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Evaluation of Performance and Complications in Freediving Competitions by Gender, Discipline, and Competition Type

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Abstract

Objective: Freediving is a unique underwater sport that relies on voluntary breath-hold, with competitions held in multiple disciplines such as constant weight diving (CWT), free immersion diving (FIM), constant weight no fins (CNF), and bifins (BF). Performance depends on physiological, psychological, and environmental factors, while complications such as hypoxic blackout (BO) and disqualification (DQ) represent significant safety concerns. This study aimed to evaluate freediving competition outcomes in Türkiye by gender, discipline, and competition type, with a focus on performance parameters and complications.

Materials and Methods: A retrospective descriptive analysis was conducted using official records of national and international freediving competitions organized by the Turkish Underwater Sports Federation (TSSF) in 2021. Data from 150 athletes (57 women, 38%; 93 men, 62%) were included. Performance metrics (target distance, achieved distance, final distance, penalty distance, target/performance and final/target ratios) and complications (BO, DQ, did not start [DNS], non-participation) were analyzed. Statistical evaluations were performed with NCSS 2020, using t-tests, Mann–Whitney U, Kruskal–Wallis, and Dunn tests where appropriate, with $p<0.05$ considered significant.

Results: Among women, 74% completed their events, while 26% were eliminated, mostly due to DNS (35%) and non-participation (30%). Among men, 83% completed competitions, while 17% were eliminated, with BO being the most frequent cause (31.6%). In international competitions, male athletes achieved significantly greater target, performance, and final distances in the CWT and FIM disciplines compared to national competitions ($p<0.05$). Female athletes showed no significant differences across competition levels.

Conclusion: Male athletes demonstrated higher overall performance, while female athletes had higher DNS and non-participation rates, suggesting the influence of motivational and psychological factors beyond physiology. BO emerged as the most critical complication, underscoring the need for strict safety protocols and rapid emergency response systems. This study highlights that freediving performance is determined not only by physical capacity but also by discipline selection, competition type, and psychological readiness. Strengthening safety measures and developing prospective, multicenter studies will be essential to optimize performance and reduce risks in future competitions.

Keywords: Apnea competition, athlete safety, blackout, disqualification, freediving, gender differences, performance analysis, underwater sports

Introduction

Freediving is a sport discipline based on performances carried out underwater without the use of any breathing apparatus, relying solely on the athlete's breath-hold. Rooted in the physiology of apnea (breath-holding), this discipline has gained increasing popularity in both recreational and competitive contexts. Freediving competitions are organized in different disciplines such as static apnea (STA), dynamic apnea with fins (DYN), dynamic apnea without fins (DNF), constant weight diving (CWT), free immersion diving (FIM), and constant weight no fins (CNF). Athletes' performances are evaluated based on parameters such as dive duration, distance covered, or depth reached [1–4].

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Globally, freediving has been systematically regulated since the second half of the 20th century, and after the 1990s, it gained an institutional structure under the supervision of international federations such as the Confédération Mondiale des Activités Subaquatiques (CMAS) and the International Association for Development of Apnea (AIDA) [1–4]. In Türkiye, the development of this sport accelerated in the 2000s through competitions organized by the Turkish Underwater Sports Federation (TSSF). With the achievements of national athletes in international championships, the visibility of Türkiye in the field of freediving has increased [5,6].

The physiological foundations of this sport are explained by biological mechanisms such as cardiorespiratory adaptations, hypoxic tolerance, the diving reflex (bradycardia, peripheral vasoconstriction), and lactate accumulation. On the psychological level, mental resilience, anxiety management, and concentration are among the important determinants [7–9]. Therefore, freediving is regarded not only as a sporting activity but also as a multidisciplinary field of research that examines the limits of human physiology and adaptation to environmental stressors.

In recent years, the importance of performance analyses in freediving has increased. Associating athlete performance with biomechanical, physiological, and psychological parameters enables training processes to be based on scientific foundations and competition strategies to be optimized [7–9]. At the same time, identifying complications that may occur during competitions is of critical importance in terms of athlete safety and organizational improvement. In this context, the aim of this study is to analyze the results obtained in freediving competitions held in Türkiye in 2021, to comparatively evaluate performances across different disciplines, and to examine in detail the complications observed during the competition process.

