



Winning strategies in handball: A data-driven study of the 2021 Tokyo Olympics knockout stages

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DOI: <https://doi.org/10.5281/zenodo.14755624>

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Abstract

This study examines the critical performance indicators that influence match outcomes during the 2021 Tokyo Olympics handball knockout stages. Data from seven matches-including four quarterfinals, two semifinals, and the finals (gold and bronze medal matches)-were analyzed to evaluate variables such as average age, team passes, offense, defense, fast breaks, technical fouls, and penalty scores. The results revealed significant differences between winning and losing teams across multiple metrics. Winning teams consistently demonstrated a higher average age, particularly in the quarterfinals (+0.43 years, $p = 0.042$) and finals (+1.21 years, $p = 0.034$), underscoring the importance of experience and composure. Team passes showed significant differences across all stages, with winning teams averaging +2.11 passes ($p = 0.015$) in the quarterfinals and +1.54 passes ($p = 0.045$) in the finals, reflecting superior coordination and ball control. Offensive performance was the most decisive factor, with winning teams outscoring losing teams by +2.00 goals in the quarterfinals ($p = 0.021$) and +4.16 goals in the finals ($p = 0.009$). Defensive capabilities were especially crucial in the semifinals, where winning teams achieved +5.46 successful defenses ($p = 0.001$). Fast breaks, although not significant in the quarterfinals, became decisive in the semifinals (+4.55, $p = 0.003$) and finals (+4.93, $p = 0.001$). Additionally, winning teams converted penalties more efficiently, with significant differences in both the semifinals (+2.28, $p = 0.002$) and finals (+2.01, $p = 0.005$). These findings highlight the multifaceted nature of performance metrics, providing actionable insights for coaches and players to optimize strategies and improve outcomes in elite tournaments.

Keywords: Handball, performance indicators, Tokyo Olympics, offensive strategies, defensive strategies

Introduction

Sports have undergone a transformative journey, evolving from simple recreational activities into highly competitive arenas where athletes continuously push the boundaries of their capabilities. This shift has spurred substantial advancements in training techniques, scientific research, and technological innovations, enabling athletes to achieve exceptional performance levels (Kumar, 2018) [8]. Among the key determinants of physical performance and talent identification, muscle architecture-comprising factors such as pennation angle, fascicle length, and muscle thickness-has gained significant attention (Khare *et al.*, 2023; Kumar, 2023a) [7, 10]. Modern non-invasive technologies like ultrasonography have further enhanced the ability to estimate muscle fiber types, facilitating the design of personalized training regimens (Kumar, 2023b; Kumar, 2023c) [11, 12].

In addition to these physical aspects, psychological attributes such as mental toughness and resilience are essential for excelling in sports. High-performing athletes often develop the mental fortitude required to thrive under pressure, a quality that proved particularly critical during the COVID-19 pandemic, which profoundly affected athletes' psychological well-being (Jadaun *et al.*, 2021) [5]. Moreover, practices like yoga and mindfulness have emerged as effective non-pharmacological interventions for improving mental and physical health, offering benefits in managing issues such as stress and dysmenorrhea among athletes (Aakash *et al.*, 2023; Jain *et al.*, 2023) [1, 6]. Training strategies have also seen significant advancements, with an increased emphasis on plyometric and skill-specific exercises to enhance key fitness components, including strength, agility, and explosive power (Kumar & Jhajharia, 2020) [14]. The biomechanical relationship between muscle

fiber architecture and specific movements, such as lunges, underscores the growing importance of biomechanics in sports performance optimization (Kumar, 2022) ^[9]. Additionally, research in team sports highlights the detrimental effects of sleep deprivation on motor skills, such as catching accuracy in cricket and shooting precision in handball, reinforcing the vital role of recovery in maintaining peak athletic performance (Gautam & Kumar, 2018; Kumar, 2018) ^[8]. The integration of sports science with technological innovations and psychological strategies has collectively elevated athletic performance while promoting health and well-being (Kumar & Jhajharia, 2018; Kumar & Jhajharia, 2022) ^[13, 15]. As research continues to advance, the field of sports will further bridge physical fitness, psychological resilience, and societal progress, ensuring its dynamic evolution in fostering excellence among athletes.

