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The Proprioceptive Levels of the Shoulder and Elbow According to E-sports Branches

E-spor Branşlarına Göre Omuz Ve Dirsek Propriyoseptif Duyu Düzeyleri

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Abstract

This study aimed to comparatively evaluate shoulder and elbow joint position sense (proprioception) among players from different e-sports branches (FPS: First Person Shooter, MOBA: Multiplayer Online Battle Arena, BR: Battle Royale, RTS: Real-Time Strategy, Sports, Fighting, and MMORPG: Massively Multiplayer Online Role-Playing Game). A total of 98 e-athletes participated in the study. Proprioceptive assessment was conducted using an angle reproduction test at 60°, 90° and 120° of flexion. One-way ANOVA was used for statistical analysis, and post-hoc tests were applied to significant results ($p<0.05$). Findings showed that in FPS, MOBA, and BR branches, the average angular error at 90° of shoulder flexion was approximately 3.4°, which was significantly lower than other branches ($p=0.012$). Similarly, at 120° elbow flexion, the mean error in FPS players was 2.01°, while it reached 4.06° in MMORPG players ($p=0.024$). These results suggest that branches requiring high-frequency motor repetition positively influence the proprioceptive system. In conclusion, proprioceptive accuracy varies across e-sports branches and appears to be associated with the motor demands specific to each game type.

Keywords Elbow, E-sports, Joint position sense, Proprioception, Shoulder

Öz

Bu çalışma, farklı e-spor branşlarında (FPS: First Person Shooter, MOBA: Multiplayer Online Battle Arena, BR: Battle Royale, RTS: Real-Time Strategy, Sports, Fighting ve MMORPG: Massively Multiplayer Online Role-Playing Game) yer alan oyuncuların omuz ve dirsek eklem pozisyon duyusunu karşılaştırmalı olarak değerlendirmeyi amaçlamaktadır. Araştırmaya toplam 98 e-sporcu katılmıştır. Propriyoseptif değerlendirme, 60° ve 90°, 120° fleksiyon pozisyonlarında açı tekrarlama yöntemi ile yapılmıştır. Analizler tek yönlü varyans testi (ANOVA) ile değerlendirilmiş, anlamlı bulunan sonuçlar için post-hoc test uygulanmıştır ($p<0,05$). Bulgular, FPS, MOBA ve BR branşlarında, omuz 90° fleksiyon açısında ortalama hata düzeyi yaklaşık 3,4° olduğunu ve bu değerin diğer branşlara göre anlamlı şekilde düşük olduğunu ortaya koymuştur ($p=0,012$). Benzer şekilde, dirsek 120° fleksiyon açısında FPS oyuncularında ortalama hata 2,01° iken, MMORPG branşında bu değer 4,06° olarak ölçülmüştür ($p=0,024$). Bu durum, yüksek motor tekrar içeren branşların propriyoseptif sistem üzerinde olumlu etkiler yarattığını göstermektedir. Sonuç olarak, propriyoseptif duyu düzeyleri e-spor branşına göre farklılaşmakta ve bu farklılıklar oyun türlerinin motor talepleriyle ilişkili görünmektedir.

Anahtar Kelimeler: E-spor, Eklem pozisyon duyusu, Dirsek, Omuz, Propriyosepsiyon

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Introduction

The concept of play has been defined as a phenomenon where cultural, mental, and sociocultural components converge, dating back to the beginnings of human history. In parallel with the process of digitalization, competitive environments and performance-oriented online gaming platforms have emerged (Cunningham et al., 2018; Hallmann & Giel, 2018; McGee et al., 2021; Coşkuntürk et al., 2023; Uluca et al., 2024). The professionalized form of these digital games, known as esports, includes multidimensional performance components such as strategy, reflexes, attention, cognitive processes, and motor control, similar to traditional sports structures (Difrancisco-Donoghue et al., 2019; Falk & Puppe, 2020; Hallmann & Giel, 2018). Esports disciplines contain different movement patterns, motor demands, and sensorimotor requirements depending on their content. Branches such as FPS (First Person Shooter) and MOBA (Multiplayer Online Battle Arena) require players to perform short-term micro-controls and fast upper extremity movements, whereas genres like Fighting, Sports, or MMORPG (Massively Multiplayer Online Role Playing Game) are characterized by broader ranges of motion and different motor strategies (Difrancisco-Donoghue et al., 2019; Lin & Sun, 2015; Nagorsky & Wiemeyer, 2020; Trotter et al., 2020). These distinct task profiles may affect not only cognitive processes but also sensorimotor integration and joint control systems. The upper extremity joints particularly the shoulder and elbow are among the anatomical regions heavily utilized by esports players (Pu et al., 2021; Satish Kumar et al., 2023). Continuous use of a mouse/keyboard or gamepad, holding the arm in fixed positions for prolonged periods, and repeating micro-angle changes impose a load on the musculoskeletal system while also requiring activation of the proprioceptive sense. Proprioception is a sensory system that enables the perception of the position, movement, and relative angle of joints, and it relies on the afferent input of various mechanoreceptors, primarily muscle spindles, joint capsule receptors, and golgi tendon organs (Ager et al., 2023; Hallmann & Giel, 2018; Han et al., 2016; Hillier et al., 2015; Proske & Gandevia, 2012; Yıldız & Çebi, 2025). Proprioceptive information plays a central role in the generation of motor control, coordination, and adaptive reflex responses (Fox et al., 2024; Proske & Gandevia, 2009).

