ISSN: 2618 – 5911
Turkish Journal of Sports Science
2025; 9(1);10-20
DOI: 10.32706/tusbid.1692694
Research Article

An Examination of Volleyball's Impact on Lateralization and Motor Performance Based on the Proprioceptive Task in Female Children Aged 12 to 16[1]

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Abstract

Athletes from different sports may show varying motor performance based on their sport's demands and individual talents. Volleyball, emphasizing perceptual-motor skills like reaction time and eye-hand coordination, can enhance players' physical capacities. Comparing volleyball players with same-age sedentary individuals is important to understand the sport's potential effects. In this context, the present study examined the motor performance of female volleyball players aged 12–16 and compared it with that of sedentary girls in the same age group during a proprioception-based reaching task. In addition, a comparative evaluation of the performance between the dominant and non-dominant arms was conducted to assess lateralization. Speed, reaction time, accuracy, and linearity in a proprioceptive reaching task were analyzed via 2x2 mixed-model ANOVA to compare group (volleyball vs. sedentary) and hand effects in 30 female volleyball players and 30 sedentary girls. The results indicated that volleyball players performed significantly better than sedentary individuals in terms of reaction time and movement linearity. These motor performance parameters may offer valuable insights for talent identification and player development in sports.

Keywords: Lateralization, Motor performance, Proprioception, Volleyball.

Voleybolun 12–16 Yaş Grubu Kız Çocuklarında Lateralizasyon ve Proprioseptif Göreve Dayalı Motor Performans Üzerine Etkisinin İncelenmesi

Öz

Farklı spor dallarındaki sporcular, sporun gereksinimleri ve bireysel yeteneklerine bağlı olarak motor performans açısından farklılıklar gösterebilir. Reaksiyon zamanı ve el-göz koordinasyonu gibi algısal-motor becerilere vurgu yapan voleybol, oyuncuların fiziksel kapasitelerini geliştirebilir. Aynı yaş grubundaki voleybolcular ile sedanter bireylerin karşılaştırılması, bu sporun potansiyel etkilerini anlamak açısından önemlidir. Bu bağlamda, mevcut araştırmada 12–16 yaş aralığındaki kadın voleybolcuların motor performansları incelenmiş ve aynı yaş grubundaki sedanter kızlarla propriosepsiyona dayalı bir uzanma görevi sırasında karşılaştırması yapılmıştır. Ayrıca, lateralizasyonu değerlendirmek amacıyla baskın ve baskın olmayan kollar arasındaki performans da karşılaştırmalı olarak değerlendirilmiştir. Proprioseptif bir uzanma görevinde hız, reaksiyon zamanı, doğruluk ve doğrusallık ölçümleri 2x2 karma model ANOVA ile analiz edilerek grup (voleybol vs. sedanter) ve el etkileri karşılaştırılmıştır (30 kadın voleybolcu ve 30 sedanter kız). Sonuçlar, voleybolcuların reaksiyon zamanı ve hareket doğrusallığı açısından sedanter bireylerden anlamlı derecede daha iyi performans sergilediğini

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Citation/Atıf: Gürlek, E.B., Akpınar, S. (2025). An Examination of Volleyball's Impact on Lateralization and Motor Performance Based on the Proprioceptive Task in Female Children Aged 12 to 16. *Turkish Journal of Sports Science*, 9(1):10-19. DOI: 10.32706/tusbid.1692694.

Received: 06.05.2025
Accepted: 24.06.2025

göstermiştir. Bu motor performans parametreleri, sporda yetenek seçimi ve oyuncu gelişimi açısından değerli bilgiler sağlayabilmektedir.

Anahtar Kelimeler: Lateralizasyon, Motor Performans, Propriosepsiyon, Voleybol.