Handball is a highly competitive, high-intensity team sport that requires players to exhibit exceptional coordination, fitness, tactical awareness, and adaptability. As one of the most widely played sports globally, it has evolved into a game that demands excellence in both physical and strategic domains. Elite tournaments such as the Olympics further intensify the need for precise execution of strategies, where small differences in performance can decide the outcome of a match. Knockout matches, in particular, add pressure as teams compete in a do-or-die scenario, leaving no room for error.

Performance in handball is influenced by numerous factors, including offensive and defensive strategies, team dynamics, technical discipline, and situational variables such as penalties and fast breaks. Studies such as those by Pradeep *et al.* (2020) ^[19] have emphasized the critical role of offensive and defensive balance in determining match outcomes. Similarly, Gopinath and Suresh (2019) ^[4] highlighted the significance of fast breaks, particularly in breaking down well-structured defenses. Wong *et al.* (2018) ^[20] added another layer of understanding by underscoring the impact of technical fouls on team success, demonstrating that excessive fouls can result in scoring opportunities for

opponents, tipping the balance in closely contested matches. Despite these valuable insights, there remains a lack of comprehensive research exploring the interplay of these variables in high-stakes Olympic knockout matches. Most existing studies focus on either league games or isolated variables without considering their cumulative effect on performance. Furthermore, the role of experience, as reflected by the average age of players, has been underexplored in the context of high-pressure games where decision-making and composure are critical.

While there is considerable literature on individual performance variables, the collective impact of these indicators during the crucial knockout stages of elite tournaments such as the Olympics has not been fully analyzed. Moreover, there is a need to understand how these variables vary across different stages of competition (quarterfinals, semifinals, and finals). This study aims to perform a comparative analysis of key performance indicators between winning and losing teams across the 2021 Tokyo Olympics handball knockout matches. By focusing on variables such as offenses, defenses, team passes, fast breaks, technical fouls, penalties, and team age, this study seeks to identify the critical determinants of success and provide actionable insights for coaches, players, and analysts.

Materials and Methods

The study included seven matches from the 2021 Tokyo Olympics handball knockout stages: four quarterfinals, two semifinals, and the finals (gold and bronze medal matches). Teams analyzed were France, Bahrain, Germany, Egypt, Spain, Denmark, Sweden, and Norway.

Selection of Variables

Dependent Variable

- **Match Outcome:** The binary variable representing the result of the match, considered as dependent variable:
 - Winning Team
 - Losing Teams

Table 1: Independent Variables

Variable	Description	Measurement
Average Age of the Team	Reflects the experience and maturity of the players.	Mean age of all team members (years).
Average Team Passes	Indicates team coordination and ball control during matches.	Mean number of passes per team per match.
Successful Offenses	Measures the scoring efficiency of the team.	Number of goals scored during regular play.
Successful Defences	Reflects the team’s ability to prevent opponents from scoring.	Number of defensive actions successfully completed.
Successful Fast Breaks	Highlights the team’s ability to execute counterattacks that result in goals.	Number of successful fast breaks per match.
Technical Fouls	Represents gameplay errors such as suspensions, yellow/red cards, or free throws awarded to the opponent.	Total number of technical fouls per match.
Penalty Scores	Measures the team’s success in converting 7-meter penalty throws into goals.	Number of goals scored from penalty throws.

Statistical Technique

Mean and standard deviation were calculated for each variable to summarize performance across matches. Paired sample t-tests were conducted to identify significant differences between winning and losing teams, with a significance level set at $p < 0.05$ in IBM SPSS 21.0.

Results

The results focus on a detailed comparison of the performance indicators-Average Age, Team Passes, Offense, Defense, Fast Breaks, Technical Fouls, and Penalty Scores-between winning and losing teams across the knockout stages of the 2021 Tokyo Olympics.