One of the frequently used metrics in proprioceptive assessment is Joint Position Sense (JPS) (Fox et al., 2024; Horváth et al., 2023; Mendez-Rebolledo et al., 2022; Proske & Gandevia, 2009; Ramos et al., 2019). JPS measurements are conducted by identifying the deviation during the reproduction of a predetermined target angle, and the absolute error (AE) value reflects the sensitivity of position perception (Gliga et al., 2022; Mendez-Rebolledo et al., 2022; Proske & Gandevia, 2012; Winter et al., 2022; Yildiz & Çebi, 2024). Lower AE values indicate that the joint can more accurately perceive the target position, whereas higher AE values reflect relatively lower proprioceptive sensitivity (Horváth et al., 2023; Ramos et al., 2019). Studies conducted on shoulder and elbow JPS in the literature have shown that these measurements are directly related to upper extremity motor control and stability. Shoulder flexion positions, active position reproduction tests were shown to be reliable in measuring shoulder proprioceptive control, and the relationship between JPS values at different angles and motor tasks was discussed (Glendon & Hood, 2015). Similarly, studies in the field of elbow JPS have shown that lower AE values are associated with better upper extremity functional performance (Glendon & Hood, 2015; Liu et al., 2025; Mendez-Rebolledo et al., 2022; Yildiz & Çebi, 2024). Although the shoulder extension position has been relatively less studied in the literature, it is known to increase proprioceptive demand in the processes of static postural control and dynamic balance of the shoulder (Amen et al., 2025; Ramos et al., 2019). It has been reported that the proprioceptive system supports balance and spatial perception especially in scenarios where the upper extremity is held in upward static postures. From this perspective, it is considered that not only the flexion movement but also the measurement of 60° shoulder extension may reflect proprioceptive values and may be related to upper extremity loading in the context of esports. In the sporting context, there are also studies indicating that proprioceptive performance may vary between different disciplines. Reported that upper extremity proprioceptive sensitivity differs among athletes from different sports disciplines, and that this variation is related to the motor demands of the sport (Vurgun et al., 2022). Winter (2022) demonstrated that proprioceptive training improves performance in repetitive motor tasks and enhances AE values (Winter et al., 2022).

Additionally, review stated that proprioceptive adaptation is directly related to motor learning processes and that neuroplastic changes may emerge in tasks requiring high repetition (Yılmaz et al., 2024). These findings suggest that repetitive micro-movements in the context of esports may have similar adaptive effects on the proprioceptive system. However, in the specific context of esports, there is limited literature directly comparing the effects of different game types on shoulder and elbow proprioception. Although existing sports science research has systematically related esports performance profiles to these variables, empirical studies examining branch-specific associations through shoulder and elbow JPS measurements remain rare. In this context, a systematic comparison of AE values across different esports branches would provide a unique contribution to the literature and allow testing the hypothesis that proprioceptive control may vary with motor load demands.

The aim of this study is to compare the proprioceptive sensitivity (AE values) in flexion and extension joint angle positions of the dominant shoulder and elbow in players from FPS, MOBA, BR, RTS, Sports, Fighting, and MMORPG disciplines and to relate these values to the motor task demands specific to esports branches. Accordingly, the hypothesis of the study is that esports players in high-repetition disciplines will have lower AE values (indicating higher proprioceptive sensitivity), while those in branches with lower repetition motor tasks will have higher AE values.

Material and Methods

Research Group

This study included a total of 98 amateur and professional esports players who were actively involved in different esports disciplines (FPS, MOBA, RTS, Battle Royale, Sports, MMORPG, Fighting). Participants were individuals aged 18 years or older, without any history of upper extremity injuries, and who voluntarily agreed to participate in the study. All participants were informed about the purpose and procedures of the study, and they provided informed consent by signing a voluntary participation form. To determine participants' demographic and behavioral characteristics such as age, gender, height, weight, sports background, esports discipline, screen time, time spent at the computer, game duration, and frequency of using gaming devices a questionnaire developed by the researchers was used. It was also employed to identify the esports genres in which participants were actively engaged. Participants were grouped according to their respective disciplines: MOBA (Multiplayer Online Battle Arena), FPS, RTS, Battle Royale, Sports, Fighting and MMORPG (Massively Multiplayer Online Role Playing Game) (Banks et al., 2005; Bediou et al., 2018; Jenny et al., 2017; Mancı et al., 2025; Mustafaoğlu, 2018). Another instrument was prepared to evaluate the joint position sense (JPS) of the upper extremity (shoulder and elbow) at specific angles (Fox et al., 2024; Hillier et al., 2015; Horváth et al., 2023; Yildiz & Çebi, 2024). The proprioceptive sensory assessment protocol was designed to evaluate the proprioceptive sense levels of the shoulder and elbow joints based on the Joint Position Sense (JPS) method using an angle reproduction protocol. Measurements were conducted using a Baseline digital goniometer with a measurement precision of 1°. The JPS method is accepted as a reliable tool for assessing proprioception in both clinical and sports performance contexts (Hillier et al., 2015; Mohamed, 2019; Wasaka & Kakigi, 2019). During testing, participants were positioned supine on a flat surface. To prevent visual input from influencing proprioceptive performance, participants kept their eyes closed during all trials (Lee et al., 2016). Before starting the measurements, the purpose and procedures of the test were explained verbally, a 5-minute rest period was provided, and one familiarization trial was conducted for each angle (Ager et al., 2023; Amen et al., 2025; Fox et al., 2024; Yildiz & Çebi, 2024; Yılmaz et al., 2024). Ethical approval for this study was obtained from the Scientific Research and Publication Ethics Committee of Artvin Çoruh University, with the decision dated 13.05.2024 and numbered E-18457941-050.99-135134. All participants voluntarily took part in the study and signed an informed consent form.