INTRODUCTION

Volleyball is a dynamic and fast-paced sport that demands high levels of coordination, agility, and control. The sport involves continuous movement, rapid decision-making, and repetitive interactions with the ball—skills that heavily rely on effective neuromuscular functioning. Volleyball players must frequently perform actions such as jumping, setting, spiking, and serving, all of which require precise control of body position and movement. Notably, these skills are executed not only with visual input but also through sensory systems like proprioception, which enables athletes to respond to fast-changing game situations with accuracy and fluidity (Almeida and Soares, 2003; Golmoghani, 2009; Achilleopoulos et al., 2022). The bilateral nature of volleyball skills—especially in tasks such as setting, which require the coordinated use of both arms—suggests that the sport may influence the motor performance of both dominant and non-dominant limbs, thus playing a role in lateralization.

The repetitive and structured movements inherent in volleyball training are expected to contribute to the development of proprioceptive abilities (Yoon, Ha, Ko and Kim, 2022). This makes volleyball an ideal context in which to explore how athletic training affects proprioception and related motor functions, particularly during adolescence when these abilities are still developing. Understanding how young athletes adapt to training stimuli can shed light on the developmental pathways of motor control and coordination.

Proprioception enables accurate movement by providing spatial position information between the brain and various parts of the body, as well as in relation to the external environment (Sherrington, 1906). In addition to offering a sense of joint position, the proprioceptive sensory system gathers data on motion and muscle tension (Schacter, Gilbert and Wegner, 2010). This information is essential for the coordination of body movements, especially when combined with the visual system, which translates environmental input into precise motor actions (Batista, Buneo, Snyder and Andersen, 1999). Together, proprioception and visuomotor coordination support balance, postural control, and quick responses to external stimuli—critical elements in both sports and daily life (Guskiewicz and Perrin, 1996; Tyldesley and Grieve, 1996).

In sports contexts, proprioceptive feedback is particularly valuable in ensuring correct body positioning, executing accurate movements, and maintaining coordination under pressure (Han, Anson, Waddington and Adams 2014a; Hang et al., 2014b). Volleyball players, for instance, rely on proprioception to time their movements, stabilize their posture, and adjust quickly to ball trajectories—all of which influence performance outcomes.

Another key concept related to motor control is lateralization, which refers to functional differences between the left and right sides of the body (Sainburg, 2016; Wang and Sainburg, 2006). Since volleyball skills such as setting and serving require the coordinated use of both limbs, the sport may influence the development of lateralization during adolescence. Examining how volleyball training affects lateralization and motor performance, in comparison to peers who do not engage in sports, provides valuable insight into how training impacts sensorimotor development.

The primary objective of this study is to investigate performance differences during a proprioception-based test between volleyball players and sedentary individuals. Additionally, the study examines motor performance differences between these two groups in terms of lateralization (dominant vs. non-dominant arm use). Within this framework, the study aims to compare motor performance parameters such as movement speed, accuracy, linearity, and reaction time between the volleyball and sedentary groups.

The focus of this research is to identify potential differences in proprioception skills between volleyball players and sedentary individuals and to assess how these differences impact motor performance. Parameters such as movement speed, accuracy, linearity, and reaction time allow for a detailed analysis of motor abilities in both groups. This comparative analysis will help reveal the specialized motor skills developed by volleyball players due to the specific demands of their sport and will shed light on how the 12–16 age group is affected by these skills. The findings can be used to develop specific training strategies for performance enhancement and to support proprioceptive abilities in aging individuals.

METHOD

Study Group

This study was conducted with female participants aged between 12 and 16 years. The study included two groups: one group consisted of sedentary female students, and the other group included female volleyball players of the same age range. Participation was based on voluntary consent. To determine the sample size, a G*Power power analysis test was conducted. Based on the analysis, with a 95% confidence level (1-α), 95% power (1-β), and an effect size of d = 0.5, the total sample size was calculated to be 36 for a repeated measures mixed model ANOVA. However, a total of 60 participants were recruited for this study, with 30 in the volleyball group (M_{age} = 14.1 ± 1.12 years old) and 30 in the sedentary group (M_{age} = 14.16 ± 1.08 years old). The volleyball group, consisting of 30 players, engaged in regular volleyball training three times per week. Participants in the volleyball group had a minimum of two years of volleyball experience.