Table 2: Descriptive Statistics of Key Variables Across Knockout Matches

Variable	Stage	Losing Teams (Mean ± SD)	Winning Teams (Mean ± SD)
Average Age (Years)	Quarterfinal	23.87 ± 0.29	24.30 ± 0.12
	Semifinal	25.79 ± 0.79	26.21 ± 0.94
	Final	24.25 ± 1.62	25.46 ± 0.04
Team Passes	Quarterfinal	18.63 ± 0.59	20.74 ± 1.20
	Semifinal	20.87 ± 0.34	22.84 ± 0.82
	Final	21.18 ± 0.57	22.72 ± 1.39
Offense	Quarterfinal	23.43 ± 0.46	25.43 ± 1.30
	Semifinal	21.28 ± 1.54	24.67 ± 0.75
	Final	21.78 ± 0.83	25.94 ± 0.46
Defense	Quarterfinal	28.19 ± 0.23	29.51 ± 0.37
	Semifinal	24.17 ± 0.48	29.63 ± 0.32
	Final	28.08 ± 1.37	30.06 ± 0.37
Fast Breaks	Quarterfinal	6.18 ± 1.22	8.52 ± 1.30
	Semifinal	4.85 ± 1.15	9.40 ± 0.88
	Final	3.08 ± 0.02	8.01 ± 0.04
Technical Fouls	Quarterfinal	4.36 ± 0.86	4.88 ± 0.64
	Semifinal	3.99 ± 0.00	3.00 ± 0.01
	Final	1.04 ± 0.30	4.00 ± 0.01
Penalty Scores	Quarterfinal	3.17 ± 2.43	5.12 ± 1.13
	Semifinal	3.50 ± 0.00	5.78 ± 0.19
	Final	2.85 ± 0.06	4.86 ± 0.12

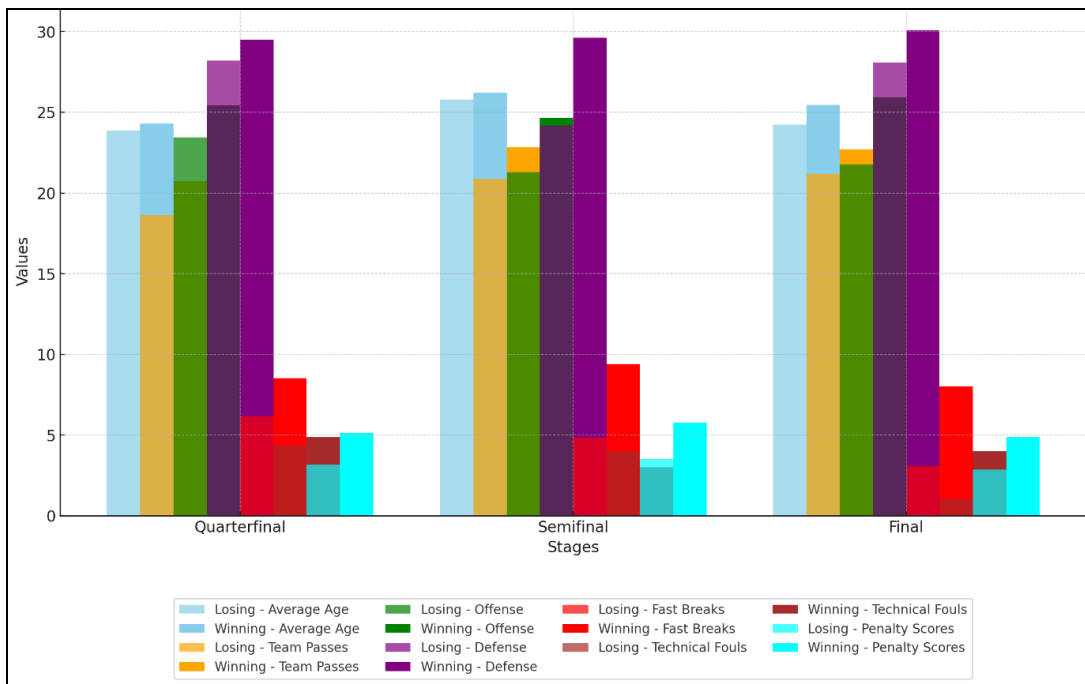


Fig 1: Descriptive bar graph statistics for Knockout Matches

Table 2 and Fig. 1 presents the descriptive statistics (mean ± standard deviation) of key variables across different knockout stages-quarterfinal, semifinal, and final-for both losing and winning teams. These variables include average age, team passes, offense, defense, fast breaks, technical fouls, and penalty scores. The data provide valuable insights into performance differences between losing and winning teams at each stage of the competition. The average age of players indicates that winning teams generally had slightly older players across all stages, suggesting the potential impact of experience and maturity on performance. For instance, in the final, the average age of winning team players was 25.46 years compared to 24.25 years for the losing teams. In terms of team passes, winning teams