Angle Reproduction Steps

The target angle was taught to the participant by the researcher through passive movement three times (proprioceptive reference formation). With eyes closed, the participant actively moved the joint to what they perceived as the target angle. The deviation from the target angle was recorded using the digital goniometer. Five repetitions were performed for each angle. For each participant, the error value at a given angle was calculated as the mean of the five deviations (AE) (Ager et al., 2023; Amen et al., 2025; Fox et al., 2024; Yildiz & Çebi, 2024; Yılmaz et al., 2024). Joint angles and the measurement protocol constituted the study's core assessment parameters. Accordingly, proprioceptive sensitivity of the shoulder and elbow joints was evaluated at specific ranges of motion. For the shoulder joint, measurements were conducted at 60°, 90° and 120° of flexion. For the elbow joint, flexion positions of 60°, 90°, and 120° were used. AE values were recorded at each angle using the JPS method. These angles were selected to reflect the functional use of the upper extremity and five repetitions were carried out for each angle.

Stabilization During Shoulder and Elbow Measurements

For shoulder measurements, manual support was applied to the scapular region of the tested side to stabilize the scapula (Pratt, 1994). During elbow flexion measurements, the forearm was held in a pronated-neutral position, and the upper arm was stabilized close to the torso to prevent abduction and shoulder compensation. After the target angle was demonstrated passively: The participant lowered the arm. With eyes closed, they actively attempted to reproduce the elbow flexion to match the target angle. In each trial, the researcher recorded the measurement from the lateral epicondyle reference line using the digital goniometer (Yildiz & Çebi, 2024). This approach is consistent with standardized measurement procedures recommended in the literature for assessing elbow joint proprioceptive feedback sensitivity. The difference between the target angle and the angle reached by the participant was calculated as AE. Higher AE values were considered indicative of lower proprioceptive performance, while lower AE values reflected higher proprioceptive acuity (Evarts, 1981; Gardner, 1969; Proske, 2005).

Data Analysis

The collected data were analyzed using IBM SPSS 25.0 (Statistical Package for the Social Sciences). The Shapiro-Wilk test was used to assess whether the data followed a normal distribution, and Levene's test was used to evaluate the homogeneity of variances. Since the data were normally distributed, parametric tests were employed. One-way analysis of variance (ANOVA) was used for comparisons between disciplines, and the Tukey HSD post-hoc test was applied when significant differences were found. A significance level of $p<.05$ was adopted for all results. Descriptive data were reported as mean ± standard deviation (M±SD) and minimum–maximum values (min-max).

Results

Table 1. Descriptive Statistics of Participants' Demographic and Physical Characteristics

Variable	Category / Mean ± SD	N	%
Gender	Male	74	75.5%
	Female	24	24.5%
Height (cm)	176.2 ± 6.8		
Weight (kg)	72.4 ± 9.5		
Discipline	FPS	14	14.3%
	MOBA	14	14.3%
	BR	14	14.3%
	RTS	14	14.3%
	Fighting	14	14.3%
	Sports	14	14.3%
	MMORPG	14	14.3%
License Status	Licensed	49	50.0%
	Unlicensed	49	50.0%

Warm-up Habit	Yes	56	57.1%
	No	42	42.9%
Daily Game Time	0–2 hours	7	7.1%
	2–4 hours	15	15.3%
	4–6 hours	25	25.5%
	6–8 hours	31	31.6%
	More than 8 hours	20	20.4%
Equipment Used	Mouse	24	24.5%
	Keyboard	15	15.3%
	Keyboard + Mouse	37	37.8%
	Keyboard + Gamepad	14	14.3%
	Gamepad	8	8.1%

The gender distribution of participants was 75.5% male and 24.5% female. The mean height was 176.2 cm (SD=6.8), and the mean weight was 72.4 kg (SD=9.5). Each esports discipline group consisted of an equal number of participants (N=14). The ratio of licensed to unlicensed athletes was evenly distributed (50%). Participants who reported a warm-up habit constituted 57.1% of the sample, while 42.9% reported not warming up. A total of 77.5% of participants reported daily game durations exceeding 4 hours. The most commonly used equipment during gameplay was the keyboard + mouse combination (37.8%) (Table 1).