Materials and Methods

Study Design

This research is a retrospective, descriptive analytical study conducted using the official records of freediving competitions held in Türkiye. The study examined the performance data of male and female athletes competing in different disciplines, as well as the reasons for disqualification and complications recorded during the competition process.

Study Population

The research was conducted through a retrospective examination of data from athletes who participated in freediving competitions held in Türkiye in 2021. A total of 189 athletes who took part in national and international freediving competitions organized by the Turkish Underwater Sports Federation (TSSF) were included in the study. Due to incomplete or incorrect data, 39 athletes were excluded from the analysis. Ultimately, the data of 150 athletes (57 women, 38%; 93 men, 62%) were evaluated.

Only participants with complete official result sheets who completed the competitions were included in the study, whereas athletes with insufficient data, those who did not participate, or those who were disqualified were excluded.

Performance Variables

In this study, the performance levels of athletes and the data related to the competition process were considered in a multidimensional manner. The gender of the participants (female/male), competition type (national/international), and discipline types [constant weight no fins (CNF), constant weight diving (CWT), free immersion diving (FIM), and bifins (BF)] constituted the basic demographic and structural variables. In the performance evaluation, target distance, achieved performance distance, and final distance measurements were taken into account. In addition, target/performance percentage and final/target percentage ratios were calculated, and the penalty distances received by the athletes were recorded. Complications and reasons for disqualification during the competition process were also classified; these included blackout (BO), did not start (DNS), disqualification (DQ), and non-participation. In this study, the term "complications" is used as a general expression encompassing both medical adverse events and non-medical competition-related outcomes recorded during the competition process. Medical adverse events include fainting (BO), while non-medical outcomes include failure to start the race (DNS), disqualification (DQ), and non-participation, as documented in official competition records.

Blackout (BO) was defined as a transient loss of consciousness occurring during ascent or immediately after surfacing, as identified and recorded by competition judges and on-site medical staff in accordance with CMAS and AIDA competition regulations.

Statistical Analysis

For the evaluation of the findings obtained in the study, NCSS (Number Cruncher Statistical System) 2020 Statistical Software (NCSS LLC, Kaysville, Utah, USA) was used for statistical analyses. While evaluating the study data, quantitative variables were expressed as mean, standard deviation, median, minimum, and maximum values, and qualitative variables were expressed using descriptive statistical methods such as frequency and percentage. The Shapiro–Wilk test and box plot graphics were used to assess the conformity of the data to normal distribution.

For comparisons of two groups of quantitative variables showing normal distribution, the Student's t-test was applied. For variables not showing normal distribution, the Mann–Whitney U test was used for comparisons of two groups; for comparisons of three or more groups, the Kruskal–Wallis test was used, and the Dunn test was employed to determine the group responsible for the difference. The results were evaluated within a 95% confidence interval, with a significance level of $p<0.05$.

Ethical Considerations

This study was approved by the Non-Interventional Clinical Research Ethics Committee of Erzincan Binali Yıldırım University with the decision dated 09.08.2024 and numbered 378201. The study data were obtained solely from the official and open-access competition records published by the Turkish Underwater Sports Federation (TSSF). The identity information of the participants was kept confidential, and only anonymized data were analyzed. The article is conducted according to the Declaration of Helsinki.

Results

A total of 189 athletes were initially assessed. Following the exclusion of 39 athletes due to elimination or incomplete participation, the final analysis included 150 athletes, comprising 38% women (n=57) and 62% men (n=93).

Participant Characteristics and Elimination Outcomes

Overall, 79.4% of participants successfully completed the competition, while 20.6% were eliminated. Completion rates were higher in men than in women (83.0% vs. 74.0%). Blackout accounted for a greater proportion of eliminations among male athletes, whereas did not start (DNS) was more frequent among female athletes. A detailed summary of completion status and reasons for elimination stratified by gender and competition level is presented in Table 1.