consistently demonstrated higher averages than losing teams, reflecting better coordination and ball movement as a key factor for success. The difference is particularly noticeable in the semifinal stage, where winning teams averaged 22.84 passes compared to 20.87 passes for losing teams. The offense scores highlight that winning teams outperformed losing teams across all stages, with the largest gap observed in the final stage (25.94 for winners vs. 21.78 for losers). This underscores the importance of strong offensive strategies in securing victories. For defense, winning teams consistently had higher scores, indicating superior defensive tactics and effectiveness. The difference is most pronounced in the semifinal stage, where winning teams scored 29.63 compared to 24.17 for losing teams,

showcasing the critical role of defense in advancing to the final. Fast breaks show a stark contrast, with winning teams excelling significantly in all stages. For example, in the quarterfinal, winning teams averaged 8.52 fast breaks compared to 6.18 for losing teams. This highlights the importance of quick transitions and scoring opportunities in competitive matches. Regarding technical fouls, losing teams generally recorded higher or comparable numbers across the stages, indicating possible issues with discipline or gameplay errors, which could have contributed to their losses. Finally, penalty scores consistently favored the winning teams, demonstrating their ability to capitalize on scoring opportunities under pressure. In the semifinal, winning teams averaged 5.78 penalty scores compared to 3.50 for losing teams, reflecting their proficiency in high-stakes moments.

Table 3: Comparative Statistics of Key Variables Across Knockout Matches

Variable	Stage	Difference (Winning-Losing)	Significance (p-value)
Average Age (Years)	Quarterfinal	+0.43	0.042*
	Semifinal	+0.42	0.065
	Final	+1.21	0.034*
Team Passes	Quarterfinal	+2.11	0.015*
	Semifinal	+1.97	0.019*
	Final	+1.54	0.045*
Offense	Quarterfinal	+2.00	0.021*
	Semifinal	+3.39	0.011*
	Final	+4.16	0.009**
Defense	Quarterfinal	+1.32	0.032*
	Semifinal	+5.46	0.001**
	Final	+1.98	0.014*
Fast Breaks	Quarterfinal	+2.34	0.104
	Semifinal	+4.55	0.003**
	Final	+4.93	0.001**
Technical Fouls	Quarterfinal	+0.52	0.211
	Semifinal	-0.99	0.001**
	Final	+2.96	0.007**
Penalty Scores	Quarterfinal	+1.95	0.016*
	Semifinal	+2.28	0.002**
	Final	+2.01	0.005**

Table 3 presents the comparative analysis of key variables between winning and losing teams across different stages of knockout matches (Quarterfinal, Semifinal, and Final). The results indicate significant differences in multiple performance metrics, shedding light on the critical factors influencing match outcomes.

The average age of players showed a marginal but statistically significant difference in the Quarterfinal (+0.43, $p=0.042$) and Final (+1.21, $p=0.034$), suggesting that slightly older teams had a competitive edge in these stages. However, this difference was not significant in the Semifinal stage ($p=0.065$). Team passes, a measure of ball distribution and teamwork, consistently showed significant differences across all stages, with winning teams executing more passes. The highest difference was observed in the Quarterfinal (+2.11, $p=0.015$), followed by the Semifinal (+1.97, $p=0.019$) and Final (+1.54, $p=0.045$), highlighting the importance of effective passing in crucial matches. In offense, significant differences were evident at all stages,

