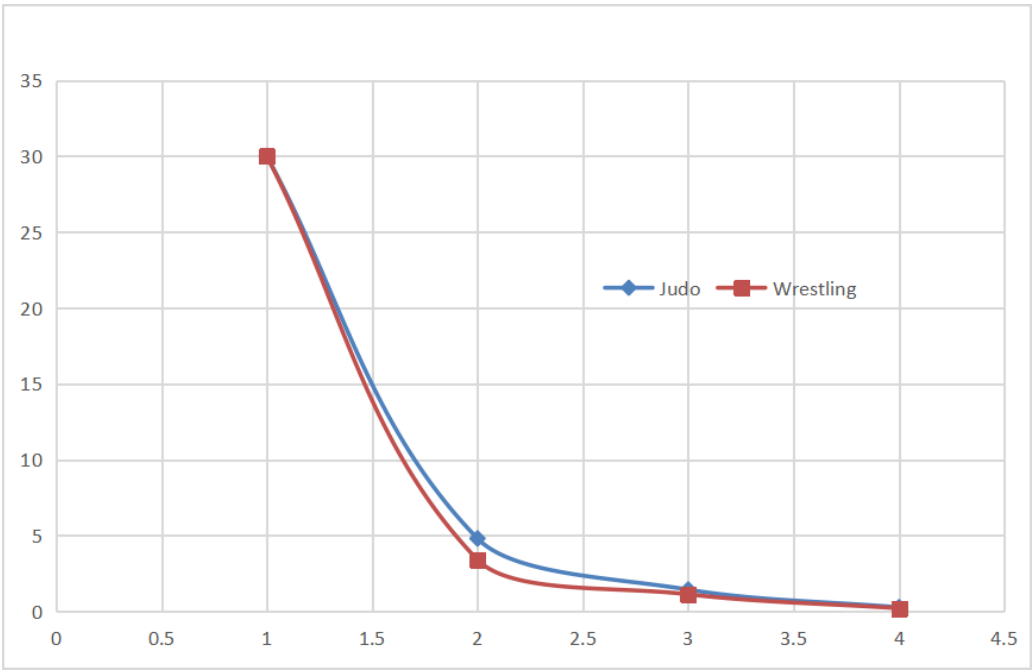

Figure 7. Sport-specific coordinative Analysis of Judo and Wrestling Athletes.

4. Result Analysis

Table 10 and **Figure 8** reveal that the analysis of the sport-specific coordinative abilities of Judo and Wrestling athletes reveals distinct differences between the two groups across various motor tasks. Below, each case study will be examined based on the results for orientation ability, differentiation ability, balance ability, reaction ability, and rhythm ability.

Table 10. Results Comparison.

Group	Orientation Ability (sec)	Differentiation Ability (points)	Balance Ability (sec)	Reaction Time (ms)	Rhythm Ability (errors)
Judo	8.43 ± 1.67	12.8 ± 2.34	18.2 ± 4.12	284.6 ± 38.7	4.8 ± 1.43
Wrestling	7.12 ± 1.23	13.6 ± 2.67	21.7 ± 3.85	267.3 ± 32.1	3.4 ± 1.12
p-value	0.001*	0.148	0.011*	0.044*	0.004*
Effect Size	0.78	0.31	0.64	0.47	0.71

* *p*-value is negligibly small.

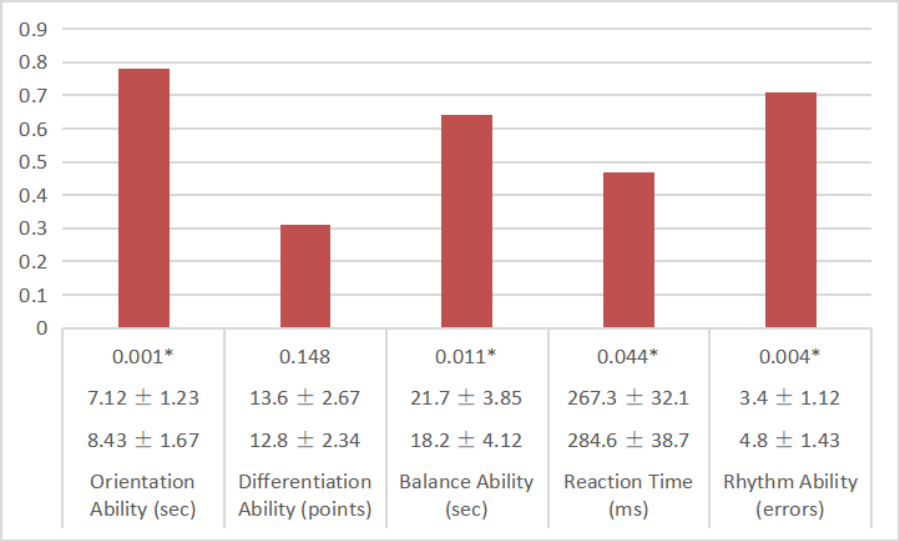

Figure 8. Results Comparison.

* *p*-value is negligibly small.