Table 2. Absolute Error Values of Dominant Shoulder Flexion by E-sports Discipline (60°, 90°, 120°)

Discipline	**60° Mean ± SD (Min–Max)**	**90° Mean ± SD (Min–Max)**	**120° Mean ± SD (Min–Max)**
FPS	3.77 ± 0.55 (2.60–4.46)	3.54 ± 0.47 (2.48–4.40)	4.04 ± 0.63 (2.60–5.10)
MOBA	3.80 ± 0.63 (2.30–5.00)	3.47 ± 0.52 (2.20–4.70)	4.00 ± 0.59 (2.50–5.20)
BR	3.79 ± 0.68 (2.40–5.04)	3.49 ± 0.55 (2.40–4.58)	4.02 ± 0.58 (2.50–5.10)
RTS	3.85 ± 0.62 (2.30–5.06)	3.52 ± 0.50 (2.30–4.46)	4.07 ± 0.61 (2.60–5.20)
Fighting	5.05 ± 0.69 (3.72–6.58)	4.66 ± 0.64 (3.70–6.52)	5.08 ± 0.63 (4.00–6.70)
Sports	5.02 ± 0.64 (3.76–6.60)	4.69 ± 0.59 (3.72–6.60)	5.11 ± 0.66 (4.00–6.60)
MMORPG	4.91 ± 0.68 (3.80–6.58)	4.58 ± 0.62 (3.80–6.52)	5.04 ± 0.61 (3.90–6.60)

In the FPS discipline, the absolute error value at the 60° flexion position was measured as 3.77 ± 0.55, 3.54 ± 0.47 at 90°, and 4.04 ± 0.63 at 120°. In the MOBA discipline, the values were recorded as 3.80 ± 0.63 at 60°, 3.47 ± 0.52 at 90°, and 4.00 ± 0.59 at 120°. In the BR discipline, the corresponding values were 3.79 ± 0.68, 3.49 ± 0.55, and 4.02 ± 0.58. For the RTS discipline, the absolute error was measured as 3.85 ± 0.62 at 60°, 3.52 ± 0.50 at 90°, and 4.07 ± 0.61 at 120°. In the Fighting discipline, the values were determined as 5.05 ± 0.69 for 60° flexion, 4.66 ± 0.64 for 90°, and 5.08 ± 0.63 for 120°. In the Sports discipline, the absolute error was recorded as 5.02 ± 0.64 at 60°, 4.69 ± 0.59 at 90°, and 5.11 ± 0.66 at 120°. In the MMORPG discipline, the values were measured as 4.91 ± 0.68 at 60°, 4.58 ± 0.62 at 90°, and 5.04 ± 0.61 at 120° (Table 2).

Table 3. Comparative Analysis of Dominant Shoulder 60° Flexion Proprioceptive Accuracy Across Different Esports Disciplines

	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.821	0.764	0.690	**0.009***	**0.004***	**0.002***
MOBA		0.902	0.813	**0.021***	**0.012***	**0.006***
BR			0.858	**0.019***	**0.011***	**0.008***
RTS				**0.013***	**0.008***	**0.005***

Fighting					0.741	0.651
Sports						0.872

*p<0.05

Statistically significant differences were found in proprioceptive error levels at the 60° shoulder flexion position among esports disciplines (p<0.05). Significant differences were observed between FPS and Fighting (p=.009), Sports (p=.004), and MMORPG (p=.002); between MOBA and Fighting (p=.021), Sports (p=.012), and MMORPG (p=.006); between BR and Fighting (p=.019), Sports (p=.011), and MMORPG (p=.008); and between RTS and Fighting (p=.013), Sports (p=.008), and MMORPG (p=.005). In contrast, no significant differences were found between FPS and MOBA (p=.821), FPS and BR (p=.764), FPS and RTS (p=.690), MOBA and BR (p=.902), MOBA and RTS (p=.813), and BR and RTS (p=.858). Additionally, no significant differences were detected among the Fighting, Sports, and MMORPG disciplines (p > 0.05) (Table 3).

Table 4. Comparative Analysis of Dominant Shoulder 90° Flexion Proprioceptive Accuracy Across Different Esports Disciplines

	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.831	0.998	0.987	**0.006***	**0.008***	**0.005***
MOBA		0.853	0.884	**0.012***	**0.010***	**0.007***
BR			0.891	**0.011***	**0.009***	**0.006***
RTS				**0.009***	**0.007***	**0.004***
Fighting					0.721	0.668
Sports						0.883

*p<0.05

Statistically significant differences were identified between groups in the comparative analysis of proprioceptive error levels at the 90° shoulder flexion position of the dominant arm (p<.05). Specifically, significant differences were found between the FPS discipline and Fighting (p=.006), Sports (p=.008), and MMORPG (p=.005); between MOBA and Fighting (p=.012), Sports (p=.010), and MMORPG (p=.007); between BR and Fighting (p=.011), Sports (p=.009), and MMORPG (p=.006); and between RTS and Fighting (p=.009), Sports (p=.007), and MMORPG (p=.004). In contrast, no significant differences were observed between FPS and MOBA (p=.831), FPS and BR (p=.998), FPS and RTS (p=.987), MOBA and BR (p=.853), MOBA and RTS (p=.884), or BR and RTS (p=.891). Furthermore, no statistically significant differences were found among the Fighting, Sports, and MMORPG disciplines (p > .05) (Table 4).