Data Collection Tools

The data collection process was carried out at the laboratory of the Faculty of Sports Sciences at Nevşehir Hacı Bektaş Veli University. Measurements focused on predetermined parameters to assess participants' motor performance. These parameters included movement speed, accuracy, linearity, and reaction time. The assessments were conducted using the KineReach system (Figure 1, experimental setup) during reaching movements. Participants' hand dominance was determined using the Edinburgh Handedness Inventory, which objectively identifies right or left hand preference. All participants in the study reported being right-handed and scored above 90% on the Edinburgh Handedness Inventory, confirming right-hand dominance. The instruments used in this study were selected and standardized to ensure validity and reliability.

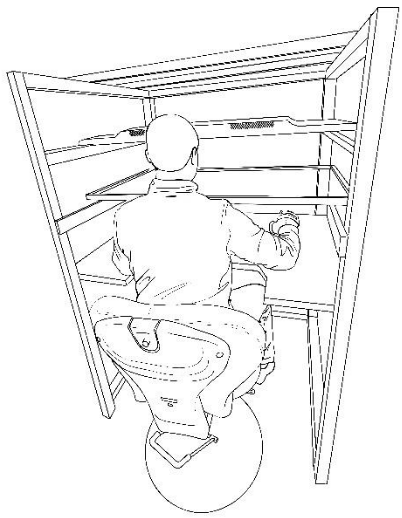

Figure 1. Experimental Setup

Data Collection

To measure proprioception, an experimental setup based on electromagnetic sensors (TrackSTAR, Ascension Technology, USA) was used, as shown in Figure 1, to assess reaching movements. Participants were seated on height-adjustable chairs, and sensors were placed on the tips of their index fingers. The setup ensured that their head level was aligned with a mirror placed in front of them. Measurements were taken using both dominant and non-dominant arms.

In the experimental setup, a starting point and multiple target positions were displayed via a mirror located below a horizontally placed 55" screen (Figure 2). Participants were asked to reach for the targets with the cursor corresponding to the position of their index finger, even though they could not see their arms. Once the cursor left the starting point, it disappeared from the screen, requiring participants to rely solely on proprioceptive input to complete the reaching task. These movements were recorded in real-time at a sampling rate of 100 Hz. Data collection was conducted using custom software developed in the MATLAB environment (Akpınar, 2015, 2016).

In the test, a white starting point with a radius of 1.5 cm and one of three randomly selected targets (3 cm in diameter, with a 1 cm blue center and a grey border) were shown on the mirror display (Figure 2). The starting point was positioned 30 cm from the sternum and 20 cm to the left or right, depending on the arm being used. While the system resembled an interactive gaming interface in real-time, the reaching movements were recorded only in two dimensions.

Procedure

Parental consent was obtained via a "Informed Consent Form" based on approval from the Ethics Committee of Nevşehir Hacı Bektaş Veli University and the Nevşehir Provincial Directorate of National Education (Approval No: 2022.10.99). The rights and privacy of the participants were respected, and all procedures were conducted in accordance with ethical guidelines. Data were collected during the 2022–2023 academic years.