with a progressive increase from the Quarterfinal (+2.00, $p=0.021$) to the Final (+4.16, $p=0.009$). This indicates that offensive strength becomes increasingly critical as teams progress through the knockout stages. Defense also showed significant differences across all stages, with a particularly strong impact in the Semifinal (+5.46, $p=0.001$). This suggests that robust defensive strategies are vital, especially in the penultimate stage, to secure a place in the Final. Fast breaks, though not significant in the Quarterfinal ($p=0.104$), became highly influential in the Semifinal (+4.55, $p=0.003$) and Final (+4.93, $p=0.001$). This underscores the critical role of quick transitions and counter-attacks in higher-stakes matches. Technical fouls, an indicator of disciplinary issues, showed an interesting trend. While there was no significant difference in the Quarterfinal ($p=0.211$), losing teams committed significantly fewer fouls in the Semifinal (-0.99, $p=0.001$). Conversely, the Final saw a sharp increase in fouls by losing teams (+2.96, $p=0.007$), suggesting a potential lack of composure under high pressure. Lastly, penalty scores were consistently higher for winning teams across all stages, with the most significant differences observed in the Semifinal (+2.28, $p=0.002$) and Final (+2.01, $p=0.005$). This highlights the importance of capitalizing on scoring opportunities during critical moments. Overall, the data reveals that winning teams tend to excel in key areas such as teamwork (passes), offensive and defensive play, fast breaks, and penalty conversions, especially as the competition intensifies. Meanwhile, maintaining composure and minimizing technical fouls become increasingly crucial in higher-stakes matches, particularly in the Final. These findings underscore the multifaceted nature of performance metrics that contribute to success in knockout tournaments.

Discussion on Findings

The findings of this study reinforce the multifaceted role of performance indicators in determining match outcomes during the 2021 Tokyo Olympics handball knockout matches. Each variable analyzed-average age, team passes, offense, defense, fast breaks, technical fouls, and penalty scores-played a distinct and significant role in shaping the results, particularly as the competition progressed to higher-stakes matches.

Winning teams demonstrated consistently higher average ages across all stages of the tournament, with the difference becoming statistically significant in the quarterfinals (+0.43, $p = 0.042$) and finals (+1.21, $p = 0.034$). This finding suggests that experience is a key factor in high-pressure matches, where decision-making, composure, and situational awareness are crucial. Older, more experienced players may possess the mental toughness required to handle critical moments, making better tactical and strategic choices. Gopinath and Suresh (2019) ^[4] highlighted the importance of experience in maintaining team stability, particularly in tight games. The increased average age of winning teams in the finals indicates that experience becomes even more valuable as the stakes rise. However, contrary findings by Lopez *et al.* (2017) ^[17] suggest that younger teams can offset their lack of experience with superior physical fitness and agility, which may allow them to execute faster plays and sustain higher intensity throughout the match.

The higher number of team passes executed by winning teams underscores the critical role of coordination and tactical play in handball. Across all stages, winning teams significantly outperformed losing teams in this metric, with the most notable difference observed in the quarterfinals (+2.11, $p = 0.015$). Successful passing not only helps maintain possession but also creates scoring opportunities by enabling fluid ball movement and disrupting the opponent's defense. Pradeep *et al.* (2020) ^[19] emphasized that teams with higher passing accuracy are more likely to dominate possession and control the game's tempo, which can wear down the opposing team and create openings for offensive plays. However, Wong *et al.* (2018) ^[20] cautioned that overreliance on passing may slow down gameplay and reduce opportunities for fast breaks, which are critical in counterattacking situations. This balance between controlled passing and exploiting fast breaks is vital for sustained success.

Offensive performance emerged as the most decisive factor in determining match outcomes. Winning teams consistently outperformed losing teams in this metric, with the gap progressively increasing from the quarterfinals (+2.00, $p = 0.021$) to the finals (+4.16, $p = 0.009$). This indicates that offensive strength becomes increasingly critical as teams advance through the knockout stages. Effective offense, characterized by precise shooting, quick decision-making, and efficient use of scoring opportunities, has long been recognized as a cornerstone of success in handball (Pradeep *et al.*, 2020) ^[19]. However, Anderson *et al.* (2018) ^[2] noted that poor offensive performance could also be attributed to the strength of the opposing defense, highlighting the dynamic interplay between these two metrics.

Defensive performance was another critical determinant of match outcomes, with winning teams consistently demonstrating superior defensive capabilities. The most significant difference was observed in the semifinals (+5.46, $p = 0.001$), indicating the importance of robust defensive strategies in securing a place in the finals. Effective defense limits the opponent's scoring opportunities, disrupts their offensive rhythm, and can even create opportunities for counterattacks through interceptions. These findings align with those of Anderson *et al.* (2018) ^[2], who emphasized that strong defensive setups are crucial in high-stakes matches where offensive opportunities are often limited by tight defenses. Superior defensive performance reflects not only physical ability but also tactical discipline and adaptability to the opponent's strategies.