Table 5. Comparative Analysis of Dominant Shoulder 120° Flexion Proprioceptive Accuracy Across Different Esports Disciplines

	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.809	0.794	0.788	**0.004***	**0.003***	**0.002***
MOBA		0.841	0.827	**0.008***	**0.007***	**0.005***
BR			0.859	**0.009***	**0.007***	**0.004***
RTS				**0.010***	**0.006***	**0.003***
Fighting					0.734	0.682
Sports						0.803

*p<0.05

Statistically significant differences were found between groups in the comparative analysis of proprioceptive error levels at the 120° shoulder flexion angle of the dominant arm (p<.05). The FPS discipline showed a significantly lower error level compared to Fighting (p=.004), Sports (p=.003), and MMORPG (p=.002). Similarly, the MOBA discipline showed significant differences compared to Fighting (p=.008), Sports (p=.007), and MMORPG (p=.005); the BR discipline compared to Fighting (p=.009), Sports (p=.007), and MMORPG (p=.004); and the RTS discipline compared to Fighting (p=.010), Sports (p=.006), and MMORPG (p=.003). In contrast, no significant differences were found between FPS and MOBA (p=.809), FPS and BR (p=.794), FPS and RTS (p=.788); MOBA and BR (p=.841), MOBA and RTS (p=.827), or BR and RTS (p=.859). Additionally, no statistically significant differences were observed among Fighting, Sports, and MMORPG disciplines (p > .05) (Table 5).

Table 6. Descriptive Statistics of Proprioceptive Error Levels in Dominant Elbow Flexion Positions by Esports Discipline

Discipline	60° Mean ± SD (Min –Max)	90° Mean ± SD (Min –Max)	120° Mean ± SD (Min –Max)
FPS	2.23 ± 0.62 (1.4–3.2)	2.07 ± 0.54 (1.4–3.1)	2.01 ± 0.54 (1.4–3.1)
MOBA	2.22 ± 0.65 (1.4–3.2)	2.09 ± 0.57 (1.4–3.1)	2.02 ± 0.56 (1.4–3.1)
BR	2.23 ± 0.62 (1.4–3.2)	2.06 ± 0.53 (1.4–3.1)	2.00 ± 0.55 (1.4–3.1)
RTS	2.26 ± 0.64 (1.4–3.2)	2.10 ± 0.56 (1.4–3.1)	2.03 ± 0.55 (1.4–3.1)
Fighting	4.32 ± 0.74 (3.2–5.7)	4.18 ± 0.69 (3.0–5.5)	4.09 ± 0.68 (2.9–5.4)
Sports	4.26 ± 0.71 (3.2–5.7)	4.14 ± 0.68 (3.0–5.5)	4.04 ± 0.66 (2.9–5.4)
MMORPG	4.30 ± 0.73 (3.1–5.6)	4.16 ± 0.70 (2.9–5.5)	4.06 ± 0.69 (2.8–5.4)

In the FPS discipline, the absolute error value for the 60° flexion position was measured as 2.23 ± 0.62, 2.07 ± 0.54 for 90°, and 2.01 ± 0.54 for 120°. In the MOBA discipline, values were obtained as 2.22 ± 0.65 at 60°, 2.09 ± 0.57 at 90°, and 2.02 ± 0.56 at 120°. In the BR discipline, the values were recorded as 2.23 ± 0.62 at 60°, 2.06 ± 0.53 at 90°, and 2.00 ± 0.55 at 120°. In the RTS discipline, measurements were taken as 2.26 ± 0.64, 2.10 ± 0.56, and 2.03 ± 0.55, respectively. In the Fighting discipline, the values were determined as 4.32 ± 0.74 for 60° flexion, 4.18 ± 0.69 for 90°, and 4.09 ± 0.68 for 120°. In the Sports discipline, the values were recorded as 4.26 ± 0.71, 4.14 ± 0.68, and 4.04 ± 0.66, respectively. In the MMORPG discipline, the values were measured as 4.30 ± 0.73 at 60°, 4.16 ± 0.70 at 90°, and 4.06 ± 0.69 at 120° (Table 6).

Table 7. Comparative Analysis of Proprioceptive Error Levels in Dominant Elbow 60° Flexion Angle Position by Different E-Sports Disciplines

	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.982	0.998	0.965	**0.001***	**0.002***	**0.001***
MOBA		0.991	0.977	**0.001***	**0.002***	**0.001***
BR			0.979	**0.002***	**0.002***	**0.001***
RTS				**0.001***	**0.002***	**0.001***
Fighting					0.834	0.781
Sports						0.855

*p<0.05

According to the variance analysis regarding the 60° elbow flexion position of the dominant arm, statistically significant differences were identified between the groups (p<.001). Based on the multiple comparison analysis, no significant differences were found among the FPS, MOBA, BR, and RTS disciplines when compared with one another (p>.05). However, each of these four disciplines showed statistically significantly lower proprioceptive error levels when compared to the Fighting (p=0.001–0.002), Sports (p=0.002), and MMORPG (p=0.001) disciplines. No significant differences were observed among the Fighting, Sports, and MMORPG disciplines (p>.05) (Table 7).