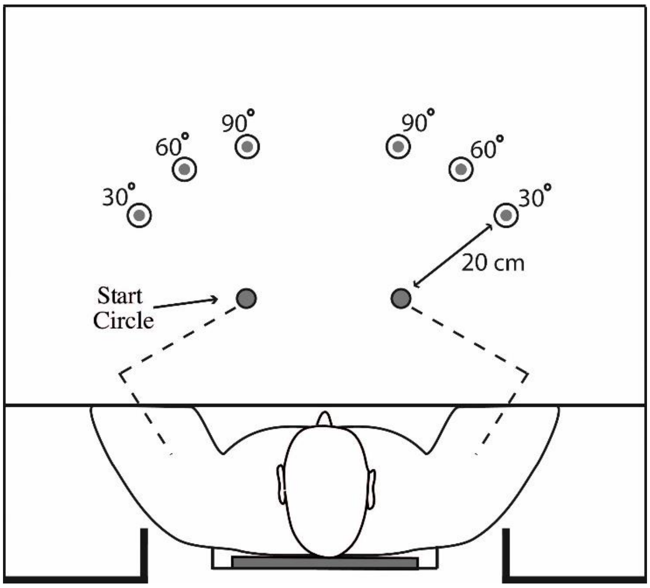

Figure 2. Experimental design, distribution of the targets

Data Analysis

Raw data obtained from the KineReach system were analyzed using custom MATLAB software, from which values for movement speed, accuracy, linearity, and reaction time were extracted. Movement speed was measured as the peak amplitude of the velocity profile. Accuracy was as sessed using the final position error (FPE), calculated as the Euclidean distance between the center of the target and the final 2D position of the index fingertip, represented by the cursor. Linearity was evaluated using the hand path linearity deviation (HPLD), defined as the ratio of the minor to the major axis of the index finger's movement trajectory. The major axis was determined as the greatest distance between any two points along the hand path, while the minor axis was the maximum perpendicular distance from any point on the hand path to this major axis. Reaction time (RT) was defined as the time interval between the appearance of the target on the screen and the initiation of movement toward that target (Akpinar, 2015).

For the statistical analysis of motor performance data, the JMP Pro statistical software was used. A 2x2 mixed model ANOVA was performed for each variable, with “group” (sedentary vs. volleyball) and “arm” (right vs. left) as factors in repeated measures.

The level of statistical significance for each motor performance parameter in the reaching test was set at $p < .05$. This threshold was used to determine whether observed differences were statistically significant. The aim was to identify performance differences between the groups and variability related to hand dominance.

RESULTS

Motor performance in terms of movement speed during the reaching movements without visual feedback was measured in sedentary individuals and volleyball players. Since the speed-accuracy trade-off (Coker, 2017) can affect movement performance, it was first examined whether there was a statistically significant difference between the dominant and non-dominant arm performances of the groups in terms of movement speed.

In this model, groups (sedentary vs. volleyball) were treated as the between-subjects factor, and arms (right vs. left) as the within-subjects factor. According to the statistical analysis results, the group × arm interaction was not statistically significant, $F(1, 116) = 0.36$, $p > .05$, $\eta^2 = .003$. Additionally, the group effect was also not statistically significant, $F(1, 116) = 0.17$, $p > .05$, $\eta^2 = .002$. Finally, no statistically significant difference was found between the arms as a within-subject factor, $F(1, 116) = 0.37$, $p > .05$, $\eta^2 = .003$.

The reaction time parameter was examined during reaching movements without visual feedback in both sedentary and volleyball participant groups. Whether there was a significant difference between right and left arm performances in terms of reaction time was also analyzed. The findings are presented in Figures 3 and 4. As before, the group (sedentary vs. volleyball) was treated as a between-subjects factor, and arms (right vs. left) as a within-subjects factor.

The statistical analysis showed that the group × arm interaction was not statistically significant, $F(1, 116) = 0.10$, $p > .05$, $\eta^2 = .001$. Similarly, no significant difference was found between the arms, $F(1, 116) = 0.004$, $p > .05$, $\eta^2 = .001$. However, a statistically significant group effect was observed, $F(1, 116) = 3.93$, $p < .05$, $\eta^2 = .08$ (Volleyball group: $M = 0.387 \pm 0.04$ sec; Sedentary group: $M = 0.407 \pm 0.06$ sec).