Participation Rates by Discipline and Gender

The distribution of freediving disciplines differed between women and men (Fig. 1). Among women, bifins (BF) was the most frequently competed discipline (38.6%), followed by free immersion (FIM, 29.8%), constant weight with fins (CWT, 17.5%), and constant weight no fins (CNF, 14.0%). In contrast, male participants most commonly competed in free immersion (FIM, 37.6%), followed by constant weight with fins (CWT, 24.7%), bifins (BF, 23.7%), and constant weight no fins (CNF, 14.0%).

Overall Performance by Gender

General performance characteristics stratified by gender are summarized in Table 2. Mean target, performance, and final distances were comparable between women and men. Both sexes demonstrated high achieved/target and final/target percentages, indicating that most athletes reached distances close to their declared targets, with no clinically meaningful difference in performance efficiency between genders.

Comparison Between National and International Competitions

Athletes competing in international competitions achieved significantly greater target, performance, and final distances compared with those participating in national competitions (Fig. 2). Despite these differences in absolute distances, relative

Table 1. Distribution of notes regarding the reasons for elimination of participants

	Women n (%)	Men n (%)	Total n (%)
National – Completed	23 (67.6)	50 (82.0)	73 (76.8)
International – Completed	34 (79.1)	43 (84.3)	77 (81.9)
Total – Completed	57 (74.0)	93 (83.0)	150 (79.4)
Total – Eliminated	20 (26.0)	19 (17.0)	39 (20.6)
Blackout – National	2 (18.2)	2 (18.2)	4 (18.2)
Blackout – International	1 (11.1)	4 (50.0)	5 (29.4)
Blackout – Total	3 (15.0)	6 (31.6)	9 (23.1)
Did Not Start – National	0 (0.0)	0 (0.0)	0 (0.0)
Did Not Start – International	7 (77.8)	2 (25.0)	9 (52.9)
Did Not Start – Total	7 (35.0)	2 (10.5)	9 (23.1)
Disqualification – National	3 (27.3)	1 (9.1)	4 (18.2)
Disqualification – International	1 (11.1)	2 (25.0)	2 (11.8)
Disqualification – Total	4 (20.0)	3 (15.8)	6 (15.4)
Did Not Participate – National	6 (54.5)	8 (72.7)	14 (63.6)
Did Not Participate – International	0 (0.0)	0 (0.0)	0 (0.0)
Did Not Participate – Total	6 (30.0)	8 (42.1)	14 (35.9)

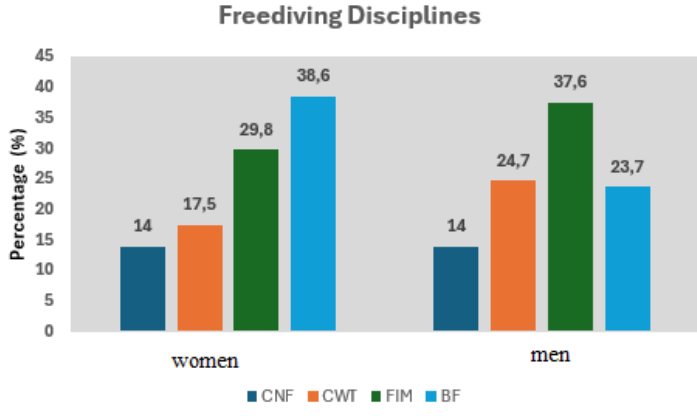

Figure 1. Participation rates in disciplines by gender.

performance efficiency, reflected by achieved/target and final/target percentages, remained similar between competition levels.

Discipline-Based Performance Characteristics

Discipline-specific differences were observed in target, performance, and final distances (Fig. 3). Constant weight with fins (CWT) consistently demonstrated the greatest distances, followed by free immersion (FIM) and bifins (BF), while constant weight no fins (CNF) showed the lowest values across all distance measures.

When discipline-specific comparisons were examined in detail, significant differences between national and international competitions were primarily observed in the CWT discipline among male participants, with higher target, performance, and final distances achieved in international events (Table 3). No significant differences were observed in performance efficiency ratios.

Discussion

In this study, the performance data of athletes and the complications that emerged during competitions organized in Türkiye were examined according to gender, discipline, and competition type. The findings indicate that success and safety in freediving depend not only on physiological capacity but also on psychological preparation, discipline selection, and organizational factors.