Table 8. Comparative Analysis of Proprioceptive Error Levels in Dominant Elbow 90° Flexion Angle Position by Different E-Sports Disciplines

Discipline	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.974	0.992	0.964	**0.001***	**0.002***	**0.001***
MOBA		0.985	0.976	**0.001***	**0.002***	**0.001***
BR			0.978	**0.001***	**0.002***	**0.001***
RTS				**0.001***	**0.002***	**0.001***
Fighting					0.851	0.793
Sports						0.864

*p<.05

In the variance analysis regarding the proprioceptive error levels measured in the 90° elbow flexion position of the dominant extremity, statistically significant differences were observed between the groups (p<.001). According to the multiple comparison analysis, there were no significant differences among the FPS, MOBA, BR, and RTS disciplines when compared with each other (p>.05). However, each of these four disciplines showed statistically significantly lower error values when compared to the Fighting, Sports, and MMORPG disciplines (p<.05). No significant differences were found among the Fighting, Sports, and MMORPG disciplines (p>.05) (Table 8).

Table 9. Comparative Analysis of Proprioceptive Error Levels in Dominant Elbow 120° Flexion Angle Position by Different E-Sports Disciplines

Discipline	MOBA	BR	RTS	Fighting	Sports	MMORPG
FPS	0.984	0.993	0.976	**0.001***	**0.002***	**0.001***
MOBA		0.978	0.974	**0.001***	**0.002***	**0.001***
BR			0.986	**0.001***	**0.002***	**0.001***
RTS				**0.001***	**0.001***	**0.001***
Fighting					0.842	0.877
Sports						0.889

*p<.05

According to the one-way variance analysis results regarding the proprioceptive error levels measured at the 120° elbow flexion position of the dominant extremity, statistically significant differences were identified among the e-sports disciplines (p<.001). In the multiple comparison analysis, no significant differences were found among the FPS, MOBA, BR, and RTS disciplines (p>.05). However, each of these four disciplines exhibited significantly lower error values when compared with the Fighting, Sports, and MMORPG disciplines (p<.05). No statistically significant differences were observed among the Fighting, Sports, and MMORPG disciplines (p>.05) (Table 9).

Table 10. Correlation Between Proprioceptive Error Levels of Dominant Upper Extremity Flexion Angles by E-Sports Disciplines

Discipline	Shoulder 60° – Elbow 60° Flexion	Shoulder 90° – Elbow 90° Flexion	Shoulder 120° – Elbow 120° Flexion
FPS	**r=0.612*, p<0.05**	**r=0.582*, p<0.05**	**r=0.619*, p<0.05**
MOBA	**r=0.547*, p<0.05**	**r=0.511*, p<0.05**	**r=0.562*, p<0.05**
BR	**r=0.628*, p<0.01**	**r=0.593*, p<0.01**	**r=0.615*, p<0.01**
RTS	**r=0.534*, p<0.05**	**r=0.504*, p<0.05**	**r=0.553*, p<0.05**
Fighting	r=0.391, p>0.05	r=0.426, p>0.05	r=0.437, p>0.05
Sports	r=0.421, p>0.05	r=0.449, p>0.05	r=0.461, p>0.05
MMORPG	**r=0.589*, p<0.05**	**r=0.601*, p<0.05**	**r=0.633*, p<0.05**

*p<.05

According to the Pearson correlation analysis conducted on proprioceptive error levels based on flexion angles, significant and positive correlations were found between the shoulder and elbow joint measurements at matching flexion angles in the FPS, MOBA, BR, RTS, and MMORPG disciplines ($p<0.05$; $p<0.01$). Notably, the Battle Royale discipline showed a strong correlation in the 60° flexion position of the shoulder and elbow joints ($r=0.628$; $p<0.01$). In the Fighting and Sports disciplines, positive but statistically non-significant correlations were observed between the AE values at equal angles of the shoulder and elbow joints ($p>0.05$) (Table 10).

Discussion

This study evaluated the effects of motor task patterns on proprioceptive control by comparing absolute error (AE) values in 60°, 90°, and 120° flexion positions of the dominant shoulder and elbow joints across various e-sports disciplines. The analyses revealed that AE values for both the shoulder and elbow joints were significantly lower in FPS, MOBA, BR, and RTS disciplines compared to the Fighting, Sports, and MMORPG disciplines. These differences can be consistently linked to factors such as task type, repetition frequency, motor control demands, and sensorimotor integration. Proprioceptive perception is assessed via joint position sense (JPS), which quantitatively measures joint position awareness. Previous research has shown that lower AE values in shoulder and elbow JPS measurements are associated with higher proprioceptive sensitivity (Ramos et al., 2019). This study confirms that JPS is a reliable assessment tool and that the AE value serves as an indicator of proprioceptive accuracy. The low AE values obtained in this study align with the sensitivity ranges measured using these protocols.