4.1. Orientation Ability

The comparison of spatial orientation ability between wrestlers and judokas revealed a significant difference, with wrestlers completing the task faster (7.12 ± 1.23 seconds) compared to judokas (8.43 ± 1.67 seconds), $p = 0.001$. The large effect size (0.78) suggests both statistical and practical significance. This advantage in spatial awareness among wrestlers is likely due to the nature of wrestling, which involves continuous ground-based engagements that require athletes to maintain heightened spatial awareness and proprioceptive accuracy. The smaller standard deviation in wrestlers further suggests greater consistency in orientation ability, which may be attributed to sport-specific training that emphasizes spatial control and body positioning during mat-based interactions.

4.2. Differentiation Ability

No significant differences in kinesthetic differentiation ability were observed between wrestlers and judokas ($p = 0.148$), with both groups demonstrating comparable proficiency in executing precise movements. Wrestlers scored 13.6 ± 2.67, while judokas scored 12.8 ± 2.34. The small effect size of 0.31 further supports the finding that kinesthetic differentiation ability is similarly developed in both sports. This suggests that both judo and wrestling require a similar level of precision in movement execution, likely due to the need for fine motor control in both disciplines.

4.3. Balance Ability

Wrestlers exhibited superior balance performance, maintaining a one-leg stance for significantly longer than judokas (21.7 ± 3.85 seconds vs. 18.2 ± 4.12 seconds), $p = 0.011$, with a moderate-to-large effect size (0.64). The findings align with previous research linking wrestling to enhanced postural control, as the sport's emphasis on stability, sprawling, and weight distribution during ground control naturally fosters both static and dynamic balance. The reduced variability in wrestlers' balance scores further suggests a more consistent and effective balance training regimen, high-

lighting the importance of stability in wrestling techniques.

4.4. Reaction Ability

Significant differences were found in reaction times between the two groups, with wrestlers responding faster (267.3 ± 32.1 ms) than judokas (284.6 ± 38.7 ms), $p = 0.044$, and a moderate effect size (0.47). This suggests that the rapid-response demands inherent in wrestling, with its emphasis on fast-paced action and reaction to an opponent's movements, contribute to superior neuromotor responsiveness. In contrast, judo athletes, whose tactics often involve deliberate timing and counter-attacks, may intentionally delay their reactions to gain an advantage in certain situations.

4.5. Rhythm Ability

Significant differences in rhythmic coordination ability were also observed between the groups, with wrestlers committing fewer rhythmic errors (3.4 ± 1.12 errors) compared to judokas (4.8 ± 1.43 errors), $p = 0.004$, and a large effect size (0.71). This finding supports the notion that wrestling, which frequently incorporates repetitive movement patterns, dynamic tempo control, and flow drills, enhances temporal coordination. The reduced error rate among wrestlers indicates a more consistent integration of rhythm into their training, highlighting the role of rhythmic movement in effective wrestling techniques.

5. Conclusions

The findings of this study reveal the distinct, sport-specific coordinative profiles of judo and wrestling athletes from Haryana. Wrestlers significantly outperform judokas in spatial orientation, likely due to wrestling's focus on positioning, ground-based control, and constant engagement with opponents. However, both groups exhibit similar levels of kinesthetic differentiation, suggesting that both sports require comparable precision in movement control. Wrestlers also demonstrate superior balance, which is crucial for maintaining stability during dynamic wrestling exchanges, such as sprawling or transitioning between positions. Furthermore, wrestlers have faster reaction times, reflecting the fast-paced, real-time nature of their sport, where quick responses to an opponent's movements are critical. In addition, wrestlers excel in rhythmic coordination, likely driven by the repetitive movement patterns and tempo control central to their training. These results underscore that neuromotor adaptations are closely tied to the biomechanical and tactical demands of each sport. The more dynamic, high-intensity nature of wrestling training fosters enhanced spatial awareness, balance, reaction time, and rhythm, while judo's emphasis on timing and tactical movements cultivates different patterns of coordination, particularly in reaction time and spatial awareness. From a practical perspective, these findings suggest that training interventions should be tailored to each sport's specific needs. Wrestlers could benefit from drills focused on kinesthetic differentiation and precise movement execution, while judokas may improve through targeted rhythm and balance training, refining their temporal coordination and reaction strategies. Ultimately, this study not only highlights the unique coordinative strengths of judo and wrestling athletes but also provides valuable insights into sport-specific training strategies that can enhance performance outcomes in both disciplines.

Author Contributions

Conceptualization, R.N. and M.V.; methodology, R.N.; software, A.V.; validation, R.N., M.V., and A.V.; formal analysis, R.N., M.V., and A.V.; investigation, R.N.; resources, R.N.; data curation, R.N.; writing—original draft preparation, R.N., M.V., and A.V.; writing—review and editing, A.V.; visualization, A.V.; supervision, M.V. and A.V.; project administration, R.N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the approved research synopsis of Ram Niwas, Ph.D. Scholar, and was duly approved by the Board of Studies, Department of Physical Education, Ch. Devi Lal University, Sirsa, Haryana,

India. The research is titled "Analysis of body composition of judo and wrestling male players of Haryana State." (Registration No.2020035500165272).

Informed Consent Statement

Informed consent is implicit, as the study was carried out following the approval of the research synopsis of Ram Niwas, Ph.D. Scholar, by the Board of Studies, Department of Physical Education, Ch. Devi Lal University, Sirsa, Haryana, India. The approved research is titled "Analysis of body composition of judo and wrestling male players of Haryana State." (Registration No.2020035500165272).

Data Availability Statement

The data supporting the findings of this study have been presented in **Tables 1** to **10** within the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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