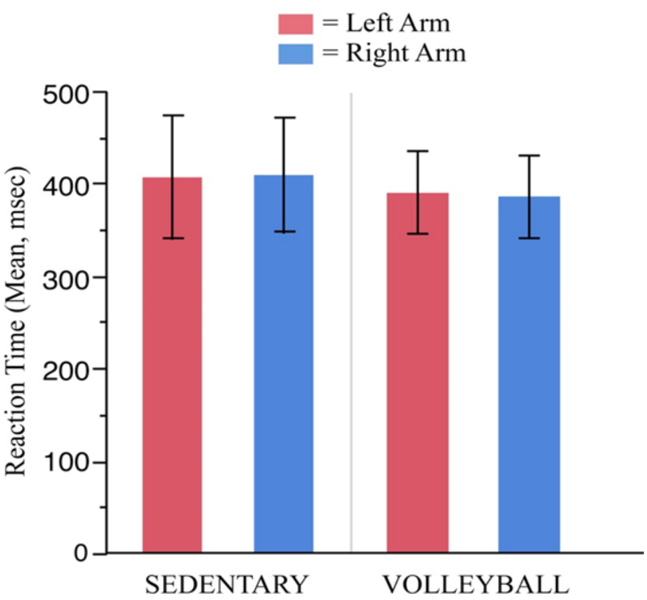

Figure 3. Average reaction time values (msec) of the right and left arms of the participants in the volleyball and sedentary groups

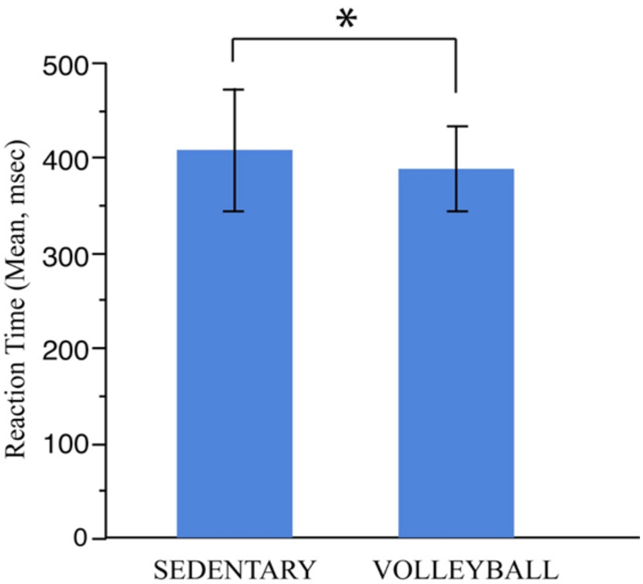

Figure 4. Average reaction time values (msec) of participants in the volleyball and sedentary groups

Linearity, defined as the ability to perform movement along a specific path without deviation, was evaluated during reaching tasks performed without visual feedback. The results are presented in Figures 5 and 6. Groups (sedentary vs. volleyball) were the between-subjects factor, and arms (right vs. left) the within-subjects factor. Statistical analysis revealed that the group × arm interaction was not significant, $F(1, 116) = 2.31$, $p > .05$, $\eta^2 = .02$. No significant difference was found between arms either, $F(1, 116) = 1.39$, $p > .05$, $\eta^2 = .01$. However, a significant group effect was found, $F(1, 116) = 4.20$, $p < .05$, $\eta^2 = .10$ (Volleyball group: $M = 0.054 \pm 0.012$; Sedentary group: $M = 0.060 \pm 0.022$).