Research on the proprioceptive function of the shoulder joint has demonstrated that this perception is not solely dependent on the initial joint position but can also be influenced by repetitive motor tasks. In studies using active joint position reproduction tests, JPS values during shoulder flexion were found to range between approximately 3° and 6°, and these values were reported to be affected by motor control demands (Glendon & Hood, 2015). In our study, the shoulder AE values observed in the FPS, MOBA, BR, and RTS groups ranged between 3.47° and 3.85°, indicating that players in these disciplines possess relatively high position sense. Shoulder proprioception measurements at different angles have been emphasized as functional parameters in both clinical and athletic performance contexts (Fox et al., 2024). This suggests that the shoulder AE values in our study can be interpreted within the framework of motor task demands. Furthermore, the systematic review by Horváth, Ács, and Kóbor (2023) reported that proprioceptive measurements should be approached holistically, encompassing not only position sense but also movement and force perception (Horváth et al., 2023). This multidimensional measurement approach indicates that heterogeneous motor requirements may produce different effects on proprioceptive perception. The differences between branches in shoulder AE values observed in our study support the applicability of this interdisciplinary approach to the shoulder joint.

The study by Méndez Rebolledo et al. (2022) reported a positive relationship between shoulder and elbow JPS values and upper extremity functional performance (Méndez Rebolledo et al., 2022). This study demonstrated that low proprioceptive errors are not merely a sensory outcome but also exhibit an integrated effect with motor performance. Similarly, the low shoulder and elbow AE values obtained in our study can be associated with more consistent position sense in disciplines with high motor performance requirements. The study by Vurgun et al., (2022) showed that there are differences in upper extremity proprioceptive sensitivity across various sports disciplines; this also supports the branch-specific AE differences found in our study (Vurgun et al., 2022). It has been reported in the literature that motor tasks requiring high repetition increase proprioceptive sensitivity, whereas tasks requiring low repetition and wide range of motion may decrease it (Horváth et al., 2023; Winter et al., 2022). These findings support that differences in motor requirements underlie the variation in shoulder and elbow AE values across branches in our study. The findings of our study regarding elbow AE values are also consistent with similar measurements reported in the literature. Ramos (2019) also reported that in JPS studies conducted on the elbow, low AE values in elbow JPS measurements are indicators of proprioceptive sensitivity (Ramos et al., 2019). In our study, the low elbow AE values measured in FPS, MOBA, BR, and RTS players indicate that proprioceptive perception is effectively utilized in tasks requiring high motor control. It has been reported that proprioceptive training improves motor performance, which supports the low AE values obtained in e-sports disciplines that demand high repetition (Winter et al., 2022). This also supports the finding in our study that low AE values are associated with high motor control requirements. The higher AE values observed in the Fighting, Sports, and MMORPG disciplines are consistently related to the fact that these branches require broader motor patterns and relatively lower levels of micro-control. The systematic review by Horváth et al. (2023) revealed that different motor patterns alter proprioceptive sensitivity and feedback mechanisms (Horváth et al., 2023).

This approach indicates that high AE values can be associated with heterogeneous motor behaviors and disciplines characterized by low repetition frequency. The proprioceptive control system functions as a holistic mechanism originating not only from peripheral sensors but also from central sensory-motor integration processes (Proske & Gandevia, 2012). As emphasized in Yılmaz's (2024) review, proprioceptive training and motor tasks requiring high repetition enhance performance through the reorganization of sensorimotor neural networks and neuroplasticity processes (Yılmaz et al., 2024). This supports the notion that the occurrence of low AE values in repetitive and high-precision motor tasks has a neurophysiological basis. The concurrent behavior of elbow and shoulder AE values indicates that upper extremity proprioceptive control is supported by an integrated network. This reveals that motor control is not limited to a single joint but is associated with the coordination of the entire extremity. Therefore, the branch-specific differences in shoulder and elbow AE values can be explained not only at the joint level but also through the holistic functioning of the motor and sensory systems of the upper extremity. Our study demonstrated that the differences in AE values for the shoulder and elbow joints are linked to the motor task profiles specific to each e-sports discipline. These variations are consistent with the theoretical and experimental findings presented in studies supporting the relationship between proprioceptive control and motor performance in the literature. In this study, the proprioceptive error (AE) values measured at 60°, 90°, and 120° flexion positions of the dominant upper extremity specifically the shoulder and elbow joints were compared among players involved in different e-sports disciplines. The findings revealed that both shoulder and elbow AE values were systematically lower in FPS, MOBA, BR, and RTS disciplines, whereas higher AE values were observed in Fighting, Sports, and MMORPG disciplines. These results indicate that the development of the proprioceptive system is not solely driven by passive responses of peripheral mechanoreceptors but also shaped through interaction with complex neurophysiological processes such as game-specific motor task patterns, task repetition frequency, the level of sensorimotor integration, and motor control requirements. Particularly, disciplines such as FPS and MOBA, which demand frequent task repetition and precise motor responses, appear to enhance the functional plasticity capacity of the proprioceptive system, thereby enabling more accurate organization of joint position sense. The AE values obtained in this study are directly comparable to JPS (Joint Position Sense) measurement protocols found in the literature, supporting the notion that proprioceptive sensitivity is a measurable and discipline-specific variable. Therefore, it is evident that the development of the proprioceptive system should not rely solely on peripheral stimuli, but must also consider the complexity and intensity of in-game tasks, as well as the cognitive demands associated with motor planning.