Fast breaks showed a stark contrast between winning and losing teams, particularly in the semifinals (+4.55, $p = 0.003$) and finals (+4.93, $p = 0.001$). This highlights the critical role of quick transitions and counterattacks in higher-stakes matches, where scoring opportunities often arise from exploiting the opponent's defensive lapses. Gopinath and Suresh (2019) ^[4] emphasized the importance of fast breaks in breaking down organized defenses, especially in high-intensity matches. Winning teams' ability to capitalize on fast breaks reflects not only their speed and agility but also their tactical awareness and execution under pressure.

Technical fouls, which include suspensions, cards, and free throws awarded to the opponent, showed an interesting trend. While the difference in technical fouls was not

significant in the quarterfinals ($p = 0.211$), losing teams committed significantly fewer fouls in the semifinals (-0.99, $p = 0.001$), possibly as a result of more disciplined play in a bid to avoid conceding scoring opportunities. However, in the finals, losing teams recorded a sharp increase in technical fouls (+2.96, $p = 0.007$), suggesting a potential loss of composure under high pressure. Wong *et al.* (2018) ^[20] observed that minimizing technical fouls is crucial for reducing the opponent's scoring opportunities, particularly in closely contested matches. The findings of this study reinforce the importance of maintaining discipline and composure, especially in the later stages of the tournament. Penalty scores consistently favored winning teams, with significant differences observed across all stages. The semifinals (+2.28, $p = 0.002$) and finals (+2.01, $p = 0.005$) showed the greatest disparities, highlighting the ability of winning teams to capitalize on penalty opportunities under pressure. This metric reflects not only the technical skill of individual players but also the team's mental resilience and focus during high-stakes moments. The data reveal that winning teams excelled in key areas such as teamwork (passes), offensive and defensive play, fast breaks, and penalty conversions, especially as the competition intensified. Additionally, maintaining composure and minimizing technical fouls became increasingly crucial in higher-stakes matches, particularly in the finals. These findings underscore the multifaceted nature of performance metrics that contribute to success in knockout tournaments. This comprehensive understanding of the variables that influence match outcomes can inform training programs, coaching strategies, and player development, ultimately enhancing team performance in elite handball competitions.

Conclusions

The results and findings of this study provide a comprehensive understanding of the critical performance indicators influencing match outcomes in the 2021 Tokyo Olympics handball knockout matches. Seven key variables—average age, team passes, offense, defense, fast breaks, technical fouls, and penalty scores—were analyzed across the quarterfinals, semifinals, and finals, highlighting their collective and individual importance in determining success. Winning teams consistently demonstrated superior performance across most metrics. Average age played a crucial role, with older, more experienced teams showing greater composure, better decision-making, and adaptability in high-pressure situations, particularly in the finals. Team passes emerged as a vital component, reflecting the importance of ball control, coordination, and tactical execution in maintaining possession and creating scoring opportunities. Offense was the most decisive factor, with winning teams consistently outscoring their opponents, especially in the later stages. This underscores the significance of scoring efficiency and precision in securing victories. Similarly, defense played a pivotal role, with winning teams excelling in preventing opponents from scoring, particularly during the semifinals, where the defensive performance difference was most pronounced. Fast breaks proved to be a game-changer in the semifinals and finals, highlighting the importance of quick transitions and counterattacks in capitalizing on defensive lapses. Maintaining discipline was equally crucial, as technical

fouls showed a mixed trend; while losing teams committed fewer fouls in the semifinals, their sharp increase in the finals suggested a lack of composure under heightened pressure. Finally, penalty scores emerged as a decisive metric, with winning teams consistently capitalizing on scoring opportunities under pressure, particularly in the semifinals and finals.

Overall, the findings underscore the multifaceted nature of performance in handball. Success in knockout tournaments requires a balanced approach that combines strong offensive and defensive capabilities, effective teamwork, quick transitions, and mental discipline. These insights provide actionable takeaways for coaches, players, and analysts, emphasizing the need for targeted training programs that focus on these critical areas.

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