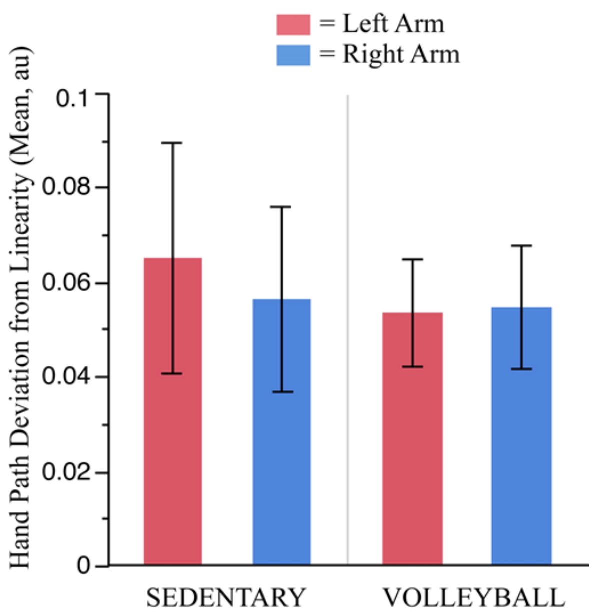

Figure 5. Average hand path deviation from linearity (au) of the right and left arms of the participants in the volleyball and sedentary groups

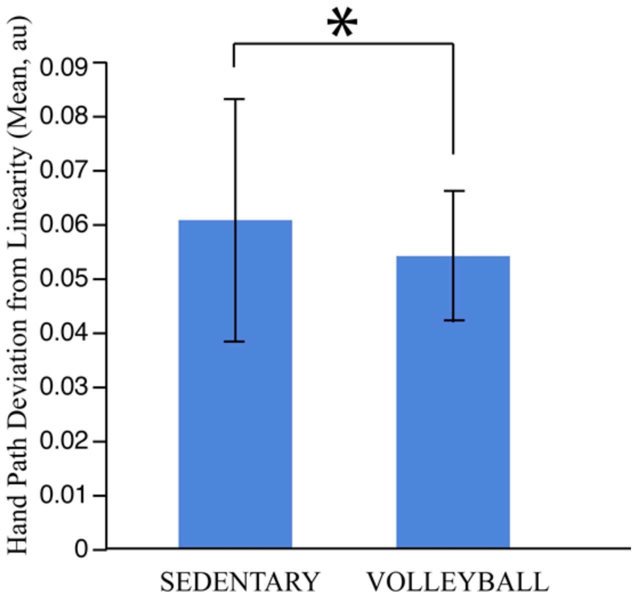

Figure 6. Average hand path deviation from linearity (au) of participants in the volleyball and sedentary groups

The accuracy parameter was measured during reaching movements without visual information in sedentary and volleyball groups. The group (sedentary vs. volleyball) was considered a between-subjects factor, and arms (right vs. left) as a within-subjects factor. The related data are presented in Figure 7. Statistical analysis revealed that the group × arm interaction was not significant, $F(1, 116) = 1.42$, $p > .05$, $\eta^2 = .003$. The group effect was also not significant, $F(1, 116) = 0.37$, $p > .05$, $\eta^2 = .001$. Likewise, no significant difference was found between arms, $F(1, 116) = 0.36$, $p > .05$, $\eta^2 = .001$

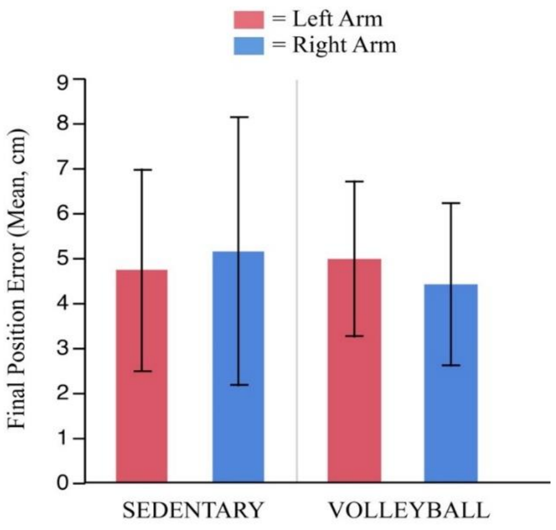

Figure 7. Average final position error (cm) of the right and left arms of the participants in the volleyball and sedentary groups

DISCUSSION and CONCLUSION

This study investigated the differences in motor performance associated with lateralization between sedentary individuals and volleyball players. A reaching test conducted using proprioceptive feedback assessed motor parameters such as movement speed, accuracy, linearity, and reaction time, revealing significant differences between the groups. The literature suggests that proprioception and motor performance improve with age and engagement in sports. The current findings indicate that repetitive motor activities, such as volleyball, may enhance motor control by reducing lateralization (Goble, Noble and Brown, 2006; Vaeyens, Lenoir, Williams and Philippaerts, 2007).