Proprioception should be taken into account in the evaluation of e-sports performance. Particularly in high-precision disciplines such as FPS and MOBA, proprioceptive sensitivity appears to be a determining factor in player performance. Therefore, JPS-based tests can be employed in talent identification and performance monitoring processes. Training protocols aimed at enhancing proprioceptive development should be established. The high AE values observed in Sports, Fighting, and MMORPG disciplines indicate that proprioceptive sensitivity is a trainable attribute. Specific exercises targeting joint position sense such as active repositioning and motor repetitions with eyes closed can be integrated into training routines. The impact of hardware and control interfaces on motor control should also be investigated. The finding that keyboard-mouse usage provides higher proprioceptive stimulation compared to gamepads highlights the need for a more in-depth examination of the neuromotor effects of control devices. In this context, changes in upper extremity JPS following long-term use of control devices should be assessed. Future research should also account for levels of cognitive-motor integration. It is known that AE values are not solely related to peripheral sensitivity but are also influenced by motor planning, attention, and decision-making processes. Accordingly, upcoming studies should include concurrent assessments of cognitive load and attentional performance alongside JPS measurements.

Kısaltmalar / Abbreviations

AE	Absolute Error
JPS	Joint Position Sense
FPS	First Person Shooter
MOBA	Multiplayer Online Battle Arena
BR	Battle Royale
RTS	Real-Time Strategy
MMORPG	Massively Multiplayer Online Role-Playing Game
SD	Standard Deviation
$\bar{X}$	Mean
ANOVA	Analysis of Variance
SPSS	Statistical Package for the Social Sciences
R	Pearson Correlation Coefficient
P	Significance Value
N	Number of Participants
Min	Minimum
Max	Maximum
Cm	Centimeter
Kg	Kilogram

Beyanlar / Declarations

Etik Onay ve Katılım Onayı / Ethics approval and consent to participate

Bu çalışmanın hazırlanma ve yazım sürecinde "Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi" kapsamında bilimsel, etik ve alıntı kurallarına uyulmuş olup; toplanan veriler üzerinde herhangi bir tahrifat yapılmamış ve bu çalışma herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiştir. Makale ile ilgili doğabilecek her türlü ihlallerde sorumluluk yazarlara aittir. Bu çalışma, Artvin Çoruh Üniversitesi Etik Kurulu'nun onayı ile gerçekleştirilmiştir (13.05.2024, Onay No: E-18457941-050.99-135134)

During the preparation and writing of this study, scientific, ethical and citation rules were followed in accordance with the 'Higher Education Institutions Scientific Research and Publication Ethics Guidelines'; no alterations were made to the collected data, and this study has not been submitted for evaluation to any other academic publication medium. The author is solely responsible for any violations that may arise in connection with this article. The study was conducted in accordance with the Declaration of Helsinki. This study was conducted with the approval of the Artvin Çoruh University Ethics Committe (2024-05-13; Approval No: E-18457941-050.99-135134).

Veri Ve Materyal Erişilebilirliği / Availability of data and material

Bu çalışmanın bulgularını destekleyen veriler, makul talepler üzerine sorumlu yazardan temin edilebilir. Veri seti yalnızca akademik amaçlar için erişilebilir olacak ve verilerin herhangi bir kullanımı, orijinal çalışmayı referans gösterecek ve katılımcıların gizliliğini koruyacaktır.

The data that support the findings of this study are available from the corresponding author upon reasonable request. The dataset will be accessible only for academic purposes, and any use of the data will recognize the original study and maintain the confdentiality of the participants.

Çıkar Çatışması / Competing interests

Yazarlar, bu makalede sunulan çalışmayı etkileyebilecek herhangi bir çıkar çatışması veya kişisel ilişkiye sahip olmadıklarını beyan etmektedirler.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Yazar Katkıları / Authors' Contribution Statement

Çalışmanın tasarımı ve planlanması: MY, MÇ; Veri toplama, analizi ve yorumlanması: MY, MÇ; Makalenin yazımı: MY, MÇ; Veri düzenleme, yöntem belirleme, yazım – özgün taslak, yazım – gözden geçirme ve düzenleme: MY, MÇ. Tüm yazarlar (MY, MÇ) makalenin önemli noktalarını eleştirel olarak gözden geçirmiş ve makalenin son halini onaylamıştır.

Design and planning of the study: MY, MÇ; Data collection, analysis and interpretation: MY, MÇ; Manuscript preparation: MY, MÇ; Data organization, methodology development, writing – original draft, writing – review and editing: MY, MÇ. All authors (MY, MÇ) critically reviewed the manuscript and approved the final version

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