Although the completion rates of female and male athletes were similar, the success rate was found to be higher in males. In the literature, it has been reported that male athletes have advantages such as larger lung volumes, greater muscle mass, and higher maximal oxygen consumption, which are positively reflected in performance [10,11].

Some studies suggest that female athletes may exhibit adaptive responses to the diving reflex; for example, in the study by Rey-Paredes et al. [12], women demonstrated a stronger bradycardic response during the first apnea, although this difference diminished in subsequent apneas. In addition, the study by Baranova et al. [13] reported that pulmonary vasodilation responses were more pronounced in women than in men. On the other hand, Pernett et al. [14] observed similar levels of heart rate reduction between women and men.

Thus, it is known that female athletes may also have advantages in hypoxia tolerance and can exhibit adaptive responses to the diving reflex. In our study, the higher rates of DNS (Did Not Start) and non-participation among female athletes suggest that, in addition to physiological differences, motivational and psychological factors may also play a role. Indeed, performance analyses conducted in underwater sports have shown that, particularly among young female athletes, differences in club infrastructure and competitive imbalances can directly influence individual motivation and athlete development processes [15].

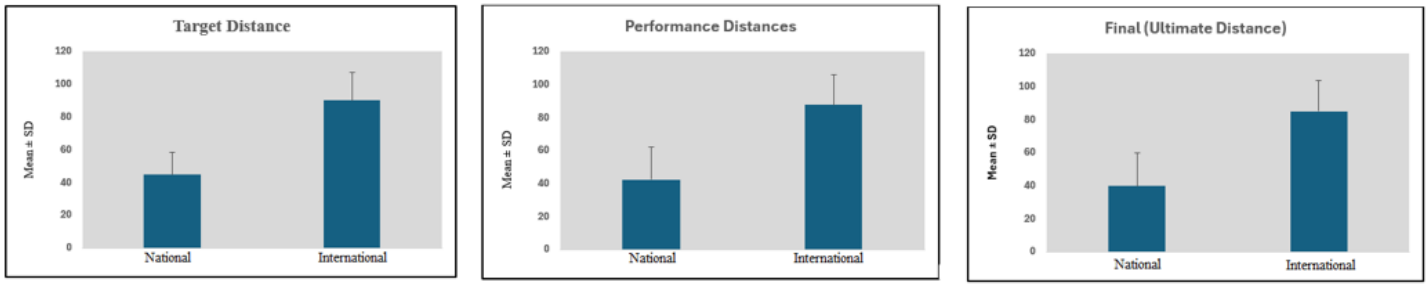

Figure 2. Comparison of target, performance, and final distances between national and international freediving competitions. (A) Target distance, (B) performance distance, and (C) final (ultimate) distance.

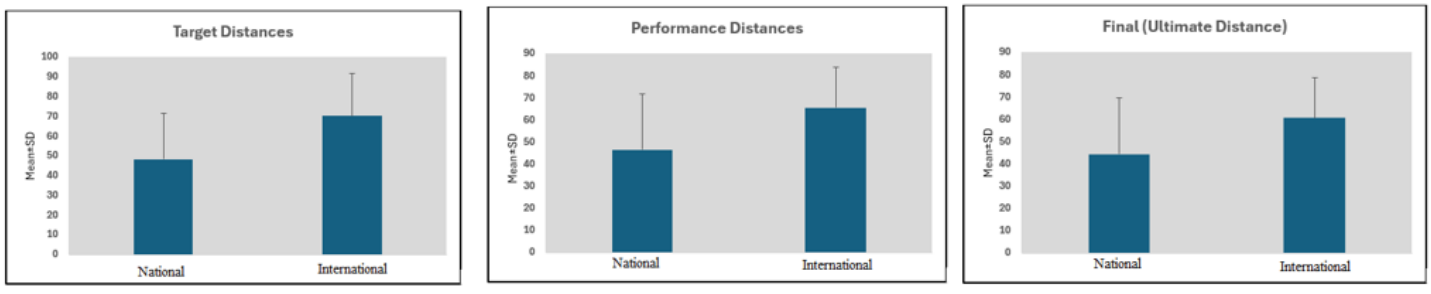

Figure 3. Discipline-based comparison of target, performance, and final distances in freediving. (A) Target distances, (B) performance distances, and (C) final (ultimate) distances across constant weight no fins, constant weight diving, free immersion diving, and bifins disciplines.