The analyses revealed no statistically significant difference in speed between the groups. This finding suggests that both groups performed the reaching movements at similar movement speeds, and that the movement speed parameter is relatively independent of an individual's sports background. Additionally, no significant differences were found between the dominant and non-dominant arms, indicating that lateralization does not significantly affect this motor parameter. Similarly, interaction effects between group and arm were not statistically significant (Goble and Brown, 2008; Sainburg, 2002).

Participants were instructed to perform the reaching movement in approximately one second, aligning with the "speed-accuracy trade-off" (Fitts, 1954) principle often emphasized in the motor control literature. As Plamondon and Alimi (1997) noted in their kinematic model of human movement, increased speed tends to negatively impact accuracy. Likewise, studies by Standage, Blohm, and Dorris (2014) have shown that faster movements lead to decreased accuracy. In our study, the uniform movement speed among participants allowed for an unbiased evaluation of the accuracy parameter.

In conclusion, these results suggest that engaging in regular athletic activity such as volleyball does not provide a distinct advantage in speed performance during reaching movements performed without visual input. Speed appears to function as a fundamental capacity within motor control processes. Moreover, lateralization did not significantly influence movement speed performance, as no significant differences were observed between the right and left arm trials. These findings underscore the importance of carefully evaluating group and arm-related differences in studies where movement speed is the dependent variable.

In the reaching test performed in response to an auditory cue, significant differences were found between volleyball players and sedentary participants in terms of reaction time. The results indicated that volleyball players had significantly shorter reaction times compared to sedentary individuals. This supports the idea that sports requiring rapid decision-making and execution—such as volleyball—positively impact reaction time. Regular training and sports participation appear to enhance this component of motor performance.

With regard to lateralization, no significant differences were found in reaction times between the dominant and non-dominant arms. Similarly, no significant interaction effects between group and arm were observed. These findings suggest that reaction time is more strongly associated with athletic performance level than with arm dominance.

These results are consistent with previous studies. Gürsoy, Akarsu and Hazar (2017) found that athletes had significantly shorter reaction times with the right arm compared to sedentary individuals, although the left arm showed no such difference. Similarly, Şenol et al. (2020) reported that individuals participating in specific sports exhibited better visual and auditory reaction times than sedentary individuals. Supporting this, a study by Mroczek, Kawczyński and Chmura, (2013) observed that elite volleyball players demonstrated faster reaction times during a game, indicating enhanced motor control. Reigal et al. (2019) also found that children engaged in regular physical activity had superior reaction times.

In summary, the current study supports the conclusion that reaction time is a motor skill that can be developed through regular athletic training rather than being determined by individual factors such as hand preference. Sports like volleyball, which require high levels of attention, speed, and coordination, appear to foster this skill, providing players with an advantage in the timing of motor responses. The findings align with existing literature, further confirming the positive effects of physical activity on reaction time.

In this study, the linearity parameter—defined as the ability to perform a movement along a straight path—was analyzed in volleyball players and sedentary individuals. The findings revealed that volleyball players performed the reaching task more efficiently in terms of linearly than sedentary participants, and this difference was statistically significant. This suggests that regular physical activity and volleyball may positively influence movement smoothness and control.

Similar results have been reported in the literature. Akpınar (2016) found that professional female basketball players performed better than sedentary individuals in both accuracy and linearity, and that the right arm exhibited more linear movement than the left. In the present study, only the between-group difference was statistically significant, with volleyball players exhibiting more linear movements. This may be attributed to factors such as age, sports history, and the lack of visual feedback in the test.

Due to the nature of volleyball, coordinated use of both arms—especially during skills such as overhead and forearm passing—is essential. Consequently, a lower level of lateralization can be expected among volleyball players. Supporting this, Stöckel and Weigelt (2012) emphasized that athletes who can use both sides of their body effectively may achieve better sports performance.

The superior performance observed in volleyball players may also be related to neurophysiological adaptations. Li and Smith (2021) highlighted that the athlete's brain exhibits enhanced adaptability to environmental conditions, contributing to improved motor preparation, decision-making, and execution. Thus, the more linear movements observed in volleyball players in this study reinforce the positive impact of sports on motor control.

In this study, the accuracy parameter was defined as the ability to reach the target during the reaching task. Unlike linearity, this parameter emphasizes the ability to precisely hit the target rather than the coordination of movement. The analyses showed no statistically significant differences in accuracy between the volleyball and sedentary groups or between the dominant and non-dominant arms. Although volleyball players demonstrated slightly higher average accuracy, the difference was not statistically significant, suggesting that volleyball does not have a definitive effect on accuracy.

The similarity in accuracy scores between both arms indicates that lateralization does not significantly influence this parameter. This result implies that both groups achieved similar target-hitting success rates with each arm. The findings may be related to the nature of the test, which required participants to rely on proprioception rather than visual input.

Additionally, the participants' age range (12–16 years) may have contributed to the absence of significant group differences.

Previous studies have reported varying results. For instance, Akpınar (2016) found that basketball players aged 18–29 outperformed sedentary individuals in terms of accuracy. Similarly, Akpınar, Sainburg, Kirazcı and Przybyla (2015) reported that elite fencers demonstrated higher accuracy than sedentary controls with both arms, suggesting that physical activity may enhance target precision. In the current study, the lack of significant differences in accuracy may be due to the younger age group and absence of visual cues during the task.

Volleyball players showed advantages in reaction time and linearity, while sedentary individuals displayed more pronounced lateralization. This can be explained by volleyball's requirement for coordinated use of both arms. The superior reaction times and more linear movements observed in volleyball players reflect more efficient motor control and coordination. The proprioceptive sense and motor performance parameters were generally more favorable among volleyball players. Furthermore, participation in sports appears to reduce lateralization, minimizing differences between limbs. The ability of volleyball players to automatically adjust their bodies to the ball's motion and game requirements may contribute to the development of their proprioceptive awareness.

Engaging in sports at a young age has a positive impact on proprioception and motor performance. These findings demonstrate that sports not only improve physical health but also contribute positively to balance, hand-eye coordination, proprioception, and motor skills. Using such performance parameters during talent selection may help evaluate players' in-game abilities more accurately, offering substantial benefits for optimizing both individual and team performance. Considering players' physical and technical attributes alongside factors such as reaction speed and coordination may provide a strategic approach to talent identification and player development. Integrating these parameters into training programs could lead to more effective and efficient long-term player development.

Author's Statement of Contribution to the Article

Idea/Concept: Emre Burak Gürlek, Selçuk Akpınar; Article design: Emre Burak Gürlek, Selçuk Akpınar; Consulting: Selçuk Akpınar; Data Collection and Processing: Emre Burak Gürlek; Analysis/Comment: Emre Burak Gürlek, Selçuk Akpınar; Literature review: Emre Burak Gürlek; Article writing: Emre Burak Gürlek; Critical Analysis: Selçuk Akpınar; Source/Material: Emre Burak Gürlek, Selçuk Akpınar; Article Submission Corresponding Author: Selçuk Akpınar

Conflict of Interest

The authors have no conflict of interest to declare.

Financial support

No financial support was received for the completion of this study.

Ethics Committee Approval

This study is in line with the Declaration of Helsinki. Parental consent was obtained via a "Informed Consent Form" based on approval from the Ethics Committee of Nevşehir Hacı Bektaş Veli University and the Nevşehir Provincial Directorate of National Education (Approval No: 2022.10.99).

Peer Review

After the blind review process, it was found suitable for publication and accepted.

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