Table 2. Performance variables of participants by gender

Variable	Women n (%) / Mean±SD	Men n (%) / Mean±SD
Gender	57 (38.0)	93 (62.0)
Discipline		
Constant weight no fins (CNF)	8 (14.0)	13 (14.0)
Constant weight diving (CWT)	10 (17.5)	23 (24.7)
Free immersion diving (FIM)	17 (29.8)	35 (37.6)
Bifins (BF)	22 (38.6)	22 (23.7)
Target distance (m)		
Mean±SD	57.79±19.21	58.08±23.16
Median (Min–Max)	55 (26–106)	56 (20–109)
Performance distance (m)		
Mean±SD	55.45±20.31	56.01±22.72
Median (Min–Max)	51 (21–106)	55 (14.5–108)
Achieved/Target distance (%)		
Mean±SD	95.20±9.95	96.30±8.34
Median (Min–Max)	100 (52.4–100)	100 (63.1–100)
Final distance (m)		
Mean±SD	52.65±22.29	53.73±23.30
Median (Min–Max)	50 (1.2–106)	53 (7.8–108)
Final/Target (%)		
Mean±SD	89.64±20.69	92.19±17.51
Median (Min–Max)	100 (2.7–100)	100 (24.5–100)
Penalty distance (m)		
Mean±SD	9.22±4.34	10.21±5.29
Median (Min–Max)	8.5 (4.1–21.4)	8.8 (3–21.4)
Achieved/Penalty (%)		
Mean±SD	18.25±11.53	17.19±9.60
Median (Min–Max)	12.8 (6–47.6)	16.9 (2–36.9)

SD: Standard deviation

Table 3. Comparison of relevant measurements by groups in the constant weight diving discipline

Variable	National	International	p
Women	n=5	n=5	
Target distance (m), Mean±SD Median (Min–Max)	57.00±17.73 50 (40–83)	75.40±11.37 78 (57–85)	[a] *0.095*
Performance distance (m), Mean±SD Median (Min–Max)	57.00±17.73 50 (40–83)	73.20±13.12 78 (51–85)	[a] *0.151*
Achieved/Target (%) Mean±SD Median (Min–Max)	100.00±0.00 100 (100–100)	96.7±4.79 100 (89.5–100)	[a] *0.310*
Final distance (m), Mean±SD Median (Min–Max)	54.84±14.05 50 (40–72.2)	70.60±15.66 73 (44–85)	[a] *0,095*
Final/Target (%) Mean±SD Median (Min–Max)	97.40±5.82 100 (87–100)	92.82±10.41 100 (77.2–100)	[a] *0.548*
Penalty distance (m) Mean±SD Median (Min–Max)	4.90±0.00 4.9 (4.9–4.9)	6.50±0.71 6.5 (6–7)	
Achieved/Penalty (%) Mean±SD Median (Min–Max)	0.00±0.00 0 (0–0)	8.24±3.23 8.2 (6–10.5)	–
Men	n=13	n=10	
Target distance (m), Mean±SD Median (Min–Max)	44.62±13.77 35 (30–67)	90.10±16.97 93 (46–108)	[a] 0.001**
Performance distance (m), Mean±SD Median (Min–Max)	42.32±16.29 35 (19.9–67)	87.80±17.02 89.5 (46–108)	[a] 0.001**
Achieved/Target (%) Mean±SD Median (Min–Max)	93.08±13.34 100 (64.2–100)	100 (86.3–100)	
Final distance (m), Mean±SD Median (Min–Max)	39.80±19.83 35 (7.8–67)	85.20±18.34 89.5 (46–108)	[a] 0.001**
Final/Target (%) Mean±SD Median (Min–Max)	85.47±27.98 100 (25.2–100)	94.77±10.09 100 (71.6–100)	[a] 1.000
Penalty distance (m) Mean±SD Median (Min–Max)	9.93±1.32 10.2 (8.5–11.1)	8.67±5.51 9 (3–14)	
Achieved/Penalty (%) Mean±SD Median (Min–Max)	29.98±5.45 29.1 (25–35.8)	8.18±5.88 8.9 (2–13.7)	–

a: Mann–Whitney U test. **p<0.01. Statistical comparisons were not performed for variables with insufficient sample size. SD: Standard deviation

When analyzed by discipline, it was found that male athletes achieved significantly greater distances in the CWT and FIM disciplines in international competitions compared to national ones. This finding suggests that the higher level of competition, preparation processes, and motivational factors in international events may positively influence performance. In female athletes, however, no significant differences were observed between national and international competitions. This may be explained by the relatively smaller number of female participants or the more homogeneous level of experience among them.

When complications were examined, it was observed that blackout (BO), DNS, DQ, and non-participation occurred at notable rates during competitions. BO was more frequent among male athletes, while DNS was more common among female athletes. BO is one of the most critical complications in freediving, as it may result in hypoxic syncope; the risk increases with the rapid decline in alveolar oxygen pressure and the prolongation of apnea duration [16,17]. Mulder et al. [18] reported that progressive changes in oxygenation and the diving response during repeated apneas increased the risk

of hypoxia-induced loss of consciousness. Similarly, Mulder et al. [19] demonstrated that multiple factors in deep dives contribute to an increased risk of hypoxic blackout. Moreover, studies using field measurements have shown that decreases in SpO2 are associated with dive depth and can be used to predict blackout risk [17]. These findings highlight the importance of strengthening safety protocols during competitions and raising athletes' awareness of risks. Particularly in life-threatening complications such as blackout, the implementation of rapid and effective emergency response protocols is of critical importance. In this context, the presence of multidisciplinary medical teams, in which emergency medicine specialists and diving physicians work in coordination, is an essential requirement for ensuring athlete safety. From an emergency medicine perspective, blackout represents an acute and potentially life-threatening event requiring immediate recognition and intervention. Rapid on-site emergency response, continuous monitoring during ascent and recovery, and the presence of trained multidisciplinary medical teams are critical components for preventing fatal outcomes. The involvement of emergency medicine specialists, in coordination with diving physicians, plays a key role in the safe organization and supervision of freediving competitions.

The strength of our study lies in the comparative analysis of a broad dataset across different disciplines, genders, and competition types. However, an important limitation is the retrospective design and the exclusive use of official competition records, which did not allow for the evaluation of individual physiological and psychological variables (e.g., VO2max, anxiety levels, years of experience).

In conclusion, performance in freediving depends not only on the athlete's physiological capacity but also on discipline selection, competition level, motivational factors, and safety strategies. Prospective and multicenter studies in the future are expected to contribute to the prevention of complications and the enhancement of athlete safety.

Conclusion

This study comparatively evaluated performance and complications across different disciplines, genders, and competition types in freediving competitions held in Türkiye. The findings showed that male athletes had higher overall success rates and, particularly in the CWT and FIM disciplines, achieved better performance in international competitions. In female athletes, higher rates of DNS and non-participation may be associated not only with physiological differences but also with motivational and psychological factors. The results highlight that in freediving competitions, not only performance but also the management of complications and emergency response processes are of vital importance.

Among complications, the most critical risk is blackout (BO), and strengthening safety protocols as well as implementing progressive training strategies are essential for athlete safety. Future prospective, multicenter, and physiologically focused studies are expected to contribute to the prevention of complications and the enhancement of athlete safety in freediving.

Study Limitations

This study has certain limitations. First, its retrospective design restricted the ability to control for potential confounding factors. Only official competition records published by the Turkish Underwater Sports Federation (TSSF) were used; thus, detailed individual physiological and psychological variables (e.g., VO2max, anxiety levels, training history) could not be evaluated. In addition, the study was limited to competitions held in Türkiye in 2021, which may reduce the generalizability of the findings to broader international freediving populations. Future prospective, multicenter studies with direct physiological and psychological measurements are needed to provide deeper insights into performance determinants and complication risks in freediving.

Ethics Committee Approval: This study was approved by the Non-Interventional Clinical Research Ethics Committee of Erzincan Binali Yıldırım University (Date: 09.08.2024, Decision no: 378201).

Informed Consent: The study data were obtained solely from the official and open-access competition records published by the Turkish Underwater Sports Federation. The identity information of the participants was kept confidential, and only anonymized data were analyzed.

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